Deriving Agent-Centred Representations of Protocols Described Using Propositional Statecharts

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ABSTRACT
Diagrammatic methodologies for the representation of agent interaction protocols can be classified as joint representations that describe an interaction in terms of a single sequential process, or agent-centred representations that provide a distinct description of the interaction protocol for each agent (or role) in the interaction. Here we discuss the process of deriving agent centred representations from joint representations and vice versa, using a variant of UML statecharts.

Categories and Subject Descriptors
D.2.2 [Design Tools and Techniques]: State Diagrams

General Terms
Design, Languages

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Interaction Protocols, Propositional Statecharts, Statecharts

1. INTRODUCTION
Joint diagrammatic representations of protocols are defined here as representations that describe an interaction in terms of a single sequential process, without explicitly representing concurrency. Joint representations have a number of benefits. They are relatively easy to understand, as the reader only has to follow a single sequential process, and they also provide an explicit representation of the possible states of the interaction as a whole. Examples of joint representations can be found in [3], [4], and [5]. Joint protocol representations are often less cluttered than agent-centred representations as they are not required to represent each agent or role separately. However, joint representations do not lend themselves well to implementation as they do not clearly define the sequences of actions appropriate for each agent. Agent-centred diagrammatic representations of interaction protocols incorporate topologically distinct descriptions of protocols from each agents perspective, or from the perspective of each agent of a particular role. Examples of agent-centred representations can be found in [1] and [2].

Here we present a means of deriving agent centred protocol representations from joint representations using the Propositional Statechart formalism described in [3] and [4] by means of three examples, each subject to different assumptions as to whether messages are broadcast, and whether the communication medium is reliable. We also show how agent-centred protocol descriptions can incorporate an explicit diagrammatic representation of the communication medium in order to model protocols designed to work effectively with specific communication media.

2. DERIVING AGENT-CENTRED PROTOCOL REPRESENTATIONS

2.1 Assuming Message Broadcasting and Perfect Communication

The Propositional Statechart in figure 1 provides a high-level joint representation of an interaction protocol. High-level representations assume perfect communication between agents, so that whenever one agent sends a message, the message is always immediately received by the other. This assumption simplifies protocol representations, since the sending and receipt of messages do not need to be represented explicitly. In an individual agent’s representation of a given protocol, state transitions may be triggered by either the sending of a message or the receipt of a message, so in order to produce an agent-centred Propositional Statechart description of an interaction protocol it is necessary to explicitly represent message sending and message receipt. In the current paper we use the keywords SEND and RECEIVE to signify the sending and receipt of messages.

Before converting a high-level joint Propositional Statechart representation of an interaction protocol into an agent-centred representation it is necessary to produce a lower-
level joint representation of the protocol that makes the sending and receipt of messages explicit. Such a representation is shown in figure 2. The event labels in figure 2 incorporate the keyword SENDS to denote the act of sending a message, and RECEIVES to denote the act of receiving a message (also dropping the $s$ from offers, accepts and rejects where appropriate for easier comprehension).

The protocol in figure 1 represents a simple case. There are only two agents so we can assume that all messages are broadcast. For this example producing a lower level representation incorporating SEND and RECEIVE labels is relatively straightforward. Since perfect communication is assumed in the Propositional Statechart in figure 1, event labels of the form X Action become X SENDS Action; Y RECEIVES Action, where Action represents any action or sequence of actions, and Y represents the agent not mentioned in the event label.

Here we assume that each of the two agents keeps its own internal representation of the variable $p$, and that these internal parameters have to be specified. Figure 2 shows the above protocol with more detailed edge labels describing each agents internal representation of $p$. We assume that each agent has its own internal representation of the variable, so $p$ becomes $pA$ and $pB$ and the assignment $p := x$ becomes $pA := x$, or $pB := x$, depending on the agent performing the action preceding it. The relatively low-level description of the joint protocol shown in figure 2 can now be used to create two agent-centred representations. In each of these only the actions relevant to the agent or role being described are preserved. We use a third Propositional Statechart to model the medium, and use orthogonality [6] to represent the fact that the agents and the medium are operating concurrently. The concurrent processes in the diagram are assumed to be in lockstep synchronisation, as described in [7]. Figure 3 combines the two agent-centred protocol representations given above with a Propositional Statechart representing a communication medium where no messages are lost, corrupted, or reordered.

2.2 Assuming Broadcasting Only

Figure 4 shows a low level joint representation of the Alternating Bit Protocol described in [8]. It is possible to decompose the joint protocol description into two agent-centred representations using a similar technique to the one used to decompose the simpler bilateral protocol. Here the situation is made slightly more complex by the fact that for each agent-centred representation, removing all actions relating to the other agent will lead to some edges which have no label. It is therefore necessary to add the extra step of merging the states before and after each unlabelled edge.

Figure 5 shows agent-centred Propositional Statechart representations of the Alternating Bit Protocol, along with a Propositional Statechart representing a faulty communication channel that loses some messages.

Naively recombining the two agent-centred descriptions of the protocol would result in a tree structure, rather than the joint protocol description in Figure 4. However the tree can be pruned during the course of the recombination if a suitable model of the medium process is used.

A suitable model of the medium can be found by naively recombining the two agent-centred descriptions as described above, and then checking the resulting tree structure against the joint protocol description, noting which of the branches is present and which is absent. In this way it is possible to work out which actions or sequences of actions are forbidden by the communication medium.

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1 In figure 4 sim stands for sender initialises message, sum for sender updates message, and rum for receiver writes message to output. $S,0$ is taken to mean $S$ SENDS $m(0)$, $R,0$ to mean $R$ RECEIVES $m(0)$. $S,0$ to mean $S$ RECEIVES $0$,

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Figure 2: A lower level joint representation of the protocol in figure 1

Figure 3: Agent-centred protocol representations combined with a representation of the communication medium

Figure 4: A low level joint representation of the alternating bit protocol

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shown in figure 7. Figure 6 represents a quite simple case, as
be simplified accordingly. An agent-centred description of
nating Bit Protocol in section 2.2, and the event labels can
unlabelled events can be merged, as in the case of the Alter-
tirely. In this case the states directly preceding or following
in question, as in section 2.1. However, as in section 2.2 this
sections of the event labels that do not apply to the agent
6 from the point of view of a particular agent by removing
create representations of protocols such as the one in figure
labels take the form of simple placeholders. It is possible to
received them as well. For the sake of simplicity the event
communications, and that broadcasting of messages is performed
to C. It is assumed that all messages are private commu-
ning B a chance to accept the offer, before sending the offer
to B, giv-
A, B, and C. In this protocol A can send an offer to B and C
protocol will be structurally similar.

2.3 Assuming Perfect Communication Only

Where private communication is necessary, it is possible to
Send labels with a TO field, specifying the
intended recipients of the message. The communication
medium can then process the messages according to their
content. However, as with the Alternating Bit Protocol, we
can no longer assume that each agents representation of the
protocol will be structurally similar.

Figure 6 shows a simple protocol involving three agents, A, B,
and C. In this protocol A can send an offer to B and C
simultaneously. Alternatively, A can send an offer to B, giving
B a chance to accept the offer, before sending the offer
to C. It is assumed that all messages are private communications,
and that broadcasting of messages is performed by Agent A, rather than the medium, so that B cannot tell
from the content of the messages it receives whether C has
received them as well. For the sake of simplicity the event
labels take the form of simple placeholders. It is possible to
create representations of protocols such as the one in figure
6 from the point of view of a particular agent by removing
sections of the event labels that do not apply to the agent
in question, as in section 2.1. However, as in section 2.2 this
will sometimes lead to some event labels being removed en-
tirely. In this case the states directly preceding or following
unlabelled events can be merged, as in the case of the Alter-
nating Bit Protocol in section 2.2, and the event labels can
be simplified accordingly. An agent-centred description of
the protocol in figure 6 from the point of view of agent B is
shown in figure 7. Figure 6 represents a quite simple case, as

3. DISCUSSION AND FURTHER WORK

In the current paper we have illustrated how a single
formalism can be used to produce both joint and agent-centred representations of different interaction protocols. We have
included a number of examples of joint and agent-centred protocol representations, subject to different combinations of
assumptions as to whether messages are broadcast, and
whether the communication medium is reliable. Although
all of the examples presented here represent bilateral proto-
tocols, joint and agent-centred representations can also be
produced for multilateral protocols.

We have also shown how agent-centred protocol descriptions
can incorporate an explicit diagrammatic representation of
the communication medium in order to model protocols
designed to work effectively with communication media that
display particular properties.

In addition, we have discussed how agent-centred proto-
col representations can be derived from sufficiently detailed
joint representations, and how their re-combination to form
a joint representation may be carried out. We are in the
process of investigating the generality of these methods. For
some protocols more complex than those discussed here, the
task of re-combining agent-centred protocol representations
may prove less tractable, and could even be impossible.

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