

Balancing Transactions in Practical Dialogues

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Abstract. In this paper a theory of dialogue acts analysis in problem-solving tasks-oriented conversations is presented. The theory postulates that in practical dialogues every transaction has a component in the obligations and the common ground planes of expression, and contributions made by dialogue acts making a “charge” in the transaction should be “balanced” by contributions making the corresponding “credit”, and a complete transaction is balanced in both of these planes. In addition, transactions have a structure which constraints strongly the realization of dialogue acts. A dialogue act tagging methodology based on the theory is also presented. The theory and its related methodology have been applied to the analysis of a multimodal corpus in a design task, and the figures of the agreement reached in the preliminary experiments are presented.

1 Introduction

In this paper a theory for the analysis of dialog acts in practical dialogs is presented. In this theory dialogues acts are analyzed in relation to the obligations and common ground structures of task oriented conversations, and we provide an explicit analysis and tagging methodology for these two dialogue structures. According to Allen et al. [1], practical dialogues have the purpose to achieve a concrete goal, and the conversational competence required to engage in this kind of dialogs is significantly simpler than general human conversation (i.e. the practical dialogue hypothesis) and the main aspects of language interpretation and dialogue management are domain independent (i.e. domain independence hypothesis). Simple dialogues can be reduced to achieve a single goal and involve only one transaction, but often the dialogue involves a sequence of transactions. From the empirical study of a corpus in the kitchen design domain we suggest that transactions are also characterized in terms of an intention specification phase, followed by the intention satisfaction phase, and the structure of the dialogue is closely related to the structure of the problem-solving task, and in this regard, our approach loosely resembles Grosz and Sidner’s discourse theory [7]. We also postulate the hypothesis that transactions can be analyzed in terms of their conversational obligations and common ground structures, and that complete transactions are balanced in these two planes of expression; this is, for every “charge” in each of these planes there must be a “credit”; otherwise, the transaction cannot be completed successfully.

In addition to the principles of cooperative conversation, in which the conversational participants share beliefs and desires, and communicative intentions can be expressed and satisfied by a shared plan, there are strong social conventions involved in linguistic interaction that hold even if one of the conversational participants opts out of cooperative behavior [9]. A question by speaker *A*, for instance, imposes the obligation on *B* to provide an answer and a commitment made by *A* imposes the obligation on *A* himself to perform an action. Conversational participants should also try to establish the mutual belief that the addressee has understood what the speaker meant for each utterance; if this common ground is lost the conversation cannot proceed successfully. Different discourse theories make different assumptions about what knowledge constitutes the common ground, and most involve presuppositions and beliefs accumulated during the conversational interchange; however, in addition to this knowledge, successful grounding behavior requires that each utterance is understood as intended [5], and this basic level of linguistic communication is independent of the content of the utterance; for instance, all utterances must be acknowledged, either explicitly or implicitly, in a reasonable amount of time, or the flow of communication is interrupted and has to be repaired. At this level, the common ground involves agreement about the intended attitude towards the content of the utterances (e.g. whether a question is accepted or put on hold) and also communication factors, as when an utterance is acknowledged directly, through a back-channel or a repetition.

The notions of conversational obligations and grounding have been applied to the definition of dialogue managers [2,9]; however, these planes of expression are not reflected directly in annotation schemes, like DAMSL [3], which has been used for analysis of dialogues with the purpose of specifying performance goals for conversational systems [2]. This latter scheme 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 are the prominent part of the forward looking functions, but these utterances have also a grounding import, and conversely, although most explicit tags of the backward looking functions are mainly concerned with grounding, there are also some backward functions that belong to the obligations structure. More generally, although the utterances of a dialogue perform both functions at the surface level, the obligations and grounding structures are different, as each is focused on a different linguistic function.

In this paper we report a study on the structure of obligations and common ground in task oriented dialogues; in this work we have extended DAMSL with a meta-layer of interpretation reflecting these structures. In this level, transactions are identified first, and utterances making a “charge” in the obligations and grounding structures must be eventually “credited” by another utterance, either implicitly or through an explicit utterance. The goal of a transaction is accomplished when the phases of intention specification and satisfaction are completed, and the transaction as a whole is balanced. This meta-level of tags is then used to identify the actual tags for dialogue acts, following closely the original DAMSL tagging scheme. A tagging exercise in the kitchen design domain is described, and the agreement among taggers is reported. Also, as the corpus is multimodal we have extended DAMSL with a dimension for tagging actions and visual interpretations that are not expressed linguistically. We refer to this tagging scheme as DIME-DAMSL.

2 The Obligations and Grounding Structures

To illustrate these structures we present the analysis of a basic transaction taken from the DIME Corpus [10], which was collected in the context of the DIME project [8]. This transaction is as follows (translated from the originally in Spanish):

Table 1. Basic transaction

Speaker	Utterance	Text
U	25	After that <sil> can you put <sil> the the air extractor on top of the <sil> of the stove
S	26	Okay
S	27	<Graphics interactive action> Is this okay?
U	28	Yes, it's okay

The transaction involves an action directive dialogue act made by the U (human-user), followed by a commitment performed by S (System); up to this point the main intention of the transaction has been expressed and its satisfaction agreed upon. Next, S performs the committed action, and asks for confirmation of whether the action was the one intended by U; finally U confirms this, and the transaction is concluded. The last two utterances, including the motor action, constitute the intention satisfaction phase of the transaction. Next we present the structure of this transaction in both of these planes, with the actual dialogue act tags in bold:

Obligations structure

- (1) Intention specification by U
 - Utt25: After that <sil> can you put <sil> the the air extractor on top of the <sil> of the stove (1st charge on S: **action-directive**)
- (2) Intention interpretation by S
 - Utt26: Okay (2nd charge on S: **commit**)
- (3) Intention satisfaction by S
 - Motor action on design space (credits 1st and 2nd charges on S: **move-object**)
 - Utt27: Is this okay? (1st charge on U: **inf-request**)
- (4) Action interpretation by U
 - Multimodal interpretation by a visual act
 - Utt28: Yes, it's okay (credits 1st charge on U: **response 27**)

The expression of an intention in (1) by U creates an obligation charge on S: to answer if the intention is an information request, or to perform an action if the intention is an action directive, as it is case in the present example; however, before U's intention can be satisfied it must be interpreted by S and this process may be complex and involve several utterances and turns, as very often happens in our corpus; when this has been accomplished, S has either to commit to satisfy the intention, or to reject it explicitly. The commitment creates an obligation charge on the speaker himself. The performance of the requested act in the intention satisfaction phase credits both U's requests and S's commitment, balancing the transaction up to this point. However, in

our multimodal setting involving a design space, in which intentions can be under-specified and references are vague, S's actions need to be accepted by U and very commonly S asks for confirmation explicitly, creating an obligation charge on U. The transaction is concluded when U interprets S's action and verifies that it was indeed what was expected; as the design actions are performed on the design space, this interpretation act is often visual. Finally, the transaction is concluded when U confirms that the intention was understood and satisfied correctly, crediting S's information request for confirmation. Next we consider the common ground structure for the transaction:

Common ground structure

- (1) Intention specification by U
 - Utt25: After that <sil> can you put <sil> the the air extractor on top of the <sil> of the stove (1st charge on S: **action-directive**)
- (2) Intention interpretation by S
 - Utt26: Okay (credits 1st charge on S: **accept 25**)
- (3) Intention satisfaction by S
 - Motor action (1st charge on U: **affirm**)
 - Utt27: Is this okay? (2nd charge on U: **inf-request**)
- (4) Action interpretation by U
 - Multimodal interpretation (visual act by U)
 - Utt28: Yes, it's okay (credits 1st and 2nd charge on U: **accept 27, affirm**)

The first difference between the obligations and the common ground planes surfaces in the interpretation of the intention in (2): while to commit to perform an action creates an obligation, the same elocution accepts the action directive that requested the action in the first place, and this elocution makes a credit at the common ground plane. The second difference appears in (3) when S performs the action, either linguistic or motor, that satisfies U's request. Through this act S provides a new piece of information to U that, although from the obligations point of view satisfies the action directive, this is also an affirm dialog act, and the new information must be accepted or rejected by U, and the confirmation that this knowledge is shared by both U and S belongs to the common ground plane of expression. If in addition to the motor action there is an explicit linguistic request for confirmation, such question should also be accepted. Finally, while the answer to the confirmation question takes place at the obligations plane, this answer is also an affirm by U that restores the common ground, letting know to S that U shares the same beliefs with S about the satisfaction of the intention.

The structure of the transaction shows that while some forward looking functions that influence the future actions of the conversational participants belong to the obligations plane (e.g. information requests, action directives, offers and commitments), other forward looking functions belong to the common ground plane (e.g. affirm and re-affirm); there are also forward looking functions that do not create an obligation either on the speaker or on the hearer, like the open-option. Similarly, although most backward functions belong to the common ground plane (e.g. all agreement acts), and also the understanding acts at the communication level, other backward functions, like responding, belong to the obligations plane. Also, in the case an intention is rejected, U and S have a conflict about the knowledge and presuppositions shared by them along the task, and a reject dialogue act belongs also to the common ground plane. Charges and credits in both planes of expression are made through the surface

utterances, and the same utterance may have one or more functions on both obligations and the common ground plane; for instance, an *okay* that functions as a commit in the obligations plane is an accept in the common ground.

3 Balancing Transactions

There are constraints between the kinds of acts that can participate in a charge/credit relation. These constraints can be stated as rules relating dialogue act tags that should be obeyed in balanced transactions. Next we illustrate the rules used in the DIME-DAMSL tagging scheme; in this specification we distinguish whether the charge has to be credited by the other conversational participant, or by the one who makes the charge on him or herself. Tables 2 and 3 summarize these relations for the obligations and common ground planes respectively.

Table 2. Balancing relations for the obligations plane

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

Where:

- **Action** = {point-object | point-zone | point-path | point-coordinated-objects | place-new-object | move-object | remove-object | graph-plan | visual-interpretation}

In the scheme it is also considered whether a charge is made at the time the dialogue act is performed, or whether a dialogue act opens a conversational context in which a charge will be made, although the act itself does not make the charge directly; for instance, an action directive establishes an obligation at the time the act is made, but an offer does not create an obligation until the offer is accepted by the interlocutor; furthermore, if the offer is declined there is no charge at all. This property is specified for the each dialogue act type in the *Time* column of Table 2, where *I* stands for “immediately” and *P* for “postponed”.

Table 3. Balancing relations for common ground plane

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
Previous dialogue act	Understanding-Act	Other
Not-understanding-Signal (NUS)	Next utterance attending such signal	Other

The balancing relations of common ground dialogue acts are illustrated in Table 3. Most dialogue acts related to the agreement dimensions are expected to be “grounded” immediately by the hearer; however, dialogue acts related to the communication dimension signal that the common ground has been lost due to problems in the communication channel or because more information is required (e.g. when spatial referents are vague), and that it needs to be reestablished immediately.

Where:

- **Agr-action** = {accept | accept-part | hold | reject | reject-part}
- **Understanding-act** = {acknowledgment | back-channel | repetition | complementation | correction}

There are dialogue acts that do not make a charge or a credit in the common ground and only mark that the agreement act on a previous act has to be postponed. This is the case for the *hold* and *maybe* dialogue acts through which the speaker signals that the he or she is not sure or has reasons to believe that a previous act performed by the interlocutor has not been understood in the intended way and these acts open a context in which the common ground has to be reestablished before the conversation can proceed, or signal that more information is required to continue with the dialogue.

Tables 2 and 3 illustrate that the main dialogue acts follow simple rules at the obligations and the common ground planes: an information request is credited with a response at the obligations plane, and the interlocutor must adopt an agreement position towards such question, and in case it is accepted, the response is also an affirm act in the common ground plane. Action directives must be credited with an action in the obligations plane and an accept act in the common ground. The obligation acts that postponed its charge present a somehow more complex behavior; for instance, an offer charges the speaker, but only when the hearer has accepted the offer.

There are also dialogue acts that have an import on the common ground plane only; for instance, an open option creates no obligation but must be acknowledged either explicitly or implicitly by the flow of the conversation; also, affirming or reaffirming something with the purpose of introducing or highlighting new information does not impose an obligation on the other conversational partner, who only has to take notice and let know that he has done so to the information provider; making an unsolicited statement, or presenting new information through the visual modality, are also affirm acts that make a contribution to the common ground, and must be credited at this plane only.

The acts that postpone agreement have a more subtle behavior. A confirmation question has the purpose to support a belief that the agent that makes such a question has already; this act is an information request at the obligations plane, but it is also a hold act in the common ground; for this reason a confirmation question marks that a previous dialogue act is not accepted nor rejected immediately, but put on hold. The hold act opens a conversational segment or context whose purpose is to reestablish the common ground, and the dialogue act that closes this context accepts or rejects the postponed act.

A dialog act tagged as *maybe* is even more subtle. It arises in check questions, where the intent is, for instance, to confirm whether an agent really wants to do something that is not entirely justified for the task at hand. In a situation where U asks S to

do an action that does not seem to be relevant, or it is too expensive to accomplish or too restrictive in the utterance's context, and this is realized by S, but the evidence is not strong enough to reject U's request directly, a maybe dialogue act may arise. If at a point in the dialogue S says: *Okay, do you want me to move the stove to the left?* where *Okay* is pronounced with a dubitative tone, it may be a *maybe* dialogue act. The maybe act opens a context that postpones the acceptance or rejection of a previous act too. Also the dialogue act that closes the maybe context accepts or rejects the act that was questioned by the maybe act, and credits the corresponding charge.

Understanding acts make contributions to the common ground directly, and these are representative contributions to this plane of expression, as their only role is to strengthen the common ground or to restore it when it is lost; acknowledgments, back-channels, repetitions, complementations and corrections strengthen or repair the common ground and permit the flow of the conversation.

In the formulation of these rules, there is not a claim that there are necessary and sufficient conditions to classify an utterance as an specific dialogue act; rather, there may be several conditions that can be considered sufficient, and nevertheless not necessary for marking an act as a member of a given category, and the strength of one condition or combination of conditions may determine whether the act belongs or not

Table 4. Analysis of a transaction

U	T	Utterance	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				accept
3		I need a stove	3		3				action-directive	
4	s	A second				3				accept
		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			6	5				afirm, accept
7	s	Okay				6				accept
	u	eh, please I need it in <sil> in the far wall			8					afirm
9	s	Which one is the far wall?	9						inf-req	hold,
10	u	Let's see, here		9	10		11		answer	afirm
11	s	There?	11					11	inf-req	hold, repetition
12	u	Yes		11					answer	
13	s	A second	13			10	8		commit	accept
14		Is there alright? <graphical action performed with the question>	14	13 3 1	14				graph-action inf-req	
15	u	Yes, for the moment, yes		14		14			answer	accept

to a given category. In particular, the intonation used in the production of a dialogue act is one of the main properties of dialogue act types. For these reasons we cannot expect complete categorical answers for tagging questions, and the theory should be supported by the definition of explicit tagging conventions, and also on empirical evidence, and the agreement between taggers. We conclude this section with the analysis of typical transaction of our corpus.

In this transaction the main intention is specified from utterance (1) to (13) and the satisfaction is produced by an immediate graphical action in (14) and a final confirmation question, also in (14), and its answer in (15). In Table 4 the entries in the charges and credits cells index the corresponding dialogue act. The charge made by the offer that the system imposes on itself in (1) is postponed until the offer is accepted by the user in (2), and this obligation act is credited in (14) when the act offered to is finally performed. The main intention is the action directive stated in (3) by the user, with the corresponding system's commit in (13), and both of these acts are credited when the action is performed too.

The structure of the common ground is a bit more subtle; the agreement level includes two hold acts, with the additional complication that the second is embedded within the first. The first hold in (9) postpones the acceptance of (8), and the second in (11) the acceptance of (10); when the reference of *the far wall* has been resolved through (12), the system can credit the charges of the two affirm acts performed by the user in (8) and (10) by accepting them in (13). The check question in (11) has a component in the understanding level too; the word *there* in (11) is considered a repetition of *here* in (10). This latter pattern is a common phenomenon observed in the corpus; the use of spatial language introduces vague references very often, and this causes the common ground to be broken down at the level of agreement, as some references cannot be resolved directly, and also at the communication level, as these charges depend on the vague nature of spatial references. The common ground is restored with a deictic act that fixes the spatial reference, crediting the agreement charge, and resolves the vagueness, crediting the communication charge.

4 The Tagging Methodology

The tagging methodology considers, in addition to a taxonomy of dialogue act types and the specification on the structural relations that constraint the realization of these acts, a well-defined set of tagging conventions. These conventions refer both to the tags associated to the content of dialogue acts, and also to the tagging format.

In relation to the conventions about content, some dialogue acts have a positive character and mark a behavior explicitly (e.g. most acts that charge the obligations plane) while others have a negative character, and are only marked when the linguistic behavior deviates from the expected one. Accordingly, a tagging convention used in the present methodology is that only dialogue acts that mark an intention have an explicit tag; also, if an utterance expresses several dialogue act types, only the most prominent dialogue act in relation of the utterance main intention is explicitly tagged. For instance, the utterance *these are the stoves* made at the time a catalogue is displayed is only marked as an open option, despite that this statement can also be considered an affirm dialogue act; the convention is that the main intention of the speaker

is to show the hearer what stoves are available in order that the hearer is able to select one for the current stage in the design task; in this situation, the hearer should know already that there are stoves available, as he or she is engaged in a kitchen design task, and for this reason the dialogue act is not an affirm, in spite that this utterance is making an statement and has a declarative form.

Conventions at this level of content determine and complement the theory of dialogue acts from a practical perspective, and our tagging exercise shows that this kind of specifications is indispensable for the speech act analysis of practical dialogues. Similarly, all utterances have to be acknowledged in the communication level, but dialogue acts at this level are marked only when the communication flow breaks down, or an explicit feedback is needed. We take the convention that if S makes a dialogue act at the communication level, it credits the previous message uttered by U, which is marked as a communication charge. However, a not-understanding signal is an explicit communication charge; in this case, the hearer is obliged to credit the speaker's signal: If U says something and S says *sorry, what did you say?* U is obliged to repeat or rephrase his last utterance in order to recover the common ground.

We have also observed that another source of confusion and low agreement is due to the tagging format and the tagging tools, and the way these are understood and used by taggers. The tagging format is a dynamic object that should be defined and refined by the tagger team during the training phase of the tagging exercise, and the productive phase should start only when taggers have mastered not only the theory and the conventions about both the interpretation of dialogue acts, but also the use of the tagging format and tools. The format should also consider an easy calculation of tagging agreement.

Theoretical guidelines, the definition of tagging conventions and the actual empirical work are three aspects of the tagging task that interact and evolve together during the tagging cycle. The present theory and its associated tagging rules and conventions were developed in conjunction with the tagging task, and we considered two phases for the work and a specific methodology for carrying on with the exercise. The first phase is a training one in which we had to make sure that the theory and tagging conventions were mature enough, that taggers were familiar enough with the theory, the conventions and the annotation scheme, and that they had enough tagging experience to carry out the task successfully. The second phase is a production one in which tagging tasks are assigned to individual taggers or taggers teams.

In terms of the methodology, we divide the tagging tasks on three levels. First, we identify the transactions in a dialogue; here, we rely on two main guidelines: transactions have a main intention, with its corresponding specification and satisfaction stages, and transactions are balanced at both planes of expression. Once transaction boundaries have been marked by several teams, we compute agreement factors through the kappa statistic [4] at this level; the kappa statistic is a measure of how well annotators agreement is better than random annotation, and figures above 0.8 are usually considered very good. If these values are not high enough, specific discrepancies are identified and discussed by the tagging team, and the task is repeated until the kappa statistic is satisfactory. The methodology involves refining and identifying new tagging conventions in every tagging round.

The second step consists of marking charges and credits of both the obligations and common ground planes, and balance each individual transaction. Here again, we

compute the kappa statistics that measure the agreement with regard to the balancing structure of the transactions. When the kappa values are acceptable, we proceed to the third stage in which the actual tags of the DIME-DAMSL scheme are transcribed. The tagging task is supported by an excel format that allows to input the tags for transactions boundaries, the obligations and common ground structures and the actual DIME-DAMSL tags directly, and the computation of kappa statistics for transaction boundaries is supported by the same excel format.

For the validation and training phase we selected two dialogues with 117 and 137 utterances from our corpus; these dialogues have been studied in several dimensions including their prosodic structure, and were tagged in preliminary experiments performed by a team of 15 people. In the training phase several tagging cycles were required to reach an acceptable level of agreement for the identification of the transaction boundaries and also for balancing the transactions. In the formal experiment, the first dialogue was tagged by 3 teams of three people each and the second by three experimented taggers. The overall figures for this process are shown in Table 5. In this table the kappa statistics for the agreement acts and understanding acts of the common ground plane are shown explicitly. The global figures for the four main dimensions of the tagging scheme are shown in Table 6. As can be seen, our current figures are very promising.

Table 5. Kappa values for transactions balance

Tagging cycle	Trans. Bounds	Charge/credits Structure		
		Obligations Plane Chrs/Cdts	Common Ground Plane	
			AGR Chrs/Cdts	UND Chrs/Cdts
kappas	0.87	0.94/0.92	0.83/0.85	0.82/0.83

Table 6. Kappa values for the tagging exercise

Dimension	Tagging categories	Kappa
Information level	Task, Task-managment, Communication-management	0.83
Forward looking functions	Declarative: Affirm, Reaffirm, Other	0.87
	Information request	0.93
	Influence future actions of listener: Action-directive and Open-option	0.89
	Influence future actions of speaker: Offer and commit	0.89
Backward looking functions	agreement	0.82
	understanding	0.89
	response	0.94
Modality	Graphical actions	0.80

5 Conclusion

A theory of dialogue acts involves not only the specification of a set of dialogue act types, but also the way these are related systematically in relation to the transaction's

structure. The present theory provides an ontology of dialogue act types for multimodal practical dialogues, and several structural constraints for the realization of specific dialogue acts. The main kind of constraint is defined in terms of the obligations and common ground planes of expression, that have to be balanced in complete transactions; other structural constraints impose contextual restrictions on the realization of dialogue acts. The theory contemplates, in addition, the definition of tagging conventions related to the content of the dialogue acts, and also to the tagging format. The tagging task involves the creation of a tagging team that evolves and matures throughout the tagging exercise, and the whole of the process must be developed in the context of a well-defined methodology; currently, this methodology is being applied to the transcription of the DIME Corpus, and we hope to have a large number of dialogues fully transcribed in the near future. A good value of the kappa statistic for this larger exercise would provide a strong support for our theory.

There are also interesting implications of the present theory and methodology for a more comprehensive theory of dialogue structure, reference resolution and vague reference in spatial discourse; we have also observed that discourse markers are important indicators for the main transaction boundaries, and also that the scope of referential terms is local to the transaction context. We have also noticed that spatial language introduces vague references very often and that this kind of reference disrupts the common ground, and prompts a conversation segment involving check questions and confirmations that is closed with a spatial deictic reference that resolves vagueness, reference, and reestablishes the common ground all at once. We let the investigation of these issues for further research.

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