Agents that speak: modelling communicative plans and information sources in a logic of announcements

(Extended Abstract)

Philippe Balbiani
CNRS, IRIT, France
balbiani@irit.fr

Nadine Guiraud
IRIT, France
guiraud@irit.fr

Andreas Herzig
CNRS, IRIT, France
herzig@irit.fr

Emiliano Lorini
CNRS, IRIT, France
lorini@irit.fr

ABSTRACT

We present a modal logic of belief and announcements in a multi-agent setting. This logic allows to express not only that ψ holds after the announcement of φ as in standard public announcement logic (PAL), but also that the announcement of φ occurs. We use the logic to provide a formal analysis of several concepts that are relevant for multi-agent systems (MAS) theory and applications: the notions of communicative action (an agent informs another agent about something) and communicative intention (an agent has the intention to inform another agent about something), and the notion of information source.

Categories and Subject Descriptors

I.2.11 [**Distributed Artificial Intelligence**]: Multiagent Systems; I.2.4 [**Knowledge representation formalisms and methods**]

General Terms

Theory

Keywords

logic, speech acts

1. DEFINITION OF THE LOGIC OF BA

In this section, we introduce our logic **BA** of beliefs and announcements in a linear time setting.

Let PRP and AGT be countable sets of propositions and agents. The grammar for the language $\mathcal{L}_{\mathbf{BA}}$ of **BA** is:

$$\varphi \ ::= \ p \mid \ \bot \ \mid \neg\varphi \mid \varphi \vee \varphi \mid \widehat{Bel}_i\varphi \mid \langle\varphi\rangle\varphi$$

where $p \in PRP$ and $i \in AGT$. $\langle\varphi\rangle\psi$ can be read *"the announcement of φ occurs, and afterwards ψ is true"*, and $\widehat{Bel}_i\varphi$ can be read *"φ is consistent with i's beliefs"*.

Cite as: Agents that speak: modelling communicative plans and information sources in a logic of announcements (Extended Abstract), P. Balbiani, N. Guiraud, A. Herzig, E. Lorini, *Proc. of 10th Int. Conf. on Autonomous Agents and Multiagent Systems (AAMAS 2011)*, Tumer, Yolum, Sonenberg and Stone (eds.), May, 2–6, 2011, Taipei, Taiwan, pp. 1207-1208.

The Boolean operators $\top$, $\wedge$, $\rightarrow$, and $\leftrightarrow$ are defined in the usual way, and the dual modal operators are defined by: $[\varphi]\psi \stackrel{\text{def}}{=} \neg\langle\varphi\rangle\neg\psi$ and $Bel_i\varphi \stackrel{\text{def}}{=} \neg\widehat{Bel}_i\neg\varphi$.

A **BA**-model is a tuple $M = \langle \mathbb{P}, \pi, \{\mathcal{B}_i\}_{i\in AGT}, V\rangle$ where $\mathbb{P} = \{w, u, ...\}$ is a non-empty set (the set of protocols), $\pi : \mathbb{P} \times \mathbb{N}^* \rightarrow \mathcal{L}_{\mathbf{BA}}$ is a function, each $\mathcal{B}_i \subseteq \mathbb{P} \times \mathbb{P}$ is a transitive and euclidean relation on $\mathbb{P}$ and $V : \mathbb{P} \rightarrow 2^{PRP}$ is a valuation.

Let $M = \langle \mathbb{P}, \pi, \{\mathcal{B}_i\}_{i\in AGT}, V\rangle$ be a model. Truth of a formula φ in a protocol $w \in \mathbb{P}$ at a moment $n \in \mathbb{N}^*$ is inductively defined as usual for the Boolean operators, and as follows for the modal operators:

$$\begin{array}{rcl} M, u, n \models \widehat{Bel}_i\varphi & \text{iff} & \text{there is } u \text{ s.th. } u\mathcal{B}_i v \text{ and } M, v, n \models \varphi \\ M, u, n \models \langle\psi\rangle\varphi & \text{iff} & \pi(u, n) = \psi \text{ and } M, u, n \models \psi \text{ and} \\ & & M^{\psi,n}, u, n{+}1 \models \varphi \end{array}$$

where $M^{\psi,n} = \langle \mathbb{P}, \pi, \{\mathcal{B}_i^{\psi,n}\}_{i\in AGT}, V\rangle$ is the update of M by the announcement of ψ at n, defined as:

$$u\mathcal{B}_i^{\psi,n}v \quad \text{iff} \quad u\mathcal{B}_i v \text{ and } \pi(v, n) = \psi \text{ and } M, v, n \models \psi$$

Doxastic operator $\widehat{Bel}_i$ is interpreted as usual. The truth condition for $\langle\psi\rangle\varphi$ is not. Just as in PAL [4], only true announcements can occur, and they do not change the valuation V. However: (1)Announcements do not modify the set $\mathbb{P}$, but only the accessibility relations $\mathcal{B}_i$; (2)At a given state at most one announcement is possible (and there is none for example when $\pi(u, n) = \bot$, or when $M, u, n \not\models \pi(u, n)$).

A formula φ is said to be valid, noted $\models \varphi$, if and only if for all models $M = \langle \mathbb{P}, \pi, \{\mathcal{B}_i\}_{i\in AGT}, V\rangle$, for all protocols $u \in \mathbb{P}$, and for all $n \in \mathbb{N}$, $M, u, n \models \varphi$.

2. APPLICATIONS

In this section, we show how **BA** can be used in order to model some concepts that are relevant for MAS theory and applications: the concept of communicative action, the concept of communicative intention (or communicative plan), and the concept of information source.

As a first step, we incorporate a basic notion of preferences in our framework. Modal operators for preferences and goals have been widely studied (see e.g. [2]). Our alternative is to specify propositional atoms $good_i$ (in PRP) for every agent i that capture the "goodness" of the protocols for this agent.

We say that i wants that φ is true (or i prefers φ to be true), noted $Goal_i\varphi$, if and only if i believes φ is true in all states that are good for him:

$$Goal_i\varphi \stackrel{\text{def}}{=} Bel_i(good_i \rightarrow \varphi).$$

2.1 "Telling" and "intention to tell"

In DELs announcements are usually viewed as communication actions performed by an agent that is 'outside the system', i.e. that is not part of the set of agents AGT under consideration. However, communicative actions performed by agents from AGT can be modelled in our logic **BA** by considering particular announcements that are about agents' mental states. We do so by identifying agent i's action of *telling* agent j that φ with:

$$\langle tell_{i,j}\ \varphi\rangle\psi \stackrel{\text{def}}{=} \langle Goal_i Bel_j Bel_i\varphi\rangle\psi.$$

Following speech act theory, we identify the assertive act of "telling" with the event of making public the speaker's goal that the hearer believes that the assertive act's sincerity condition (the speaker believes what he is telling) is satisfied.

As common in Propositional Dynamic Logic (PDL), we introduce an operator of sequential composition ";". We define the set SEQ of announcement sequences as the smallest set such that: $\varphi \in SEQ$ for any formula $\varphi \in \mathcal{L}_{\mathbf{BA}}$, and if $\chi_1, \chi_2 \in SEQ$ then $\chi_1;\chi_2 \in SEQ$. Thus:

$$\langle tell_{i,j}\ (\chi_1;\chi_2)\rangle\psi \stackrel{\text{def}}{=} \langle tell_{i,j}\ \chi_1\rangle\langle tell_{i,j}\ \chi_2\rangle\psi.$$

We use the notion of "Telling" in order to define the concept of communicative intention or communicative plan. Following some foundational works on the theory of intention [1],we here consider that *having a plan* means nothing else than *intending to perform a certain sequence of actions* which leads to a given state. We identify "i intends to tell to j that χ" (or "i has the plan of telling to j that χ"), noted $CInt_{i,j}\ \chi$, with "i wants to tell to j that χ":

$$CInt_{i,j}\ \chi \stackrel{\text{def}}{=} Goal_i\langle tell_{i,j}\ \chi\rangle\top.$$

2.2 Reasoning about information sources

From now on, we study in our logic the relationships between the notion of "Telling" defined above and the properties of information sources like sincerity, competence, validity, etc. An information source is for us nothing else than an agent informing another agent about something. We call the agent that is informed *information receiver*.

Following [3], we suppose that the properties of an information source can be all defined in terms of the relationships between three facts: (1) an information source j informs an agent i that a certain fact φ is true; (2) an information source j believes that φ is true; (3) the fact φ is true.

Thus, agent j is a *valid* information source about φ with regard to i if and only if, if j tells to i that φ then φ is true:

$$Valid(j,i,\varphi) \stackrel{\text{def}}{=} \langle tell_{j,i}\ \varphi\rangle\top \rightarrow \varphi.$$

Agent j is a *sincere* information source about φ with regard to i if and only if, if j tells to i that φ then j believes that φ:

$$Sinc(j,i,\varphi) \stackrel{\text{def}}{=} \langle tell_{j,i}\ \varphi\rangle\top \rightarrow Bel_j\varphi.$$

REMARK 1. *One might be tempted to say that sincerity (resp. validity) could be defined in standard PAL by the formula $[tell_{j,i}\ \varphi]Bel_j\varphi$ (resp. the formula $[tell_{j,i}\ \varphi]\varphi$) and there is no need to make the distinction between the effects of a given announcement and the fact that a given announcement takes place. That is, j is sincere (resp. valid) about φ with regard to i if and only if after j tells to i that φ, she believes φ (resp. φ is true). However, this goes wrong when φ is a Moore sentence of the form $p \wedge \neg Bel_i p$. We only present the informal argument. Suppose agent j tells to agent i that p is true and that i does not believe this. Moreover, suppose that what j tells to i is true, that j believes what she tells to i, that i trusts what j tells and that j believes that i trusts what j tells. Hence, after j's speech act, i believes that p and j believes that i believes that p. In this situation, j has been a valid and sincere information source with regard to i even though, after j's speech act, what j told to i is false and j does not believe anymore what she told to i. This example indicates that defining sincerity and validity in standard PAL by the formulas $[tell_{j,i}\ \varphi]Bel_j\varphi$ and $[tell_{j,i}\ \varphi]\varphi$ would be incorrect, and that a logic like ours expressing that a given announcement takes place is necessary in order to define such concepts.*

Agent j is a *complete* information source about φ with regard to i if and only if, if φ is true then j tells to i that φ:

$$Compl(j,i,\varphi) \stackrel{\text{def}}{=} \varphi \rightarrow \langle tell_{j,i}\ \varphi\rangle\top.$$

Agent j is a *competent* information source about φ if and only if, if j believes that φ then φ is true:

$$Compet(j,\varphi) \stackrel{\text{def}}{=} Bel_j\varphi \rightarrow \varphi.$$

Agent j is a *vigilant* information source about φ if and only if, if φ is true then j believes φ:

$$Vigil(j,\varphi) \stackrel{\text{def}}{=} \varphi \rightarrow Bel_j\varphi.$$

Agent j is a *cooperative* information source about φ with regard to i if and only if, if j believes that φ then j tells to i that φ: [1]

$$Coop(j,i,\varphi) \stackrel{\text{def}}{=} Bel_j\varphi \rightarrow \langle tell_{j,i}\ \varphi\rangle\top.$$

The following validities describe the conditions under which the information receiver infers whether a certain fact is true or false through the attribution of certain properties to the information source. If $\varphi \neq \psi$, with φ Boolean, then:

$$\models Bel_i Valid(j,i,\varphi) \rightarrow [tell_{j,i}\ \varphi]Bel_i\varphi \quad (1)$$

$$\models Bel_i Sinc(j,i,\varphi) \rightarrow [tell_{j,i}\ \varphi]Bel_i Bel_j\varphi \quad (2)$$

$$\models Bel_i Compl(j,i,\varphi) \rightarrow [tell_{j,i}\ \psi]Bel_i\neg\varphi \quad (3)$$

3. REFERENCES

[1] M. E. Bratman. *Intentions, plans, and practical reason.* Harvard University Press, 1987.

[2] P. R. Cohen and H. J. Levesque. Intention is choice with commitment. *Artificial Intelligence Journal*, 42(2–3):213–261, 1990.

[3] E. Lorini and R. Demolombe. From binary trust to graded trust in information sources: a logical perspective. In *Trust in Agent Societies 2008 (Selected papers)*, volume 5396 of *LNAI*. Springer-Verlag, 2008.

[4] H. P. van Ditmarsch, W. van der Hoek, and B. Kooi. *Dynamic Epistemic Logic.* Kluwer, 2007.

[1] This definition of cooperativity does not exclude that i does not want to be informed about φ, like in spamming.