Towards a Conversational Language for Artificial Agents in Mixed Community

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Abstract. Present agent and interaction (agent communication language: ACL) models have been conceived for pure artificial agent communities, most often strongly linked with knowledge exchange. But these models are not adapted to conversational interactions, and particularly to mixed community melting artificial and human agents. We first underline these model limitations. We propose a first step towards a *conversational* agent language fitting with a BDI agent model in respect with Speech Acts Theory and integrating essential elements of the conversational background. This proposition is a continuation of Chaib-draa and Vanderveken's work [1] on a recursive semantics for ACL according to the situation calculus.

1 Introduction

Artificial agent models like BDI (Belief, Desire, Intention) agents [2,3] and models of interaction between agents like KQML (*Knowledge Query Manipulation Language*) [4] and FIPA ACL (*Foundation for Intelligent Physical Agent*) [5], have always been conceived for precised application tasks, and mostly for information exchange. These communication languages are only dedicated to artificial agents systems. However, we are meeting a new step in the evolution of computing systems in which these models are not enough efficient, the task being not yet the exclusive issue for multi-agent systems. Because we now need to count with human agents in agent communication, we also need to ensure more common conversations between artificial and human agents evolving into mixed community.

Considering these mixed communities, usual pure artificial agent communication languages are no more adapted. Usual ACLs are too task-linked and do not take the background parameters into account, and as far as we are concerned the conversational background ones. We then propose a first step towards a *Conversational Language* between artificial agents of mixed community fitting as close as possible with Speech Acts theory [6,7,8], a valid theory of human interaction.

So as to build this language, we propose to lean our research on Vanderveken's work [8] on speech act theory and those in recursive semantics for an agent communication language [1]. We carry on and complete this research by a formal definition of the set of speech acts and take into account the conversational background essential for speech acts comprehension.

Our aims in this article is to consider the current interaction languages, then to introduce a formalization of speech acts theory and finally to propose, in accordance with the theory, a possible capture of the conversational background for an efficient agent *Conversational* language between human and artificial agents.

2 BDI Agents and Agent Communication Languages nowadays

2.1 BDI Agents

BDI agent model roots in Bratman's [9] research on intentions integration into action theory, taking future directed actions and consequently partial planning into account. Cohen and Levesque [2] have formalized this philosophical research on which the BDI intelligent agents of Rao and Georgeff [3] was constructed. These BDI agents have mental states : beliefs (B), desires (D), and intentions (I) which permit them to act *rationally*. These are parts of the field of cognitive agents which aims to create agents not only intelligent, but also rational because they can *reason* before acting. BDI models are nowadays a crucial paradigm for human like agent actions modeling [10]. But, if action theory is surely adapted for *basic* actions, we believe that conversational actions need a particular management such as the contextualization that could be captured by means of speech act theory.

2.2 Agent Communication Languages

Agent Communication Language, like KQML and FIPA ACL have the same seminal idea from ordinary language philosophy [11,6] that each utterance is an act – *i.e., an action* – which aims to accomplish, to do something. So that FIPA ACL and KQML messages, like speech acts, express an illocution value – *i.e. an action specification* – applied to a propositional content. The essential difference between these two languages stands in theoretical considerations, more precisely in the language semantics which roots in different agent theory. For FIPA ACL, the theoretical aspects dealing with the formal semantics of interaction languages were largely developed by Sadek [12]. Although these languages were founded on Speech Act theory [6,8], they do not define language primitives in each act categories, but only in assertive and directive primitives – *i.e., respectively, Inform and Request and their derived acts*. So that agent communication capabilities are sharply restricted : agents cannot produce commissive or expressive acts, such as: *promise, felicitate,* or *apologize*. Primitives are essentially task-oriented which seems to be justified because FIPAs project was to propose specifications for an interaction langage so as to maximize agent-based applications interoperability, and only for artificial agents.

As Singh [13] noticed, these languages are neither conceived nor usable for exchanges such as dialog ones. Recent Phd Thesis of Guerin [14] also supports this idea. Singh argues also that acts should not be defined anymore exclusively on agent mental states, because this provide an unique model of agency which reduces the set of realizable agent models. Interactions are over-controlled and sometime counter-intuitives, *e.g.* an agent cannot repeat so as to confirm a proposition. According to Singh, it is necessary to take account of social aspects in order to evolve from *mental agency* to *social agency* to consider current situation, and in particular the agents social context which needs to be apprehended, according to us, by the consideration of the conversational background. Then, so as to permit artificial agents to ensure dialog with other agents, humans included, with a larger autonomy of interpretation and expression, we propose to keep the use of speech act theory but to exploit it deeper, consequently we could make use of the overall set of existing performative verbs.

In the next section, we expose speech act theory and its advantages for the definition of a conversation language between agents (Conversational-ACL).

3 Speech Acts Theory

3.1 Theory presentation

According to the ordinary language philosophy initiated by Austin [11], primary units of meaning in the natural language use and comprehension are illocutionary acts with felicity conditions (success and satisfaction conditions), despite of *simple* truth conditions of propositions as in the *classical* logical trend. By attempting to perform illocutionary acts that the speaker expresses and communicates his minds by means of discourse. The speaker expresses propositions with diverse defined forces, he refers to objects under concepts, makes predication acts and expresses a propositional content with certain conditions. So that, elementary illocutionary acts are like *F(P)*: they are composed by an illocutionary force *F* and a propositional content *P*. We can then express a proposition *P* with some constraints with the help of the illocutionary force applied on this proposition. By studying the illocutionary force and the propositional content, illocutionary logics appears to be an efficient tool for formal semantics to analyse the meaning of every type of sentences which expresses every type of illocutionary acts. Illocutionary logics, for speech acts theory, is essential and complete for discourse analysis and synthesis. Speech acts theory, considering each utterance as a whole action, is entirely enrolled in action theory's domain. So that, it looks relevant to practically make use of it, by defining a Conversational-ACL, inside a BDI agent model which roots in a compatible theory of action.

3.2 Speech Acts Theory taxonomy

As we have mentioned it, elementary speech acts are formally traduced by *F(P)*, where *F* stands for the illocutionary force with which the act is performed on *P*, the propositional content. The illocutionary force components define conditions which must be observed for the speech act to be performed with success and satisfaction. The six illocutionary force components are: the **illocutionary point**, the **mode of achievement**, the **degree of strength**, the **propositional content conditions**, the **preparatory conditions**, the **sincerity conditions**. There is five primitive illocutionary forces which have respectively an illocutionary point, no particular mode of achievement, a neutral degree of strength, and propositional content, preparatory and sincerity conditions determined by the illocutionary point. The five primitive illocutionary forces are: **assertive** to describe states of the world, **directive** to attempt to make someone do something by telling him, **commissive** to commit yourself to do something, **declarative** to do something only by performing the corresponding illocutionary act, **expressive** to express feelings and attitudes. These five forces are expressed through five verb classes named *performative verbs*. The set of performative verbs of each class is obtained by varying the different primitive forces components applying the following operations: addition of propositional content, preparatory or sincerity conditions, restriction of the mode of achievement or modulation of the degree of strength.

3.3 Success and satisfaction conditions

Like all human actions, illocutionary acts have success conditions considering that they can succeed or not (*e.g.* when I order something to someone on which I have no authority). Illocutionary acts have also satisfaction conditions because they are directed to some states of affairs on which the speaker has no control (*e.g.* if someone who has authority on me orders me something and I do not obey). **Success conditions** are those that must be observed in the context of utterance for the speaker to perform the speech act.An illocutionary act *F(P)* is performed with success if and only if the speaker: (i) has achieved the illocutionary point of the force *F* on the propositional content *P* with the correct mode of achievement, and *P* respects all the propositional content conditions of *F* in this context; (ii)presupposes all the propositions determined by the preparatory conditions of *F*; (iii) expresses, with the right degree of strength, mental states noted *m(P)* having the psychological modes *m* deduced from the sincerity conditions of *F* (joy, sadness, compassion,. . .).

The **satisfaction conditions** must be met in the world of an utterance context for an illocutionary act to be satisfied. An illocutionary act *F(P)* is satisfied in a context of utterance if and only if *P* is true considering the right direction of fit of the illocutionary point *F*. As a conclusion, giving a complete set of practical tools for utterance analysis [7], illocutionnary logics allows to complete a cognitive approach of BDI agents. Moreover, the *"catalogue"* of performable speech acts for conversation is multiplied by the great combinatory possibility of the illocutionary forces components of speech acts theory; we can then go through the carency of slight differences and types of performative verbs in ACL as a response to Singh [13].

4 Towards an ACL for conversational agents

In Chaib-draa and Vanderveken [1], the authors propose a recursive semantics based on success and satisfaction conditions for agent communication langages. This work roots in Vanderveken's general semantics [8] and in illocutionnary logics [7], in accordance with speech acts theory. This work constitutes a semantical base for an ACL which seems to us particularly relevant to evolve towards an efficient Conversational-ACL. As a conclusion, giving a complete set of practical tools for utterance analysis [7], illocutionary logics allows to complete a cognitive approach of BDI agents. Moreover, the *catalogue* of performable speech acts for conversation is multiplied by the great combinatory possibility of the illocutionary forces components of speech acts theory;

we can then go through the deficiency of slight differences and types of performative verbs in ACL as a response to Singh [13].

In order to clarify this presentation, we expose briefly, in the next section, the proposition of Chaib-draa and Vanderveken [1]. Then, we introduce our proposition to complete this semantics and illustrate it through two essential primitive illocutionnary acts (as in FIPA ACL): *Inform* and *Request*, we then propose a formal definition of the performative verb *Promise* which may expand the capabilities of expression of artificial agents in mixt community. The entire set of available speech acts in not described here.

4.1 The recursive semantics of Chaib-draa and Vanderveken

Chaib-draa and Vanderveken [1] proposed the use of the situation calculus as to formalize an adequate reasoning about action (language or not) and its effects in the world. The situation calculus is originally a first order formalism for action modelization. In the case of actions to communicate, the situation calculus enables the representation of the preconditions and the consequences of each action. As far as FIPA ACL is concerned, we should talk about *FP – i.e., feasibility preconditions* – and *RE – i.e., rational effects*. The most important point, according to us, in the situation calculus is that it allows to formalize strong context dependent utterances, because it takes the current situation (conversational background included) and the immediate next one into account. So that, the situation calculus appears to be an efficient tool for action formalization in multi-agent systems, and, particularly, for conversation between agents. According to this point of view, Chaib-draa and Vanderveken [1] have proposed a semantics based on the situation calculus integrating intensional logics' and illocutionary logics' semantics.

In the situation calculus, terms represent complete states of the world – *i.e. situations*. To perform – *i.e. to accomplish with success and satisfaction* – an action α in a situation *s* will be noted by *do*(α,*s*). The possibility to perform α in a situation *s* will be formalized by *Poss*(α,*s*). The initial situation will be noted S_0 and the situations will be arranged by the relation $\succ$, where *s'*$\succ$*s* means *s' can be achieved from s by performing one or more actions*. The authors [1] have introduced a set of binary accessibility relations on situations for an adequation with speech acts theory. These operators are the following : **belief** (*bel(i,p)*), **desire** (*wish(i,p)*), **goal** (*goal(i,p)*) (non-primitive operator contrary to Cohen and Levesque [2]), **capability** (*can(i,a,p)*), **commitment** (*cmt(i,p)*), **has.plan** (planning) (*has.plan*(*i*,π,*p*)), **intention** (*int(i,p)*) defined on the base of *commitment* and *has.plan*, and **obligation** (*oblig(i,j,p)*) in connection with a norm. The definition of these operators allows the expression of the **success** (*success(ACT)*) and **satisfaction** (*satis(direction of fit)(ACT)*) **conditions** of each act type also formalized by the enunciation of six propositions permitting to express all the possible nuances of the illocutionary force components of an act, and then, all the performable illocutionary acts.

As a result, the situation calculus enables to express the different states of affairs encountered in speech acts theory in agreement with a rational BDI modeled agent. Moreover, as we will illustrate it, mental attitudes can be embedded in a background, in this case conversational, and we think this is the power of this semantics to evolve from *mental agency* to *social agency* [13]. Actually, Chaib-draa and Vanderveken have suggested that it is possible to take into account some elements of the background necessary for the definition of the success and satisfaction conditions of an act, such as the degree of strength or the role of an agent. We then propose a solution to include them, considering the fundamental role of the context *-i.e., conversational background*. Moreover, by considering the conversational background, we reach a higher level of interpretation *-i.e., a pragmatical level-* and not only a semantical or syntactical level of meaning without any context.

Remark 1. This formalization is a compromise between theory and computation in order to allow the use of speech acts theory into artificial agents so as to permit them to converse as adequately as possible in natural language with human agents. As a result, it is not a formalization of human-human interaction but of a possible human-agent interaction.

4.2 A conversation language between agents: Conversational-ACL

Among all elements of the conversational background that an agent must take into account when he analyses and interprets speech acts, the degree of strength and the role of agents are certainly the most important ones [15]. Actually, they are necessary for the contextualization of an act: the degree of strength to quantify the emphasis with which the act was performed, and the role to interpret acts where the hierarchy is needed for comprehension and for production too. These variables were not included in the proposition of Chaib-draa and Vanderveken [1], we then make a proposition of inclusion: to evolve from *do(says.to(i,j,$\langle f,p \rangle$),s))* to *do(says.to(i,j,$\langle f,p \rangle$),s), degree, role)*. The degree of strength and the role are expressed by relative integer number (positive or negative) clearly pointing out the power more or less important of the illocutionary act. The role is expressed by a relative integer number too interpretable from a given semantics. We can then think over to precise some elements (*e.g.* the sex or the age of agents) or to take other elements into account, like variables denoting emotional aspects involved in a rational contextualized reasoning.

Remark 2. The force *f* is a primitive one (assertive, directive,...) and the degree of strength is rejected outside its scope for more visibility and flexibility.

The possibility of verifying the success and satisfaction conditions of illocutionary acts is essential, in particular for a conversational agent because we cannot perform adequately an illocutionary act if these conditions are not encountered. These constraints also allow to form attempts on the subsequent situations since the situation of utterance only by placing some clues of comprehension in the linking of actions. For example, in the case of a command which is satisfied only when it is obeyed, we then emit the attempt for the performance of an action satisfying the illocutionary act, in other words the illustration of obedience. For an act of promising that should be successful only if the speaker commit himself to accomplish a given action, we should then construct a list of commitments – *i.e., commitment stores* – of the conversation members noticeable with the consideration of the subsequent situations. The formalization of the natural language utterance into speech acts can permit to extract commitments and then use them into dialog games for a dynamical management of interaction [16]. Finally the ability to manage a large variety of parameters into the same communication language allows a dynamical management of acts sequencing, whereas classical interaction protocols define *a priori* and consequently fix series of actions. So that we should organize conversations between agents in function of a dialog taxonomy like the one of Walton and Krabbe [17], or in function of the agent capability coming from its role, or else in function of dialog strategies in accordance with game theory [18].

So as to illustrate our proposition, we propose a re-definition of two of the primitive communicative acts of FIPA ACL *Inform* and *Request* using the recursive semantics to carry out interesting aspects. We then give the formal definition of the performative verb *Promise* to show the possibility to allow artificial agents to interact with human agents as close as it is permitted by speech acts theory.

Inform In speech acts theory, the performative verb *Inform* is not a primitive but an assertive verb of degree of strength 2 (+2) in reference to the assertive primitive *assert*, because *informing of a proposition p* is not only *asserting a proposition p*, but it means *believing the proposition* (having reason(s) for the truth of proposition p) and also *believing that the hearer do not already believe it* and then *having the intention of causing him to believe it*. We consider here that the agents role is neutral (0 value) and not relevant for the example. The speech act *Inform* in a given situation *s* is formalized by:

$$s = do(says.to(i, j, \langle inform, p\rangle), s_u, 2, 0) \quad (1)$$

$$\text{with} \quad (\forall s')(s' \succ s)$$

$$s_u = bel(i, p)[s] \wedge bel(i, (\neg bel(j, p)))[s] \wedge int(i, bel(j, p))[s'] \quad (2)$$

$$\text{and } s' = bel(j, p)[s'] \quad (3)$$

The speech act depends on the preconditions defined in the situation of utterance s_u and has effects on the following situation s' – *i.e. the next complete state of the world* –, in other words, a *perlocutionary* effect which might be verified by the agent in the following conversation. The satisfaction conditions will then be:

$$success(says.to(i, j, \langle inform, p\rangle), s) \equiv cond.success(\langle inform, p\rangle)[s] \quad (4)$$

$$satis^{wl}_{wd}(says.to(i, j, \langle inform, p\rangle), s) \equiv p[s] \wedge p[s_u] \wedge bel(j, p)[s'] \quad (5)$$

The success conditions (4) of this speech act must then be verified in the *cognitive* state of the agent. The speech act *do(says.to(i,j,*$\langle inform, p\rangle$*),*s_u*,2,0)* will be performed *successfully* if and only if: (i)The speaker *i* has achieved the illocutionary point of *informing* on the propositional content *p*; (ii) without any particular mode of achievement; (iii) with the propositional content condition that *p* is true in the given context; (iv) *i* presupposes the preparatory condition that the hearer *j* does not know *p*; (v) *i* expresses this speech act that he believes *p* with the degree of strength 2, and his mental state is *bel(i,p)*; (vi) and the speaker *i* is sincere.

Finally, the satisfaction conditions (5) of this illocutionary act should be verified considering the following situation, next complete state of the world resulting from the speech act. The illocutionary act *do(says.to(i,j,*$\langle inform, p\rangle$*),*s_u*,2,0)* will then be *satisfied* if and only if: (i) *p* is in fact true in situation *s* and (ii) if *j* believes *p* because of *i*'s performance of the *Inform* speech act.

Request Among the communicative acts of FIPA ACL, *Request* is the directive primitive. According to speech acts theory, it is not the directive primitive which is the performative verb *question*, although *request* has a neutral degree of strength. *Request* has the particular mode of achievement that the hearer has an option to refuse the request. Moreover, the directive verbs class has the particular preparatory condition that the speaker believes his hearer is able to perform the action expressed by the conditional content. This action could be a simple demand of information. The verb *request* has also the sincerity condition that the speaker desires that proposition *p* becomes true because of the action performance of his hearer. *Request* definition will then be:

$$s = do(says.to(i, j, \langle request, p\rangle), s_u, 0, 0) \tag{6}$$

$$\text{with} \quad (\forall p')(\forall a)(p \Rightarrow a)(\forall s')(s' \succ s)$$

$$s_u = bel(i, can(j, a, p'))[s] \wedge bel(i, Poss(j, a)) \wedge wish(i, p)[s] \wedge int(i, do(j, a))[s'] \wedge \neg oblig(j, i, a) \tag{7}$$

$$\text{and } s' = a[s'] \wedge p[s'] \tag{8}$$

Success and satisfaction conditions will be:

$$success(says.to(i, j, \langle request, p\rangle), s) \equiv cond.success(\langle request, p\rangle)[s] \tag{9}$$

$$satis^{wd}_{wl}(says.to(i, j, \langle request, p\rangle), s) \equiv (\exists s', s'')(s'' \succ s' \succ s) \; Poss(a, s'), ..., Poss(a, s'') \wedge success(says.to(i, j, \langle request, p\rangle), s'') \supset p[do(a, do(a, do(a, s'')))] \tag{10}$$

do(says.to(i,j,$\langle request, p\rangle$*),*$s_u$*,0,0)* will be *successfully* (9) performed if and only if: (i)the speaker *i* has achieved the illocutionary point of *requesting* on the propositional content *p*; (ii) with the particular mode of achievement that the hearer has the option to refuse the request; (iii) with the propositional content condition that *p* becomes true in a subsequent situation because of performance of *j* of the action *a* expressed by the propositional content; (iv) the speaker *i* presupposes the preparory condition that his hearer *j* is able to perform the action expressed by the propositional content *p*; (v)*i* performed this act with the neutral degree of strength; and (vi) with the sincerity condition that *i* has sincerely the desire that *p* becomes true.

Finally, the satisfaction conditions (10) of this act will be verified from the cognitive state of the agent, in function of its conditions of success and of the situation resulting from the speech act. *do(says.to(i,j,*$\langle request, p\rangle$*),*$s_u$*,0,0)* will be *satisfied* if and only if: (i) action *a* implied by *p* is in fact possible in the following situation(s) (future action(s)); (ii) the speech act is successfully performed in *s*; and (iii) *j* makes *p* becoming true because of his action(s) in the following situation(s).

We have presented here two examples of illocutionary acts used in FIPA ACL in an other format and with other specifications. As we have seen before, from the five primitive speech acts based on recursive semantics we can derive all the possible speech acts, in all categories, by varying the illocutionary forces components. And oppositely to FIPA ACL and KQML, it is possible to define the entire set of illocutionary acts including speech acts like promising, congratulating, confirming and apologizing. . .

Promise So as to illustrate the possibility for agents to express the act of promising, here comes the formal definition of the performative verb *Promise* from which derive all the comissive performative verbs. This permitting to express commitments and then to list *commitment stores* and to verify them. The formal definition of *Promise* will then be:

$$s = do(says.to(i, j, \langle promise, p\rangle), s_u, 0, 0) \tag{11}$$

$$\text{with} \quad (\forall p')(\forall a)(p \Rightarrow a)(\forall s')(s' \succ s)$$

$$s_u = bel(i, can(i, a, p')[s] \wedge bel(i, Poss(i, a)) \wedge wish(j, p)[s] \wedge int(i, do(i, a))[s'] \tag{12}$$

$$\text{and } s' = a[s'] \wedge p[s'] \tag{13}$$

The success and satisfaction will be defined as:

$$success(says.to(i, j, \langle promise, p\rangle), s) \equiv cond.success(\langle promise, p\rangle)[s] \tag{14}$$

$$satis^{wd}_{wl}(says.to(i, j, \langle promise, p\rangle), s) \equiv (\exists s', s'')(s'' \succ s' \succ s) \; Poss(a, s'), ..., Poss(a, s'') \wedge success(says.to(i, j, \langle promise, p\rangle), s'') \supset p[do(a, do(a, do(a, s'')))] \tag{15}$$

The performance of the speech act depends on given preconditions in the situation of utterance s_u and has effects on the next situation s' *– i.e., the next complete world state –*, in other words, the act has a *perlocutionary* effect which is expected and which could be verified in the dialog continuation.

The success conditions (14) of this act will be verified from the cognitive state of the agent. The speech act *do(says.to(i,j,*$\langle promise, p\rangle$*),*$s_u$*,2,0)* will then be *successful* if and only if: (i) The speaker *i* has achieved the illocutionary point of *promising* on the propositional content *p*; (ii) without any particular mode of achievement; (iii) with the propositional content condition that *p* becomes true in a subsequent context because of *i*'s performance of action *a* implied by the propositional content *p*; (iv) *i* presupposes the preparatory condition that he is himself able to perform action *a* and that the hearer *j* has an interest for it; (v) *i* express this act with the neutral degree of strength ; and (vi) the particular sincerity condition is that *i* sincerely desires that *p* becomes true because of his performance of the action *a*.

Finally, the satisfaction conditions (15) will be verified from the cognitive state of the agent, in function of its conditions of success and of the situation resulting from the speech act. *do(says.to(i,j,*$\langle promise, p\rangle$*),*$s_u$*,0,0)* will be *satisfied* if and only if: (i) the action *a* implied by the propositional content *p* is actually possible in one of the subsequent situations, in other words, if *a* is a future action; (ii) the speech act is successfully performed in *s*; (iii) and if *i* makes *p* becoming true because of his performance of the action *a* in the subsequent situation(s).

These three examples pointed out the possibilities offered by the use of this formalism for an adequate application of speech acts theory and open real perspectives for a Conversational-ACL between agents in mixed communities. In order to evaluate agents in which this ACL can be used, we are now defining both the whole *catalogue* of agent speech acts and specifying a real application of web services in which human agents could converse with multiple artificial agents in order to construct complex plans, such as a trip planning.

5 Conclusion

The recursive semantics of Chaib-draa and Vanderveken [1] using the situation calculus appears to be an efficient tool to formalize communication between artificial and human agents in mixed community. It adequately takes the advantages of speech acts theory, insufficiently exploited in current ACL, like FIPA ACL or KQML. We can then achieve an essential *computational* dimension of speech act theory implementation for artificial agents.

We have proposed to carry on Chaib-draa and Vanderveken's work to reach a formal definition of agent speech acts strongly linked with the conversational background (situation, degree of strength, role,...) and to conform it with a rational BDI agent model. Moreover, this proposition takes mental attitudes into account like other communication languages semantics, but also the social clues which are fundamental for conversation in *context*.

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