

The obligations and common ground structure of practical dialogues

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Abstract

In this paper a theory of dialogue structure of task oriented conversations and its associated tagging scheme are presented. The theory introduces two linguistic structures supporting the dialogue that, following traditional terminology, we call the obligations and common ground. The theory is illustrated with the detailed analysis of a transaction. We also describe the empirical work supporting the theory, as well as an evaluation task. The paper is concluded with a reflection on the relation of the present theory to traditional notions of obligations and grounding, its relation to a more general theory of discourse and conversation and its potential application to the construction of spoken natural language systems.

Keywords: Conversational structure, obligations and common ground, dialogue models, dialogue managers.

1. Introduction

In this paper it is postulated that transactions in task oriented conversations or practical dialogues [2] are supported by two linguistic structures that we call the obligations and the common ground. These structures are 'built' by the speech or dialogue acts performed by the conversational participants, and a task oriented transaction is successfully concluded when the construction of these two structures comes to an end too.

The structure of obligations involves the specification of intentions through the realization of speech acts by one conversational participant, and the satisfaction of such intentions through linguistic acts, or perhaps through acts expressed in alternative modalities, by the same or the other partici-

pant. For instance, an action directive stated by U (user) creates the obligation on S (system) to perform the specified act, provided that social and other contextual conditions hold. The structure of obligations is defined as the relation between the speech acts that state this kind of intentions and the speech acts that satisfy them, within conversational transactions. This structure is based on such a strong traditions and social conventions that is even satisfied in non-cooperative conversations (e.g. [9]).

The common ground structure, on the other hand, is defined as the relation between the speech acts through which conversational participants make sure that they share a common set of beliefs and intentions, and understand the utterances performed by their partners as intended [5]. In an idealized conversation, every speech act is understood as

intended as soon as it is performed, and an implicit common ground is held between participants along the whole of the conversation; however, in real conversations, the communication flow is commonly interrupted and needs to be reestablished in order to proceed with the conversation. The common ground can be broken in two main types of situations: due to a lack of agreement between the conversational participants, and due to an understanding problem. In the former case a speech act is listened well but the hearer fails to agree with part or all of its content. The latter case is exemplified by situations in which the message is not clear due to noise, for instance, and explicit speech acts are required to ensure that the participants are 'engaged' in the conversation. We also postulate that the understanding plane includes situations in which the referent is not determined enough due to its ambiguous or vague nature.

Speech acts need to be distinguished from the utterances that express them, and the same utterance may express more than one speech act, possibly in different conversational structures. For instance, an *okay* may express a commit in the obligations structure, an accept in the agreement plane, and an acknowledgment in the understanding plane of the common ground.

There are constraints on the relation between speech acts; an action directive, for instance, needs to be paired with an action, and an information request with an answer; in the common ground, a hold act must be paired with an accept act, when the assertion that was put on hold is finally agreed upon, and an overt misunderstanding signal, like *what did you say?*, must be paired with an utterance that supplies the missing information. If a transaction satisfies all the stated constraints it is said that it is balanced, closed or completed.

Summarizing, we define the obligations and common ground structure as the relation between speech acts in a conversational transaction, in addition to a number of constraints on such relation. In the rest of this paper, the specification of a theory of dialogue acts and conversation based on the explicit realization of the obligations and common ground structure is presented. In Section 2 the basic theory and its associated tagging scheme are introduced. In Section 3, the theory is illustrated with the analysis of a transaction of a task oriented conversation. In Section 4 a summary of the empirical work supporting the theory and an evaluation exercise are presented. Finally, in Section 5, a

discussion of the theory, including its relation to previous work on obligations and grounding, and its potential applications for developing conversational systems is presented.

2. The DIME-DAMSL Tagging Scheme

The notions of conversational obligations and grounding have large tradition in philosophy, linguistics, psychology and AI, and have been applied to the definition of dialogue managers [1,9]; however, these structures are not reflected directly in annotation schemes, like DAMSL [6,3], which has been used for dialogue analysis [1]. DAMSL distinguishes between the communicative status, the information level and the forward and backward looking functions of utterances, but discourse obligations and common ground acts are distributed implicitly in these four main dimensions. In particular, utterances expressing obligations, like action directives or information requests, are the prominent part of the forward looking functions, but there are also forward looking functions related to the common ground, like an affirm act introducing new information, that must be acknowledged by the hearer; conversely, although most explicit tags of the backward looking functions are mainly concerned with grounding, there are also some backward functions, like answers, that belong to the obligations structure.

In the present investigation we develop on the DAMSL tagging scheme and, on the basis of the analysis of the DIME Corpus¹, the DIME-DAMSL tagging scheme has been introduced [8,10]. In this scheme, all four dimensions of DAMSL are considered, but in addition, the structure of obligations and common ground is made explicit; the specification of this structure includes the definition of a set of speech act types, and also the specification of the constraints that the actual performance of these acts should satisfy. This relation is defined in terms of the 'charge' and 'credit' import of these acts; for instance, an action directive creates an obligation's charge, and this charge is only credited when the corresponding action is performed later on in the transaction.

An action directive charges the common ground too, but this charge is credited immediately as soon as the act is understood and agreed upon by the interlocutor. In accordance with basic accountability

¹ <http://leibniz.iimas.unam.mx/~luis/DIME/>

principles, a transaction is balanced when all the charges made in both the obligations and common ground have been credited. The current specification of the scheme is presented in tables 1 and 2.

Charge	Time	Credit	On participant
Inf-request	I	Response	Other
Action-directive	I	Action	Other
Commit	I	Action	Same
Offer	P	Action	Same

Table 1. Balancing relations for obligations

In the table 1 *Action* is the act of pointing to an object, a zone, a path, etc., or the placing, moving or deleting a domain object in the design space. Table 1 also states if a charge is made immediately at the time the speech act is performed by the speaker (i.e. *I*) or whether it is postponed until it is accepted by the hearer (i.e. *P*). The table also specifies whether the charge is on the hearer or on the speaker himself.

The common ground is defined by agreement acts, related to the shared set of beliefs agreed along the dialogue, and by understanding acts, related to the communication channel. In normal conversation, it is assumed that the content of an utterance is accepted by the interlocutor by default, and most forward looking obligation speech acts are accepted implicitly; however, there are also agreement acts that are expressed by explicit speech acts. We have observed two main cases: (1) the common ground has been broken (e.g. by a referential failure), and needs to be repaired, and (2) the common ground is reinforced by the explicit realization of speech acts. The common ground relations are summarized in Table 2, where:

Agr-action = {*accept* | *accept-part* | *hold* | *maybe* | *reject* | *reject-part*}

Understanding-Act = {*acknowledgment* | *back-channel* | *repetition* | *rephrase* | *complementation* | *correction*}

Agreement charges are made immediately at the time the speech act is produced, and are normally credited implicitly by the next utterance produced by the interlocutor. Understanding dialogue acts may express that the common ground needs to be

strengthened; for instance, when the purpose of an utterance is to provide feedback (e.g. acknowledgments, back-channels, etc.), reinforcing the belief of the speaker that the hearer is engaged; these acts are also normally credited implicitly by the interlocutor through the normal continuation of the dialogue. This level also includes explicit non-understanding signals that the common ground has been lost (e.g. *what did you say?*) and needs to be reestablished immediately.

Finally, ambiguous or vague acts charge the understanding plane too, but this kind of acts are credited later on when the ambiguity is resolved or the vague reference is fixed. Also, unlike all other common ground act types, ambiguous and vague charges may be credited by the interlocutor that made the corresponding charge in the first place.

3. The Transaction's Structure

To illustrate this machinery, the analysis of a typical transaction of the DIME Corpus is presented in Table 3. The column # stands for utterance number, *T* for the turn (System or User), and the numbers in the charge and credit columns index the utterance that expressed the corresponding speech acts, for the obligations, agreement and understanding planes respectively.

The first utterance in this transaction is an offer which creates a charge in the agreement plane, as offers need to be accepted or rejected; through utterance 2, U accepts the offer, crediting the agreement charge and placing an obligations charge on S, as the system has now the obligation to perform the promised action; the main intention of the transaction is stated in 3 by U; this action directive places a charge on S in the obligations plane, and this charge is consistent with the offer made by S itself in the initial utterance. The action directive also places a charge in the agreement plane, which is explicitly accepted by S in 4.

Utterance 5 is an open option made by S; although this type of speech act is normally stated through a declarative statement, the utterance is not considered an affirm act, as its purpose is not to enrich the set of beliefs of the interlocutor (i.e. to add a proposition in its knowledge base) but simply to allow him to choose from a predefined set of possible courses of action; also, the open option does not charge the obligation plane, as the inter-

Charge	Credit	On participant
inf-request	Agr-action + affirm	other
action-directive	Agr-action	other
offer	Agr-action	other
open-option	Agr-action	other
affirm	Agr-action	other
reaffirm	Agr-action	other
vague-ref	Fix	same/other
ambiguous-ref	Resolve	same/other
understanding-Act	Next (or current) utterance	other
Non-understanding-Signal (NUS)	Next utterance attending such signal	other

Table 2. Balancing relations for the common ground plane

locutor has no obligation to do anything about it; however, the open option does charge the common ground, as it needs to be accepted or rejected either explicitly or implicitly by the normal flow of the conversation. Next, U determines further the main intention through an affirm act in 6, and accepts implicitly the open option; although this utterance has, perhaps, an imperative connotation at the surface level, it is not considered an action directive as its purpose is to make a choice (supported by a pointing act) within the context of the main transaction's intention; however, U needs to be sure that S took notice, and the affirm act charges the common ground; in 7, S accepts explicitly U's choice, and credits the corresponding charge.

At this point of the transaction the main intention (i.e. to place a stove) and one of its arguments (i.e. what particular stove) have been fully determined, but the second argument, the location where the stove will be placed, is still to be specified. This is carried out from utterance 8 to 13. In 8 U states the desired location through an affirm act, with the corresponding charge in the agreement plane; however, the statement involves a definite description (*the far wall*) which is ambiguous; in the 2-D and 3-D views (of the interface where the corpus was collected) there are two walls that can be the referent, depending on the position adopted by the speaker in relation to the working space; for this reason, 8 charges also the understanding plane with an ambiguous act.

The spatial ambiguity is noticed by S and utters the confirmation question in 9, making the corresponding charge in the obligations plane; this question is also a hold act that postpones accepting 8 in the common ground. At this point both U and S

are aware that the common ground has been broken and needs to be restored; for this, a problem-solving process to resolve the referent of the remaining spatial argument is started. In 10, U answers 9 through an affirm act (i.e. here) at the time a spatial zone is pointed at (i.e. the zone corresponding to the far wall). The answer act credits the obligation plane, but the affirm act needs to be accepted and makes a new charge to the agreement level. However, the question in 11 expresses that the spatial reference needs still to be confirmed (*there?*); accordingly, and in addition to its corresponding charge in the obligations plane, this is also a check question that puts on hold the affirm act in 10. The answer in 12 credits this charge, and U resolves the spatial ambiguity that he himself had introduced in 8, crediting the corresponding charge in the understanding plane of the common ground too.

Through 13, S accepts the postponed affirm acts in 8 and 10, which were uttered by U, making the corresponding credits to the understanding plane. At this point the main intention with its two arguments has been determined, and S is able to commit to do the action requested by U in 3, making the corresponding charge on himself in the obligations plane. This concludes the intention specification phase of the transaction.

The satisfaction of the intention involves a problem-solving process that has the placing of the stove as its goal; this requires pairing the spatial referent introduced with the pointing action in 10 with a reference position of the stove (e.g. the center or the bottom-left corner), and this involves the use of some design preferences and constraints adopted by the system. Finally, when the plan is decided, the

#	T	Utterance (originally in Spanish)	Obligations		Common ground				Dialogue Act Types			
			Ch	Cdt	AGR		UND		Obligations	Common ground		
					Ch	Cdt	Ch	Cdt				
1	S	Do you want me to bring a piece of furniture to the kitchen?				1					offer	
2	U	Yes	1				1				offer	accept
3		I need a stove	3			3					action-directive	action-directive
4	S	A second					3					accept
5		These are the five models of stoves that we have, simple stoves and stoves with lateral cupboards				5						open-option
6	U	Mmmm <sil> I'm going to select that stove					5					accept affirm
7	S	Okay					6					accept
8	U	eh, please I need it in <sil> in the far wall				8		8				affirm ambiguous
9	S	Which one is the far wall?	9								inf-req	hold
10	U	Let's see, here		9		10					answer	affirm point zone
11	S	There?	11								inf-req	hold
12	U	Yes		11							answer	resolve
13	S	A second	13				10				commit	accept
14		<graphical action>		13 3 1		14					graph-action	affirm
15		Is there alright?	15								inf-req	
16	U	Yes, for the moment, yes		15			14				answer	accept

Table 3. Analysis of a transaction

actual action is performed and expressed through the graphical modality. This action credits the pending offer in 2, the action directive in 3 and the commit in 13 in the obligations plane. The graphical act makes also an affirm charge in the agreement level, as U needs to agree with the result of this action. To conclude the transaction, S makes a confirmation question in 15, creating the corresponding charge in the obligations plane, and

this question is credited with U's answer in 16; finally, the graphical act is credited in the common ground with an accept act expressed by 16 too.

Table 3 also illustrates that the structure of the transaction can be partitioned in two main phases: intention specification and intention satisfaction, and that the kind of speech act is highly dependent on the part of the transaction where it occurs; for

instance, a commit is very likely to occur at the end of the intention's specification phase, but very unlikely to occur elsewhere. Also, the main intention is very likely to be expressed at the beginning of the transaction, and this is made very often in our corpus through declaratives (more than 70%) and interrogatives (about 20%); other utterances appearing within the context of the main intention are very unlikely to be action directives, unless they appear in embedded transactions. More generally, the structure of the transaction may be very helpful to interpret direct and indirect speech acts, as the interpretation process may be construed as finding the most likely speech act type given the place in the transaction's structure in which the utterance is expressed, taking into account the actual lexical content and syntactic form of the utterance, and also the interpretation domain.

Also, unlike written language in which sentences are produced as ready-made units, intentions in practical dialogues seem to be expressed incrementally. Although the main intention is understood through the meaning of the main verb in the interpretation domain and context, working out the referents of the verbal complements is produced by an incremental problem-solving process, as illustrated by the example in Table 3. In this, as in many transactions in our corpus, the accusative argument is resolved first, followed by the resolution of other spatial complements.

The transaction in Table 3 does not involve vague expressions (e.g. *to the left of the stove*) where the spatial information needs to be further determined in order to undertake action, which are common in our corpus; however, this kind of expressions require fixing reference through a problem-solving process analogous to the resolution of the ambiguity in the present example. More generally, the resolution process for each argument may involve ambiguous and vague expressions that break the common ground, and resolving these, fixing reference and restoring the common ground, seem to be three aspects of the same underlying phenomenon.

Finally, Table 3 also shows that the obligations structure 'dominates' the common ground in the sense that the dependencies of the latter structure are embedded within the ones of the former. This is illustrated by the vertical line linking the statement of the main transaction intention with its actual satisfaction, which 'encloses' the lines linking charges with their corresponding credits in the common ground. However this dominance relation

is reversed when the common ground is broken, and the acceptance of a speech act is postponed by a hold act. In this situation the obligations charges and credits are embedded within the line linking the charge made by the speech act that was put on hold with the speech act that finally accepts it and makes the corresponding credit. While in the main transaction cycle the conversation's initiative is held by U, who imposes obligations on S (in this particular setting), when the common ground is broken the initiative is shifted to S who guides the conversation in order to reestablish the common ground; when this is achieved, the conversation's initiative is passed back to U.

4. Tagging Methodology and Evaluation

The presented theory was developed in conjunction with a transcription task. The exercise started from the original DAMSL scheme and its manual [6], and a team that included up to 15 taggers at a time participated in the initial training phase. Next, one dialogue was tagged by several people, and the kappa statistics was used to measure agreement between taggers [4]. The initial agreement scores were very low, especially for the common ground speech acts and the backwards dimension. One source of confusion was the implicit assumption that utterances express speech acts in a context independent fashion, as very few constraints between tags are defined in the original DAMSL scheme. In fact, the DAMSL manual provides explicit decision trees for agreement acts, and questions in these trees are focused on the function of a particular utterance, independently of its context in the transaction's structure.

The theory presented in this paper evolved as a reaction to these problems. Dialogues were first thought of as sequences of transactions; also, the obligations and common ground were made explicit, and the common ground was also explicitly divided in the agreement and understanding planes of expression. Then, speech acts were classified according to these structures. In this exercise, the DAMSL dimensions (i.e. communicative status, information level and the forward and backward looking functions) were preserved, and the obligations and common ground structures were thought of as orthogonal to DAMSL dimensions, enriching the level of structure postulated in the original scheme. The relations between speech acts

within each plane of expression were modeled in terms of the charge and credit import of speech act types, and also in relation to the transaction context. In addition, as the DIME corpus is multimodal, tags for graphical actions and visual interpretations were included in the scheme.

In this exercise an Excel format was used to input the tags for all utterances in a dialogue; this format supported the original DAMSL's tags and dimensions as well as the obligations and common ground, and the charges and credits relations. The format also allowed the semi-automatic computation of the kappa statistics for transaction boundaries, charge and credits relations and the actual speech act type tags. Through the exercise a number of conventions about the interpretation of speech acts in relation to the context, and also about the use of the tagging tools, were defined and refined. The resulting scheme is called DIME-DAMSL.

With the tagging tool at hand, a formal experiment involving three tagging teams of three members each was developed. In this exercise two dialogues from the corpus were transcribed, in a sequence of tagging rounds; the teams were allowed to comment and discuss coincidences and discrepancies at the end of each tagging cycle and, after a few rounds, kappa statistics converged up to 0.9 for transaction boundaries, charge/credits relations and the actual DIME-DAMSL tags. This figure suggests that the agreement between taggers above chance is very good. At the moment we have 12 dialogues comprising 139 transactions with 1,702 utterances tagged with the latest version of the scheme by two expert taggers (with the exception of charges and credits for ambiguous and vague references, which we have only explored in a preliminary way). The kappa statistics for this transcription exercise are shown in Table 4. In addition, the kappa statistics for transaction boundaries is 0.83. The current results support the case for the theory, and show that the methodology and tagging scheme are reliable.

Obligations		Common Ground			
		Agreement		Understanding	
Chrs.	Cdts.	Chrs.	Cdts.	Chrs.	Cdts.
0.91	0.86	0.84	0.73	0.82	0.82

Table 4. Kappa statistics for 1,702 utterances

In addition, one expert tagger has fully tagged 8 additional dialogues and the actual tagged data comprises 20 dialogues, 269 transactions and 3283

utterances, and the scheme seems to cover most phenomena in a simple and consistent way. The video and audio, with the orthographic transcription, the charges/credits tagging and the full DIME-DAMSL annotation of the 20 dialogues is available at the DIME project's web page².

5. Conclusion and applications

The analysis of speech acts is required in linguistic studies of discourse and conversation, and also for the construction of natural language conversational systems, especially when spoken language is involved. In the present approach, the analysis of speech acts is partitioned in two levels: the level of form and the level of content. The level of form is constituted by the obligations and common ground structures, and this level is defined in terms of the relations and constraints between speech acts in the context of the transaction, and these relations are independent of the actual beliefs and intentions expressed by the speech acts. In this sense, the obligations and common ground are abstract structures and hence linguistic generalizations that are independent of content issues and knowledge about the application domain.

The notion of obligations has a long tradition in grammar and logic (e.g. deontic logics), and also in computational studies. In the former, the consequences of obligation statements that depend on syntactic form are studied, but these are not commonly or necessarily thought of as conversational obligations. In the AI and computational linguistics views, in turn, obligations are commonly defined as goals that arise in conversation and have to be dealt with in conjunction, and some times prior, to the task domain goals of the agent (e.g. [9]). Although in the present approach obligations are also thought of as goals that an agent ought to accomplish, these are stated in relation to content independent generic conversational protocols and, in this sense, the present view is orthogonal to traditional notions.

The present notion of common ground is also thought of in terms of structural relations, and in this respect it resembles Clark and Schaefer's [5] grounding model; however, unlike this latter model in which an utterance "presents" a piece of information that is "accepted" by the next utterance

²http://leibniz.iimas.unam.mx/~luis/DIME/dimedamsl/CO RPUS_DIME.htm

performed by the interlocutor, forming a grounding unit, the so-called “contribution”, the present model postulates that there is a set of speech acts that perform specific grounding functions when they are required (avoiding infinite accepting loops). Finally, the explicit demarcation of the obligations and the common ground, with the corresponding constraints and balancing relations, provides for a simple and general model for the analysis of task oriented transactions.

The main aim of the present view of dialogue structure is the construction of conversational systems in practical dialogues, where a dialogue can be analyzed as a sequence of task oriented transactions. We hold that typical transactions, in turn, can be modeled through dialogue models representing the obligations and common ground structures; in a finite state graph or a recursive transition network, for instance, states can represent conversational situations and arcs the type of speech acts that relate situations. In this view, navigation through dialogue models depends on the ability to identify the speech act types expressed by utterances, taking advantage of the context and, perhaps, prosodic information [7]. We also hold the hypothesis that this recognition is mainly a bottom-up process; however, when dialogue act types are available, issues of content can be addressed in a top-down fashion; for instance, when it has been established that an utterance expresses an action directive, lexical and syntactic information could be used to determine the specific action to be performed by the system. Also, most common ground speech acts are interpreted directly, and this interpretation requires little lexical and syntactic processing.

In the present approach, issues related to discourse structure, reference resolution, both anaphoric or indexical, may also be simplified, as top-down interpretation processes focus on the resolution of the arguments of specific instances of speech act types, when the type of the speech act in question is available already. In summary, the present theory is aimed to the construction of conversational systems in practical dialogues where the complexity of pragmatic inference can be reduced by the incorporation of dialogue models representing the obligations and common ground structures of typical transactions of the conversational domain.

In a more theoretical setting and according to the present view, a cooperative transaction can be seen as a cooperative problem-solving process in which

an intention with its arguments is specified incrementally, followed by its satisfaction. In particular, expressions filling the intention’s argument positions are initially understood through meaning, but such expressions have referents which need to be resolved, fixed or determined in order to act. The resolution of each of these arguments becomes embedded subproblems that are also solved cooperatively. The resolution of ambiguous or vague spatial referents, in particular, is an incremental problem-solving process that is often concluded with an explicit ostension, and this deictic act fixes reference and restores the common ground at the same time. In this view, anaphoric and indexical resolution is subsumed in a process that aims to resolve the referents through a problem-solving process involving conventional meanings, knowledge about the conversational domain, the transaction’s structure, and an interaction with the world.

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