Negotiation Protocols and Dialogue Games

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Abstract

In a dynamic and open environment negotiation protocols cannot be known beforehand. We propose a methodology for constructing flexible negotiation protocols based on joint actions and dialogue games. We view negotiation as a combination of joint actions. Simple dialogue games that consist of initiatives followed by responses function as 'recipes for joint action' from which larger interactions can be constructed coherently.

1 Introduction

Agent based software engineering is an active research area. One of its main challenges is to bridge theoretical models and practical applications. For example, there are many theoretical results on negotiation [11], but automated negotiation is still rare on the internet. Implementing negotiation protocols raises a number of practical questions. In particular, current negotiation systems are either closed or semi-closed. In closed and semi-closed environments, like in auctions, there is central control over the agents that can participate. In such an environment, the protocol is guaranteed to be shared among participants and remains fixed. However, the internet is an open environment that needs more flexibility.

How can we extend automated negotiation systems to a dynamic and more open type of environment? In an open environment there is no control at all over the participating agents. In a semi-open environment there is no centralized control, but there may be a form of self-regulation [2]. Negotiations form a particular class of interaction types, which correspond to a particular class of activities (e.g. trading, consulting, deliberating). In a dynamic environment the activities of agents may change between or during visits. So the rules of interaction may also change. Thus, for semi-open and dynamic environments a complete and fixed negotiation protocol can no longer be presumed. Each time that agents meet they have to learn, recognize, construct or select an appropriate protocol for that specific occasion.

The contribution of this paper is a methodology for constructing flexible negotiation protocols based on dialogue games. Although negotiating agents may have competing interests, they share a common goal to coordinate their actions. To represent coordinated actions we use partial representations, called *recipes* [4].

A particular type of recipes is formed by the so called *dialogue games*. Empirical studies of human dialogue show frequently re-occurring patterns of dialogue acts. These patterns can be described by the rules of a dialogue game [6, 7].

The layout of this paper is as follows. In section 2 we discuss the role of protocols in current negotiation systems. In Section 3 we introduce joint plans, recipes and dialogue games. In Section 4 we illustrate our approach by an example. The paper ends with a summary.

2 Negotiation Systems

Existing negotiation systems are defined by a negotiation protocol – rules specifying the possible actions for the participating agents – and a negotiation strategy – a directive for deciding between different actions at a certain stage [11]. The protocol is usually represented by a finite state machine where a state transition represents a negotiation act like a proposal, acceptance or rejection. A strategy of an agent is represented by a trace of the protocol: a sequence of negotiation acts. The protocol and strategy can be described in terms of various parameters [9]. The most important parameters are *cardinality* (one-to-one, one-to-many, many-to-many), dimensions of *negotiation items* (single-attribute item, multi-attribute item), *agent attitude* (social, selfish, cooperative, competitive) , and aspects of the *agent architectures* that are used (BDI components, commitments, trust) [10].

These negotiation parameters can be used to determine both coherency and desirability of a negotiation protocol. For example, the fact that the cardinality of negotiation is one-to-one helps to determine which actions will take place at a certain stage of negotiation: after a request only one proposal can be received and after one proposal only one counter proposal can be generated; note that this needs not be the case in many-to-many negotiation settings. To illustrate the desirability of negotiation protocols, consider a scenario where there are many seller agents but few buyer agents. The buyer agents would prefer a protocol that allow them to retract their commitments after having accepted a proposals, assuming that there is a time-limit on accepting proposals such that buyer agents cannot wait for the proposals of all seller agents to select the best one.

If agents in an open environment can be disadvantaged by the choice of protocol, they should in principle first agree on the protocol before starting to negotiate on the subject matter. This implies a pre-negotiation phase in which the negotiation item is a protocol. Each agent requires a domain theory to generate and analyze the space of possible negotiation items and to evaluate their value. The parameters listed above can be used to generate, analyze and evaluate negotiation protocols .

3 Dialogue Games

We propose a method for designing flexible negotiation protocols based on a theory of interaction developed for natural language dialogue systems [5]. A dialogue is considered to be a coherent sequence of utterances. An utterance is a single meaningful unit of communication. The information conveyed or requested by an utterance is called the *semantic content*. An utterance has a purpose: the *communicative function*. The function is usually related to the underlying activity or task, but some of the function is to maintain the interaction process itself. Each utterance is analyzed as a *dialogue act* which is again fully characterized by a semantic content and a communicative function. The goal of a dialogue model is to structure a dialogue into dialogue acts, and to find the relationships between dialogue acts that explain their coherence.

What makes a dialogue coherent? By exchanging utterances participants iteratively build up a dialogue context which contains a representation of the statements and commitments that were made. We say that an utterance is coherent with respect to the dialogue context, if at least two constraints apply: (i) the task-related function of the utterance must fit some plan related to the task that can be inferred from the previous utterances in the dialogue context, and (ii) the interaction related function of the utterance must correspond to the interaction rules for the current type of dialogue. In negotiation theory, these constraints nicely correspond to (i) following a suitable strategy, and (ii) to respecting the negotiation protocol.

How can a dialogue act fit a plan? Like any action, a dialogue act can be characterized by its preconditions and intended effect. For example, the intended effect of asking a question, is to get to know an answer. A question has as a precondition that the answerer knows the answer and is willing to reply. For each dialogue act, such pre- and post conditions can be given, just like in traditional speech act theory. A plan can be constructed from basic actions by the previously mentioned connectives, provided the preconditions of an action match the effects of the previous actions. Luckily, plans do not have to be re-constructed every time. Agents may select a suitable solution from a plan-library. The exact way a plan will be carried out cannot always be known in advance, so it pays to have only a partial specification. Details can be filled in as the interaction progresses. Such pre-compiled partial specifications of combinations of actions to reach some goal, are called *plan recipes* [8, 4]. Recipes for plans that involve several agents typically contain *roles* to be assigned to the participating agents.

Recipes are standard solutions to frequent coordination problems. If we look at a corpus of example dialogues, we find evidence of frequently occurring sequences of utterance types, called *interaction patterns*. For example, an exchange of greetings and goodbyes mark the opening and closure of an interaction; questions are followed by answers and proposals are usually countered, accepted or rejected. A useful metaphor for studying interaction patterns is that of a *dialogue game* [7, 6]. Each participant plays a role and expects the others to play their respective roles. Each participant makes the moves that are appropriate for its role. The rules and the stage of the game determine which moves are allowed, and which are beneficial.

Carletta et al. desribe hierarchically ordered interaction patterns as *games* [6]. Games are sequences of *moves*. Each move corresponds to a type of utterance. So what we called the interaction-related communicative function of an utterance, is defined as the move in a game. Moves can be either *initiatives* or *responses*. Typically, each initiative must be followed by an appropriate response, although

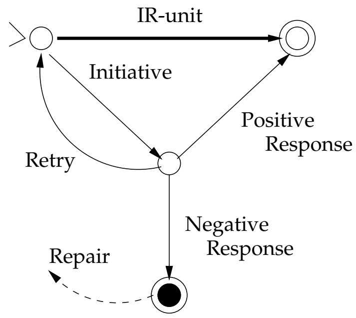

Figure 1: Initiative-response units

there may be other exchanges first. For example, a clarification exchange may precede the answer to a question.

Initiatives and responses are often related by a triangle structure such as the one depicted in figure 1. It is composed of an initiative, followed by either a positive or a negative response, or else a retry. For example, a proposal is an initiative, an acceptance is the corresponding positive response, a rejection is the negative response and a counter proposal is an example of a retry. In case of a negative response some precondition for a successful completion of the exchange may have been violated. In that case a repair may be needed of parameters that were fixed in a previous phase. Questions and answers, or assertions and acknowledgments follow similar patterns. A combined initiative-response unit results in some information being added to the common ground: the information that is mutually known among the dialogue participants. In other words, a response of the right type has a so called *grounding* effect [1]. This is one of the defining features of basic dialogue games to be used in the construction of larger coherent dialogues: they must have a grounding effect.

4 Dialogue Games for Negotiation

Can we use these insights in negotiation? Negotiation can be modeled by a particular type of dialogue game, in which each utterance is interpreted as a negotiation act. The underlying task is to reach agreement with other agents about negotiation items, as described by the parameters of section 2. The semantic content of a negotiation act describes negotiation items. The negotiation acts are proposals, counter proposals, acceptances and rejections, but other dialogue acts like greetings, questions and assertions, or checks and confirmations are needed too.

As we said, most exchanges are of the form of example (1): an initiative, followed by either a positive or negative response, or else a retry. An exchange is allowed, given that the *coherence constraint* on the semantic contents of the initiative and response is met. In other words, the response must address the initiative. In case of a response, the content of the response, denoted by ζ below, is considered grounded; it can be regarded as the resulting content of the complete exchange.

$$(1) \qquad exchange(a,b,\zeta) = \quad initiative(a,b,\eta);\ \begin{array}{l}(\ pos\_response(b,a,\zeta)\\ \mid neg\_response(b,a,\zeta)\\ \mid retry(a,b,\xi)\ ),\end{array}$$
$$\text{where } M_{a,b} \models coherent(\eta,\zeta).$$

The notation can be explained as follows. The semantic content of a declarative dialogue act, such as an inform or an assertion, is a regular proposition, denoted by $.\phi$ or simply ϕ. The content of a interrogative dialogue act, such as a question, is called an *issue*, denoted by $?\phi$. It represents the content of a question, which specifies what would count as an appropriate answer [3, 5]. Initiatives often express an issue; responses often express a proposition. The content of a directive dialogue act, such as a proposal or request, is a commitment, denoted by $!\phi$. Commitments can be modeled in terms of goals and properties of persistence [13]. Other types of content may be added for other types of dialogue acts, such as emotions for affective acts. By convention, we let ζ, η and ξ range over all types of content. The shared dialogue context which contains a representation of the previously grounded content, is denoted by $M_{a,b}$ here. M_a denotes the previously grounded content, that agent a is committed to. See [5] for more details about the underlying logic.

The initiative-response structure can be managed by a push-down automata. Initiatives are pushed; they are popped when they have been responded to. Thus, sequences like $I(IR)(IR)R$ are well-formed. Obviously, in human-human and human-computer interaction specific *dialogue control acts* may be needed to manipulate the stack ('anyway') or that return to a previous topic ('as I was saying').

Below we list some examples of basic exchanges with the corresponding coherence constraints. Example (2) shows a mutual greeting, which opens an interaction. A returned greeting is always considered coherent. We could consider adding the identity of the speaker and hearer as the semantic content of a greeting, as well as the used protocol and content description language.

Example (3) shows an information seeking exchange. For an answer to a question, we require that it be consistent, informative, relevant to the question, and not over-informative with respect to the question. A proposition is considered relevant, when it addresses some issue that was previously raised in the context. It is licensed, if it addresses only contextual issues. Such constraints can be formalized in an epistemic logic that can deal with the semantics of questions and answers [12, 3, 5]. A relevant answer ψ is considered part of the common ground afterwards, and thus can be seen as the result of the information seeking exchange.

Coherence constraints for negotiation, in example (4), are typically expressed in terms of the strengths of the commitments made by the agents, depending on the particular negotiation type. In the case of a monotonic concession protocol (MCP), a counter proposal is coherent with the context, if the commitment expressed is considered a concession for the speaker. This is for instance the case, if the new offer ϕ' is less preferred under the agent's preference order $\prec$.

(2) $greeting(a,b) = greet(a,b); greet(b,a)$.

(3) $information\_seeking(a,b,\psi) =$
$question(a,b,?\phi);\ (answer(b,a,\psi)$
$\mid clarification\_question(b,a,?\chi)),$
where $M_{a,b} \not\models \neg\psi \quad (consistent)$
and $M_{a,b} \not\models \psi \quad (informative)$
and $M_{a,b} \models relevant(?\phi,\psi)$
and $M_{a,b} \models licensed(?\phi,\psi)$.

(4) $nego\_mcp(a,b,!\phi) =$
$propose(a,b,!\phi);\quad (\ accept(b,a)$
$\mid reject(b,a)$
$\mid counter\ propose(b,a,!\psi)),$
where for all $!\phi', !\psi'$ such that $M_a \models !\phi'$ and $M_b \models !\psi'$
$!\phi \prec_a !\phi'$ and $!\chi \prec_b !\chi'$.

These examples do not pretend to give a full list of basic exchange types. They merely show the mechanism.

The last question to be answered is how such basic dialogue games are to be combined coherently. Most common is a sequential combination, of the form shown in (5). The end-result of such an exchange, is a combination of the two results, expressed here by a '$\cdot$'. For example in (6), two information-seeking games may be joined, when the second continues to be relevant for the same over-all issue. Such a topic continuation can again be expressed as a coherence constraint. The end-result is modeled here as the conjunction of the two answers[1].

(5) $game(a,b,(\eta\cdot\zeta)) = exchange(a,b,\eta); game(a,b,\zeta),$
where $M_a, b \models coherent(\eta,\zeta)$.

(6) $information\_exchange(a,b,\phi\wedge\psi) =$
$information\_seeking(a,b,\phi); information\_exchange(a,b,\psi),$
where $M_a, b \models ?\chi$ such that
$M_a, b \models relevant(?\chi,\phi)$ and $M_a, b \models relevant(?\chi,\psi)$.

One way in which we can interpret the notion of relevance used here, is by relating the content of an utterance to the apparent underlying goal of one or both of the participants. So a proposition is considered relevant when it resolves an issue in the context. Bringing up an issue is considered relevant when its solutions,would help in achieving the apparent task of the speaker. So in general, the coherence of a response is related to the initiative that prompted it. The coherence of an initiative can only be assessed relative to the apparent task of the speaker.

In another common combination type, the first move of the second game is replaced by the last move of the first game. So two negotiation exchanges can be joined, where the counter proposal of the first plays the role of the proposal in

[1] More elaborate ways of combining would involve belief revision, or update semantics [12]. Note that coherence at the dialogue level ensures that no flat contradictions are encountered

the second. In this way a chain of proposals and counter proposals may result, which continues until an acceptance or a rejection. The reason that this is a viable way of continuation is that counter proposals are really rejections of responses and initiatives collapsed into one. A counter proposal implicitly rejects the current proposal as insufficient, and replaces it by a new proposal. What counts as a counter proposal or an acceptance, often depends on the underlying negotiation task. In the monotonic concession protocol, a repetition of a's proposal by b counts as an acceptance; a repetition of a's proposal by a fails to address the proposal previously made by b, and may thus be considered a rejection. Thus a task-related notion of coherence is often also needed to recognize the dialogue act type in the first place. In this way, coherent dialogue games can be constructed from basic initiative response units. The resulting content of a dialogue game will by the nature of the basic games and the coherence preserving nature of the combination operations, always be grounded.

5 Summary

We sketched a methodology for designing flexible protocols shared among participants in dynamic and open environments. It is based on a combination of joint plans and dialogue games, i.e. on the 'why?' and 'how' of negotiation. A negotiation is described as a set of joint actions, in the sense that actions are coordinated between the participating agents. The joint actions are inspired by natural language theories. A key notion of negotiation protocols is *coherence*. An utterance or move in a negotiation dialogue is coherent with the dialogue context, if (i) it fits a plan that might achieve the apparent goals of the agent, and (ii) it fits the current interaction rules. Depending on the attitude of the agent and on who has the initiative, (i) or (ii) takes precedence.

In further research we will elaborate on the notions 'relevance' and 'coherence' of negotiation actions and negotiation protocol and formulate them for various negotiation settings specified in terms of negotiation parameters. As we have explained, constructed coherent negotiation protocols for certain negotiation settings should be evaluated to decide if they are beneficial or not. Therefore, we need to develop such evaluation functions in our future work as well.

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