Run-Time Norm Compliance in BDI Agents

(Extended Abstract)

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ABSTRACT
Normative systems offer a means to govern agent behaviour in dynamic open environments. Under the governance, individual agents themselves must reason about compliance with state- or event-based norms (or both) depending upon the formalism used. This paper describes how norm awareness enables a BDI agent to exhibit norm compliant behaviour at run-time taking into account normative factors. To this end, we propose N-Jason, a run-time norm compliant BDI agent framework which supports norm-aware deliberation as well as a run-time norm execution mechanism, through which previously unknown norms are recognized and bring about the triggering of plans. To be able to process a norm such as an obligation, the agent architecture must be able to deal with deadlines and priorities, and choose between plans triggered by a particular norm. Consequently, we extend the syntax and the scheduling algorithm of AgentSpeak(RT) to operate in the context of N-Jason/AgentSpeak(L) and provide ‘real-time agency’.

Categories and Subject Descriptors
1.2.5 [Artificial Intelligence]: Programming Languages and Software

General Terms
Algorithms, Design, Language

Keywords
Norms, BDI, Agent Programming Language, Normative System

1. N-JASON: BDI AGENT FRAMEWORK

We propose N-Jason, a BDI-based agent interpreter and a programming language for run-time norm compliance in agent behaviour. This extends Jason/AgentSpeak(L) [2] in accordance with the ‘real-time agency’ of AgentSpeak(RT) [3], which supports normative concepts (i.e. obligations, permissions, prohibitions, deadlines, priorities and durations) enabling norm-aware deliberation. Consequently, run-time norm compliance is achieved in a single reasoning cycle by the interpreter through: (i) run-time norm execution, realised by event- and option- reconsideration at a perception stage (in a belief-update process more exactly), and (ii) norm-aware deliberation, accomplished by intention scheduling with deadlines and priorities in a practical reasoning process. Scheduled intentions are executed afterwards by the N-Jason agent.

1.1 N-Jason Language Extensions

N-Jason agent consists of four main components: beliefs, goals, events and a set of plans. Beliefs and goals are identical to those in Jason (details can be found in [2]), while event and plan syntax is extended with deadline, priority and duration, in order to support normative concepts. A deadline is a real time value expressed in a some adequate unit or real world time. A priority is a positive integer value indicating a relative importance between achieving a goal and responding to belief changes. Both can be stipulated option- ally in the annotation of events, such as +!event[deadline(d), priority(p)]. A duration is a non-negative integer value representing a required time to execute the plan. This also can be optionally specified in the annotation of a plan label, such as @plan[duration(te)] +!event <- plan_body..

1.2 Run-Time Norm Execution

Our approach to run-time norm execution is to use the “pre-existing capabilities” in an agent program when an agent encounters a previously unknown (event-based) norm. This is carried out in two steps: (i) event reconsideration and (ii) option reconsideration. These reconsiderations are determined by the executability of the new and unknown norms. We say that a norm such as obl(evt, deadline, priority, violation), is executable at run-time iff:

1. \( p \in P \) and type(\( p \)) = \( \{\text{obligation} | \text{prohibition}\} \), where \( p \) is a percept, formed from a list of terms in a set of newly observed perceptions \( P \) at run-time;
2. \( te_p \notin E \), where \( te_p \) is a triggering event generated from the percept \( p \), and \( E \) is an event base, a set of intentions \( \{ (te, \tau), (te', \tau'), \ldots \} \), of which event is a pair of a triggering event and an intention \( (te, \tau) \);
3. \( edp(p) \neq \emptyset \) and \( \{te_{edp(p)}\} \cap E \neq \emptyset \), where \( edp(p) \) is a function extracting the obliged event together with its deadline and priority from \( p \) and \( te_{edp(p)} \) is a triggering event of the \( edp(p) \), an event term in the norm, and
4. \( Re_{edp(p)} \neq \emptyset \), where \( Re_{edp(p)} \) is a relevant plans selection function.

Event Reconsideration aims to verify that a norm perceived at run-time is executable although no corresponding plan exists in the agent program. If an event extracted from a detached norm has a relevance to a certain set of plans, it thus has potential to trigger specific ones, and it is concluded that the norm is executable. In consequence, the interpreter adds the norm to the event base \( E \) as an achievement goal addition event. The procedure for event

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reconsideration is as follows (see Alg. 1): (1) to extract the terms representing an obliged event, a deadline and its priority\(^1\) from the obligation using the function \(edp\) (line 2), (2) to construct a new triggering event, an achievement goal addition event in this case, from the combination of extracted terms (line 2), (3) to query the existence of a set of relevant plans to \(S_R\) with such a constructed triggering event (line 3) and (4) to add the triggering event to \(E\), if relevant plans are retrieved (line 5). (5) if norm is a prohibition, then the extracted event is added into the prohibition base (\(\Xi\)) (line 7-8) and will be revisited at the norm deliberation stage.

Option-Reconsideration aims to determine an applicable plan corresponding to the new unknown norm (whose executability is already verified) and is thus added into \(E\) as an achievement goal addition event. If the applicable plan is chosen, then it will probably be used to enact a norm-compliant behaviour, unless it is infeasible as judged by norm-aware deliberation. The procedure is shown in Alg. 2. At the beginning (line 1-3), the interpreter carries out exactly the same steps (1-3) as the event-reconsideration procedure. After that, the interpreter selects a single applicable plan as an intended means to which to commit (line 5).

Algorithm 1 Event Reconsideration

```
Require: P := P ∪ N
Require: te_p := create-event(p)
1: if p ∈ P and type(p) = obligation then
2: \(te_{edp}(p) = create-event(edp(p))\)
3: \(R_{te_{edp}(p)} := \{\tau \mid \theta\ is a mgu for te_{edp}(p) and plan \pi\}\)
4: if \(R_{te_{edp}(p)} \neq \phi\) then
5: \(E := add-event(E, te_p)\)
6: end if
7: else if p ∈ P and type(p) = prohibition then
8: \(\Xi := add-prohibition(\Xi, edp(p))\)
9: end if
```

Algorithm 2 Option Reconsideration

```
Require: \((te_p, \tau) \in E\) where \(te_p\) is an event and \(\tau\) is an intention
Ensure: \(\piθ\) where \(θ\ is a context unifier for te_{edp}(p) and plan \pi\)
1: if type(p) = obligation then
2: \(te_{edp}(p) = create-event(edp(p))\)
3: \(R_{te_{edp}(p)} := \{\tau \mid \theta\ is a mgu for te_{edp}(p) and plan \pi\}\)
4: if \(R_{te_{edp}(p)} \neq \phi\) then
5: \(\piθ' := S_θ(te_{edp}(p))\) where \(θ'\ is a context unifier for te_{edp}(p) and plan \pi\)
6: end if
7: end if
```

1. An intention is feasible iff the execution of the intention is completed before its deadline, that is, for \(\tau\),

\[
nc(\tau) + et(\tau) - ex(\tau) \leq dl(\tau)
\]

where \(\tau\) denotes an intention, \(nc(\tau)\) is the time at which \(\tau\) will next execute, \(et(\tau)\) is the time required to execute \(\tau\), denoted in the plan label, \(ex(\tau)\) is the elapsed time to execute \(\tau\) to this point, and \(dl(\tau)\) is the deadline for \(\tau\) specified in the plan [1].

2. The intention should not be prohibited, that is, for \(\tau\)
   - \(\tau \notin \Xi\) or
   - \(\tau \in \Xi\), then \(\exists \xi \in \Xi, \tau = \xi\ and priority(\tau) > priority(\xi)\)

where \(\tau\) is an intention, \(\xi\) is a prohibited event in the prohibition base \(\Xi\) and priority is a priority retrieval function.

2. CONCLUSION AND FUTURE WORK

We believe that a model for run-time norm compliance is beneficial for the enhancement of both norm compliance capability and agent autonomy from the agent’s perspective, even though the behaviour generated by run-time norm execution may appear unexpected from the agent programmer’s perspective. Although we only consider the execution of event-based norms at run-time, the extension to support state-based norms and its normative systems can easily be incorporated into N-Jason agents and will form part of future work. We also plan to detect violations which are generated in the norm aware deliberation, particularly when the normative goals are dropped during the scheduling. This offers a potentially useful link for enforcement in the context of normative system implementation.

3. REFERENCES

