Communication protocols for logic-based agents

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Protocols. A *protocol* specifies the "rules of encounter" governing a dialogue between agents [2]. It specifies which agent is allowed to say what in a given situation. It will usually allow for several alternative utterances in every situation and the agent in question has to choose one according to its *strategy.* The protocol is *public*, while each agent's strategy is *private.* When agents are involved in interactions where no concurrency is allowed, a popular representation formalism for protocols are *deterministic finite automata* and below we will propose an alternative, logic-based formalism. First we are going to discuss the notion of conformance to a protocol on a more general level.

Levels of conformance. At every stage of a dialogue, a protocol $\mathcal{P}$ defines a set of *legal* dialogue moves for an agent. Generally, conformance evaluates whether an agent's behaviour is legal with respect to the protocol. We have found it useful to distinguish the following different levels of conformance:

- *Weak conformance* —an agent is weakly conformant to a protocol $\mathcal{P}$ iff it will never utter an illegal dialogue move.
- *Exhaustive conformance* —an agent is exhaustively conformant to a protocol $\mathcal{P}$ iff it is weakly conformant and it will utter at least one dialogue move when required by the protocol.
- *Robust conformance* —an agent is robustly conformant to a protocol $\mathcal{P}$ iff it is exhaustively conformant and it utters the (special) dialogue move `not-understood` whenever it receives an illegal dialogue move from the other agent.

Weak and exhaustive conformance can be seen as allowing or disallowing (respectively) "silent moves", namely lack of response. Thus, exhaustive conformance is to be preferred in most interactions, at least to avoid confusion with lost messages. However, we believe that weak conformance can be useful too. The first reason is that some authors cite examples where the lack of response can be considered to be part of the protocol. In such circumstances, it can be sufficient to design a weakly conformant agent, provided that silent moves will not have undesirable consequences (compare for instance a Dutch auction process where a lack of response is interpreted as a lack of acceptance *vs.* some argumentation-based protocols where it is assumed that silence means consent). The second reason is that these two levels are conceptually different, since weak conformance only involves *not* uttering (any illegal dialogue move), while exhaustive conformance involves uttering (some legal dialogue move). This implies substantially different approaches to checking conformance. Robust conformance is useful in open societies where the designer cannot safely assume that other agents will never utter illegal moves, but this necessitates the agent to be able to evaluate whether received dialogue moves are legal.

A logical representation of protocols. The following if-then rule is a translation of a part of the so-called "continuous update protocol" found in [1] which aims at continuously updating the other agent about the value of some proposition P. The rule specifies that agent Y could react to an *inform* move sent by agent X either by terminating the dialogue (*end*) or sending an acknowledgement (*ack*):

$$\mathit{tell}(X, Y, \mathit{inform}(P), D, T) \Rightarrow \mathit{tell}(Y, X, \mathit{end}, D, T{+}1) \ \vee \mathit{tell}(Y, X, \mathit{ack}(P), D, T{+}1)$$

Assuming that some external events (*START* and *STOP*) can be used to trigger the start and the end of the protocol, deterministic finite automata can be easily translated into sets of such if-then rules.

Conformance checking. When one has to design an agent supposed to take part in an interaction, it is useful to check *a priori* conformance, *i.e.* to check conformance by examining the specification of the agent rather than the actual dialogues the agent does participate in. In general, this is a difficult task, because (i) the behaviour of the agent depends on some hardly tractable notions (*e.g.* beliefs, intentions), and (ii) conformance involves some temporal aspects pertaining to the history of the dialogue. We now consider logic-based agents as introduced in [3], where dialogue strategies of the agents are expressed as if-then rules similar to those used for our protocol, where the lefthand side includes some conditions referring to the private knowledge base of the agent, and the righthand side is a single dialogue move rather than a disjunction. Here is a simple example where some agent Y will terminate the dialogue if it believes that the other agent is an enemy:

$$tell(X, Y, inform(P), D, T) \wedge enemy(Y, X) \Rightarrow tell(Y, X, end, D, T+1)$$

In this context, some sufficient conditions can be found to check *a priori* weak conformance to a protocol. This result relies on two notions: *answer space* (of a strategy) and *shallowness* (of a protocol).

- The *answer space* of the agent specifies the possible moves that the agent can make when using a given strategy $\mathcal{S}$, without considering the specific conditions related to his private knowledge base. Precisely in the context of the logic-based agents of [3], the answer space can be extracted from an agent's strategy by dropping the conditions relating to the knowledge base on the lefthand side of the rules, and by compacting the resulting rules with the same lefthand side into a single rule with a disjunction on the righthand side.
- We call a protocol *shallow* iff it corresponds to an automaton where it is possible to determine the next state of the dialogue on the sole basis of the current move. Of course, this is not the case in general since it may be necessary to refer to the history of the dialogue rather than just the latest move, to determine the next move. However, we have observed that most interaction protocols proposed in the literature happen to be shallow in this sense or could be made shallow by renaming only a few transition labels.

It is possible to show that an agent is weakly conformant to a shallow protocol if the protocol is a logical consequence of the agent's answer space.

Competence. Another application of the notion of answer space is to assess how well an agent can explore a given protocol beyond the minimal requirement of being able to conform to it. Intuitively, given a protocol $\mathcal{P}$, we would expect a "competent" agent to have an answer space that (almost) "covers" $\mathcal{P}$, namely it has the potential to utter as many dialogue moves as the protocol allows.

References

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