A Context-Based Institutional Normative Environment

Henrique Lopes Cardoso and Eugénio Oliveira

LIACC, DEI / Faculdade de Engenharia, Universidade do Porto
R. Dr. Roberto Frias, 4200-465 Porto, Portugal
{hlc,eco}@fe.up.pt

Abstract. We explore the concept of an agent-based Electronic Institution including a normative environment that supports electronic contract formation by providing a contextual normative background. We formalize the normative state using first-order logic and define institutional rules and norms operating on that state. A suitable semantics regarding the use of norms within a hierarchical context structure is given, based on norm activation conflict and defeasibility. Norm activation relies on substitution as in first-order logic. Reasoning about the fulfillment and violation of deadline obligations is formalized using linear temporal logic; implementation with institutional rules is discussed. Examples exploiting the normative environment are given.

Keywords: Normative Environment, Context, Norm Activation, Defeasibility.

1 Introduction

Electronic Institutions [1][2][3] have been proposed and developed as frameworks embedding normative environments for open multi-agent systems, where heterogeneous and independently developed agents interact. Differences exist concerning the conceptual views of the "institutional environment". In [1] a restrictive "rules of the game" approach is followed, where the institution fixes what agents are allowed to do; norms are in this case a set of interaction conventions that agents must conform to. In [2] the institution is seen as an external entity that ascribes institutional powers and normative positions, while admitting norm violations and prescribing appropriate sanctions.

In our perspective [3], an *Electronic Institution (EI)* is a software framework embracing a set of *services* and a *normative environment*. Those services are meant to assist software agents in the process of creating organizational structures ruled by a set of mutual commitments, which in the end are translated into norms. Such norms are part of the normative environment that is maintained by the *EI*. In fact, one of the core services that we consider is the provision of a supportive normative framework in the institutional environment, which agents can exploit in order to establish their contracts in a more straightforward fashion. Contracts [4] can be underspecified, relying on a structured normative framework that fills in any omissions.

J.F. Hubner et al. (Eds.): COIN 2008, LNAI 5428, pp. 140–155, 2009.

The purpose of this paper is to formalize this normative environment. We define the notion of normative context, based on which a hierarchical structure provides a normative background for electronic contracts. Within that structure, we characterize the normative state of the system and define rules and norms operating on that state. We give a proper semantics for norms in our system by defining norm activation conflict and by providing an approach for conflict resolution based on defeasibility. We also detail the semantics of deontic statements (namely obligations with deadlines) using temporal logic, and discuss implementation issues.

The paper is organized as follows. Section 2 presents our institutional normative environment, based on context structures, including the normative state, rules and norms. Section 3 describes the semantics associated with norms, including defeasibility; deadline obligation semantics is also explored and implemented with rules. In Section 4 we illustrate the exploitation of the normative environment. Section 5 concludes and discusses related work.

2 An Institutional Normative Environment

We explore the concept of an agent-based EI including a normative environment as its core component. In the following definitions we try to provide a sound presentation of concepts in order to explain the use of norms within the normative environment.

Definition 1. *Normative Environment* $NE = \langle NS, IR, N \rangle$
The normative environment NE *of an EI is composed of a normative state* NS*, a set* IR *of institutional rules that manipulate that normative state and a set* N *of norms, which can be seen as a special kind of rules.*

While norms (see Def. 8) define the normative positions of each agent, the main purpose of institutional rules (see Def. 7) is to relate the normative state with the standing normative positions. A typical use of institutional rules is illustrated in subsection 3.2, where they are employed to implement the semantics of deadline obligations – rules monitor the normative state NS in order to detect the fulfillment or violation of deontic statements. On the other hand, norms "produce" those deontic statements upon certain normative state conditions.

2.1 Contexts

Our model is based on a contextualization of both the normative state and norms. In this subsection we properly introduce the notion of context and context organization.

Definition 2. *Context* $C = \langle PC, CA, CI, CN \rangle$
A context C *is an organizational structure within which a set* CA *of agents commits to a joint activity partially regulated by a set* $CN \subseteq N$ *of appropriate norms. A context includes a set* CI *of contextual info that makes up a kind of*

background knowledge for that context (see Def. 4). PC is the parent context within which context C is formed. Let PCA be the set of agents in context PC: we have that $CA \subseteq PCA$.

Contexts allow us to organize norms according to a hierarchical normative structure. Norm set N is partitioned into the several contexts that may exist, that is, sets CN for each context are mutually disjoint. Typically, we will have $CN \subset N$, in which case more than one context has a non-empty set CN; only if all norms in N are defined in the same context we may have $CN = N$. A norm inheritance mechanism, as explained later, justifies the fact that the locally-defined set CN of norms only *partially* regulates the activity of agents in set CA. We identify a *top* level context from which all other contexts are (directly or indirectly) formed; every agent is committed to the top context.

We now introduce the notion of *sub-context*.

Definition 3. *Sub-context $C' = \langle PC', CA', CI', CN' \rangle$*
A context C' is a sub-context of a context $C = \langle PC, CA, CI, CN \rangle$, denoted $C' \lhd C$, if $PC' = C$ or if $PC' \lhd C$. When C' is either a sub-context of C or C itself, we write $C' \unlhd C$. From Def. 2 we also have that $CA' \subseteq CA$.

A sub-context defines a sub-activity committed to by a subset of the original context's agents. Notice that the sub-context relationship is an explicit one. Every context is a sub-context of the *top* context.

We now turn to the definition of background information that may be defined as a foundational element of a context.

Definition 4. *Contextual info $Info^C$*
Contextual info $Info^C$ is a fully-grounded atomic formula in first-order logic, which comprises founding information regarding a context $C = \langle PC, CA, CI, CN \rangle$. $Info^C \in CI$.

The CI component in a context definition is therefore composed of first-order logic formulae that provide background information for that context.

A B2B analogy to this kind of context/sub-context relationship comes from the virtual organizations realm, wherein a group of enterprises seeks to build a mutually beneficial relationship regarding a specific business domain. They would form a contractual agreement within the top institutional context. Often, a contract is dependent on the existence of another business relation, which forms the business context for the new contract. Each contract must contain a set of definitions regarding the role of the participants, the values to be exchanged (products or services) and their provision. In our model, these comprise information that is intrinsic and foundational to the context associated with this contract – hence the term *contextual info*.

In Section 4 a supply-agreement contract is described, in which a set of agents agrees to supply certain resources under certain conditions. In that context, contextual info is expressed as first-order formula relating each agent with a resource it supplies, together with an associated price: $supply\text{–}info^C(Ag, Res, UPr)$.

2.2 Normative State

The normative state is organized through contexts. The normative state concerns the description of what is taken for granted in a model of so-called institutional reality [5]. Therefore, we call every formula in *NS* an institutional reality element, or *IRE*. Each *IRE* refers to a specific context within which it is relevant. There can be more than one *IRE* pertaining to the same context.

Definition 5. *Contextual institutional reality element* IRE^C
A contextual institutional reality element IRE^C *is an IRE regarding context* C.
We distinguish the following kinds of IRE^C *with the following meanings:*
$ifact^C(f, t)$ – *institutional fact* f *has occurred at time* t
$time^C(t)$ – *instant* t *has elapsed*
$obl^C(a, f, d)$ – *agent* a *is obliged to bring about fact* f *until deadline* d
$fulf^C(a, f, t)$ – a *has fulfilled, at time* t*, his obligation to bring about* f
$viol^C(a, f, t)$ – a *has violated, at time* t*, his obligation to bring about* f

Note that the use of context C as a superscript is only a syntactical convenience – both contextual info and institutional reality elements are first-order formulae (C could be used as the first argument of each of these formulae). While contextual info is confined to background information that is part of the context definition, contextual institutional reality elements represent occurrences taking place after the context's creation, during its lifetime.

We consider institutional facts as *agent-originated*, since they are obtained as a consequence of some agent action [4]. The remaining elements are *environment events*, asserted in the process of norm application and monitoring. Our model of institutional reality is based on a discrete model of time. The *time* elements are used to signal instants that are relevant to the context at hand. Obligations are deontic statements, and we admit both their fulfillment and violation.

Definition 6. *Normative State* $NS = \{IRE_1^{C1}, IRE_2^{C2}, ..., IRE_n^{Cm}\}$
The normative state NS is a set of fully-grounded atomic formulae IRE_i^{Cj}, $1 \leq i \leq n$*, in first-order logic.*

The normative state will contain, at each moment, all elements that characterize the current state of affairs in every context. In that sense, *NS* could be seen as being partitioned among the several contexts, as is the case with norms; however, *IRE*'s are not part of a context's definition, since they are obtained at a later stage, during the context's operation. Some of the *IRE*'s are interrelated: for instance, a fulfillment connects an obligation to bring about a fact with its achievement as an institutional fact. These interrelations are captured with institutional rules.

2.3 Rules and Norms

Given the "contextualization" of the normative state, we are now able to define rules and norms. Institutional rules allow us to maintain the normative state of the system. They are not contextualized, but yet they operate on contextual *IRE*'s.

Definition 7. *Institutional rule* $R ::= Antecedent \rightarrow Consequent$
An institutional rule R defines, for a given set of conditions, what other elements should be added to the normative state. The rule's Antecedent is a conjunction of patterns of IRE^C *(see Def. 5), which may contain variables; restrictions may be imposed on such variables through relational conditions. We also allow the use of negation (as failure):*

$$Antecedent ::= IRE^C \mid Antecedent \wedge Antecedent \mid \neg Antecedent \mid RelCondition$$

The rule's Consequent is a conjunction of IRE^C *which are not deontic statements (*$IRE\text{–}^C$*), and which are allowed to contain bounded variables:*
$Consequent ::= IRE\text{–}^C \mid Consequent \wedge Consequent$

When the antecedent matches the normative state using a first-order logic substitution Θ, and if all the relational conditions over variables hold, the atomic formulae obtained by applying Θ to the consequent of the rule are added to the normative state as fully-grounded elements.

Besides institutional reality elements, the norms themselves are also contextual.

Definition 8. *Norm* $N^C ::= Situation \rightarrow Prescription$
A norm N^C *is a rule with a deontic consequent, defined in a specific context C. The norm is applicable to a context* $C' \trianglelefteq C$*. The norm's Situation is a conjunction of patterns of* $Info^{C'}$ *and* $IRE\text{–}^{C'}$ *(no deontic statements). Both kinds of patterns are allowed to contain variables; restrictions may be imposed on such variables through relational conditions:*

$$Situation ::= Info^{C'} \mid IRE\text{–}^{C'} \mid Situation \wedge Situation \mid RelCondition$$

The norm's Prescription is a (possibly empty) conjunction of deontic statements (obligations) which are allowed to contain bounded variables and are affected to the same context C'*:*

$$Prescription ::= \epsilon \mid OblConj$$
$$OblConj ::= obl^{C'}(...) \wedge OblConj \mid obl^{C'}(...)$$

Conceptually, the norm's *Situation* can be seen as being based on two sets of elements: *background (Sb)* and *contingent (Sc)*. Background elements are those that exist at context creation (the founding contextual info), while contingent elements are those that are added to the normative state at a later stage. This distinction will be helpful when describing norm semantics.

Observe the distinction between the context where the norm is defined, and the context to which the norm applies. While, in order to make the model as simple as we can, we define a norm as being applicable to a specific context, in Section 3.1 we relax this assumption, which will in part clarify the usefulness of the model.

3 Semantics

After defining each component of our normative environment, we now proceed to defining the semantics of norms and deontic statements.

3.1 Norms and Contexts

We now turn our attention to norm applicability according to the normative state. For that, we make use of the notion of *substitution* in first-order logic. We denote by $f \cdot \Theta$ the result of applying substitution Θ to atomic formula f.

Definition 9. *Norm activation*
A norm $N^C = S \rightarrow P$, applicable to a context $C' = \langle PC', CA', CI', CN' \rangle$, is said to be activated if there is a substitution Θ such that:

- $\forall_{c \in Sc}\ c \cdot \Theta \in NS$*, where Sc is the set of contingent conjuncts (*$IRE\text{–}^{C'}$ *patterns) in S; and*
- $\forall_{b \in Sb}\ b \cdot \Theta \in CI'$*, where Sb is the set of background conjuncts (*$Info^{C'}$ *patterns) in S; and*
- *all the relational conditions over variables hold.*

We are now able to define the notion of conflicting norm activations, as follows.

Definition 10. *Norm activation conflict*
Let Act_1 be the activation of norm $N_1^{C1} = S_1 \rightarrow P_1$ obtained with substitution Θ_1 and Act_2 the activation of norm $N_2^{C2} = S_2 \rightarrow P_2$ obtained with substitution Θ_2. Let $NS_1 = \{c \cdot \Theta_1 | c \in Sc_1\}$, and $NS_2 = \{c \cdot \Theta_2 | c \in Sc_2\}$, where Sc_1 and Sc_2 are the sets of contingent conjuncts of S_1 and S_2, respectively. Both NS_1 and NS_2 represent fractions of the whole normative state NS. Norm activations Act_1 and Act_2 are in conflict, written $Act_1 \bigotimes Act_2$, if $NS_1 = NS_2$ and either $C1 \lhd C2$ or $C2 \lhd C1$.

Succinctly, we say there is a norm activation conflict if we have two applicable norms activated with the same fraction of the normative state and defined in different contexts. Notice that the fact that both norms are activated with the same contextual *IRE*'s already dictates that the norm contexts, if different, have a sub-context relationship (there is no multiple inheritance mechanism in our normative structure). This becomes clearer when taking into account the sub-context (Def. 3) and norm (Def. 8) definitions: a context has a single parent context, and a norm N^C applies to a context $C' \unlhd C$.

In principle, all norm activations are defeasible, according to the following definition.

Definition 11. *Norm activation defeasance*
A norm activation Act_1 for norm N_1^{C1} defeats a norm activation Act_2 for norm N_2^{C2} if $Act_1 \bigotimes Act_2$ and $C1 \lhd C2$.

A defeated norm activation is discarded, that is, the defeated activation is not applied to the normative state fraction used for activating the norm. Only undefeated norm activations will be applied: the substitution that activated a norm is applied to its prescription part and the resulting fully-grounded deontic statements are added to the normative state (recall that there are no free variables in the prescription part of norms). Observe that we do not talk about norm defeasance, but rather norm activation defeasance. Thus, the defeasance relationship may only materialize on actual norm applicability.

Norm Contextual Target. A question that may arise when going through the previous definitions can jeopardize the purpose of having defeasible norms as those in the model presented. Why should there be norms that, while being applicable to the same context, are defined in different contexts that have a sub-context relationship? Why not have all norms applicable to context C defined inside context C?

The reason for our approach becomes apparent when considering the stated aim of a supportive normative environment: to have a normative background that can fill-in details of sub-contexts that are created later and that can benefit from this setup by being underspecified. This leads us to the subject of "default rules" in the law field [6]. Thus, part of the normative environment's norms will typically be predefined, in the sense that they are pre-existent to the applicable contexts themselves. What we need is to typify contexts in order to be able to say that a norm applies to a certain type of contexts. This way, a norm might be defined at a super-context and applicable to *a range of* sub-contexts (of a certain type) to be subsequently created.

We can do this adaptation by considering context identifier C as a pair *id*:*type*, where *id* is a context identifier and *type* is a predefined context type. In a norm $N^C = S \rightarrow P$ (see Def. 8), patterns of $Info^{C'}$ and $IRE^{C'}$ inside S, as well as obligations inside P, will be rewritten to accommodate this kind of context reference, eventually using a variable in place of the context *id*. For instance, an $IRE^{Id:x}$ pattern, where Id is a variable, would match IRE's of any sub-context of type x. When activating a norm with this kind of pattern, the substitution Θ (as used in Def. 9) would have to bind Id to a specific sub-context identifier; every further occurrence of Id is thus a bounded-variable.

This approach allows us to maintain our definitions of norm activation conflict and defeasance, with minor syntactical changes.

3.2 Deadline Obligations

Our definition of norm includes the set of conditions upon which one or more deontic statements come into being. As such, obligations being added to the normative state are no longer conditional: they are deadline obligations, in the sense discussed in [7].

In the following explanation we borrow some operators from linear temporal logic (LTL) [8]. In LTL time is assumed to be discrete, has an initial moment with no predecessors, and is infinite into the future. Let $x = (s_0, s_1, s_2, ...)$ be a timeline, defined as a sequence of states s_i. The syntax $x \models p$ reads that p is true in timeline x. We write x^k to denote state s_k of x, and $x^k \models p$ to mean that p is true at state x^k.

The following operators shall be used:

- until (U): $x \models (p\ U\ q)$ *iff* $\exists_j (x^j \models q$ *and* $\forall_{k<j} (x^k \models p))$
- before (B): $x \models (p\ B\ q)$ *iff* $\forall_j (x^j \models q$ *implies* $\exists_{k<j} (x^k \models p))$
- henceforth (G): $x \models Gq$ *iff* $\forall_j (x^j \models q)$

The *fulf* and *viol* terms in Def. 5 allow us to reason about the fulfillment and violation of obligations. Using these terms, a deadline obligation $obl^C(a, f, t)$ has the following semantics in LTL[1]:

$$
\begin{gathered}
(\neg ifact^C(f, \_) \wedge \neg time^C(t) \wedge \neg fulf^C(a, f, \_) \wedge \neg viol^C(a, f, \_)) \\
U \\
(ifact^C(f, t') \wedge \neg time^C(t) \wedge G fulf^C(a, f, t') \wedge G\neg viol^C(a, f, \_)) \vee \\
(\neg ifact^C(f, \_) \wedge time^C(t) \wedge G\neg fulf^C(a, f, \_) \wedge G viol^C(a, f, t))
\end{gathered} \tag{1}
$$

This means that no violations can occur before the deadline, nor fulfillments before accomplishments; also, fulfillments and violations are mutually exclusive and persist over time.

In order to make the above formalization more tractable, we relate a deadline obligation with conditions for its fulfillment and violation. In LTL we express these relationships with:

$$obl^C(a, f, t) \wedge (ifact^C(f, t')\ B\ time^C(t)) \Rightarrow G fulf^C(a, f, t') \tag{2}$$

$$obl^C(a, f, t) \wedge (time^C(t)\ B\ ifact^C(f, \_)) \Rightarrow G viol^C(a, f, t) \tag{3}$$

With this approach, we are basically depending on which comes first: the deadline or the accomplishment of the fact. But in a model of discrete time, they can occur simultaneously (which is captured by operator @ defined below). In this case none of the above implications apply, therefore we add:

$$obl^C(a, f, t) \wedge (ifact^C(f, t)\ @\ time^C(t)) \Rightarrow G fulf^C(a, f, t) \tag{4}$$

where[2] $(\rho\ @\ \delta) \equiv (\neg\rho\ U\ \delta) \wedge (\neg\delta\ U\ \rho) \equiv \neg(\rho\ B\ \delta) \wedge \neg(\delta\ B\ \rho)$.

We want obligations not to persist after the deadline. This allows us to model, within this framework, both cases of legal obligations, namely obligations that stand even when violated and those that do not. For instance [7], an obligation to pay for a fine will persist if it is not fulfilled until the deadline, while an obligation to submit a conference paper will not persist after the submission deadline (because submitting makes no sense at that stage). For modeling a standing obligation, the obligation can be reinstated after a violation is detected.

This property can be stated in a more general way: a fulfilled obligation cannot be violated anymore, and a violated obligation cannot be fulfilled anymore.

$$obl^C(a, f, t) \wedge fulf^C(a, f, \_) \Rightarrow G\neg viol^C(a, f, \_) \tag{5}$$

$$obl^C(a, f, t) \wedge viol^C(a, f, t) \Rightarrow G\neg fulf^C(a, f, \_) \tag{6}$$

These relationships weaken the obligation's power after it has been fulfilled or violated.

---

[1] The time arguments in *ifact*, *fulf* and *viol* are omitted except when they have a correspondence, as expressed in (2) and (3).

[2] $(\rho\ @\ \delta)$ could also be defined as $x \models (\rho\ @\ \delta)$ *iff* $\exists_j(x^j \models (\rho \wedge \delta)$ *and* $\forall_{k<j}(x^k \models (\neg\rho \wedge \neg\delta)))$.

Implementation with Institutional Rules. As mentioned before, the normative environment (Def. 1) includes a set *IR* of institutional rules (Def. 7) that manipulate the normative state. Such rules allow us to implement the semantics of deontic statements, as defined above. The *fulf* and *viol* terms in Def. 5 are meant to allow us to reason about the fulfillment and violation of obligations as soon as they occur, by defining norms that take these elements into account in their antecedent. Institutional rules enable the specification of conditions for fulfillment and violation detection.

According to the deadline obligation semantics described above, namely (2) and (3), we may have the following institutional rules (where variables begin with an upper-case letter):

$$obl^C(A, F, T) \land ifact^C(F, T') \land \neg time^C(T) \rightarrow fulf^C(A, F, T') \tag{7}$$

$$obl^C(A, F, T) \land time^C(T) \land \neg ifact^C(F, \_) \rightarrow viol^C(A, F, T) \tag{8}$$

But what if both the fact and the deadline hold at some point in time? If $(ifact^C(f, \_)\ B\ time^C(t))$, then rule (7) asserted a fulfillment; on the other hand, if $(time^C(t)\ B\ ifact^C(f, \_))$ then rule (8) asserted a violation. But what if $(ifact^C(f, \_)\ @\ time^C(t))$? A rule like:

$$obl^C(A, F, T) \land ifact^C(F, T') \land time^C(T) \rightarrow fulf^C(A, F, T') \tag{9}$$

is not acceptable, as it would apply if $(time^C(t)\ B\ ifact^C(f, \_))$. We need to keep the property that after being violated, the obligation cannot be fulfilled anymore (as in (6) above). We may say:

$$obl^C(A, F, T) \land ifact^C(F, T') \land \neg viol^C(A, F, \_) \rightarrow fulf^C(A, F, T') \tag{10}$$

It is tempting to also explicitly state that violations can only occur if no fulfillment was achieved before. Something like:

$$obl^C(A, F, T) \land time^C(T) \land \neg fulf^C(A, F, \_) \rightarrow viol^C(A, F, T) \tag{11}$$

However, when taken together with (10), this would imply that a simultaneous occurrence of $ifact^C(f, \_)$ and $time^C(t)$ (that is, $ifact^C(f, \_)\ @\ time^C(t)$) could bring either a fulfillment or a violation! We therefore must join (8) with (10). (Notice that the pairing of (7) with (11) would bring a violation in the simultaneity case.)

Practical Issues. If we cannot assume that the above rules are evaluated at every normative state update, we may get unwanted results. For instance, assume that the following are elements of the current normative state: $obl^C(a, f, t)$, $time^C(t)$ and $ifact^C(f, t + 1)$. If rules are applied only at time $t' > t$, the violation would go unnoticed: rule (10) would apply, while rule (8) would not.

This problem can be overcome by referring explicitly to the time references of *IRE*'s:

$$obl^C(A, F, T) \wedge time^C(T) \wedge \neg(ifact^C(F, T') \wedge T' \leq T) \rightarrow viol^C(A, F, T) \tag{12}$$

$$obl^C(A, F, T) \wedge ifact^C(F, T') \wedge T' \leq T \rightarrow fulf^C(A, F, T') \tag{13}$$

If we are to relax the rule evaluation policy, the two rules for fulfillment and violation detection must become independent. The shortcoming of this approach is that it is directly applicable only when considering temporal deadlines.

Another problem that we do not consider is that we are assuming an instant recognition of each *IRE*. That is, an institutional fact occurring at time t is added at that same instant t to the normative state. Were that not the case, we could get into situations where certain violations would need to be retracted as new knowledge is acquired, otherwise inconsistencies might be obtained (which could be avoided with an extra $\neg viol^C(A, F, \_)$ test in rule (13) above).

4 Examples

In this section we sketch some examples towards the exploitation of the normative environment. The examples are necessarily simple, in order to focus on the important aspects of our approach; in the following we adopt the convention that variables begin with an upper-case letter.

Suppose that a group of companies provide household appliance solutions to their customers. However, while these solutions involve several kinds of equipment, each of the companies manufactures only a subset of them. They agree to form a virtual organization in order to better serve their customers.

This organization will define a supply-agreement that translates into a context *sa3*:*sa* in the normative environment, where *sa3* is the context id and *sa* is the context type (see end of Section 3.1). Notice that $sa3{:}sa \lhd top$, where *top* is the top context.

Suppose we have, at the top context, the following norm:

$$\begin{aligned} N_1^{top} = \; & ifact^{X:sa}(order(A1, Res, Qt, A2), T) \wedge \\ & supply\text{–}info^{X:sa}(A2, Res, Upr) \\ & \rightarrow \\ & obl^{X:sa}(A2, delivery(A2, Res, Qt, A1), T + 2) \wedge \\ & obl^{X:sa}(A1, payment(A1, Qt * Upr, A2), T + 2) \end{aligned}$$

The norm states that for any supply-agreement, when an order is made that corresponds to the supply information of the receiver, he is obliged to deliver the requested goods and the sender is obliged to make the associated payment.

Table 1. Different normative states and norm activation conflicts

NS	$\{ifact^{sa3:sa}(order(jim, r3, 5, tom), 1)\}$
Conflict	none, N_1^{top} applies
NS'	$\{ifact^{sa3:sa}(order(jim, r3, 5, tom), 1), obl^{sa3:sa}(tom, delivery(tom, r3, 5, jim), 3),$ $obl^{sa3:sa}(jim, payment(jim, 5, tom), 3)\}$
NS	$\{ifact^{sa3:sa}(order(tom, r1, 5, jim), 1)\}$
Conflict	none, N_1^{top} applies
NS'	$\{ifact^{sa3:sa}(order(tom, r1, 5, jim), 1), obl^{sa3:sa}(jim, delivery(jim, r1, 5, tom), 3),$ $obl^{sa3:sa}(tom, payment(tom, 5, jim), 3)\}$
NS	$\{ifact^{sa3:sa}(order(tom, r1, 100, jim), 1)\}$
Conflict	$N_1^{sa3:sa}$ defeats N_1^{top}
NS'	$\{ifact^{sa3:sa}(order(tom, r1, 100, jim), 1), obl^{sa3:sa}(jim, delivery(jim, r1, 100, tom), 6),$ $obl^{sa3:sa}(tom, payment(tom, 100, jim), 3)\}$
NS	$\{ifact^{sa3:sa}(order(sam, r3, 5, tom), 1)\}$
Conflict	$N_2^{sa3:sa}$ defeats N_1^{top}
NS'	$\{ifact^{sa3:sa}(order(sam, r3, 5, tom), 1), obl^{sa3:sa}(tom, delivery(tom, r3, 5, sam), 3)\}$
NS	$\{ifact^{sa3:sa}(order(sam, r3, 5, tom), 1), obl^{sa3:sa}(tom, delivery(tom, r3, 5, sam), 3),$ $fulf^{sa3:sa}(tom, delivery(tom, r3, 5, sam), 2)\}$
Conflict	none, $N_3^{sa3:sa}$ applies
NS'	$\{ifact^{sa3:sa}(order(sam, r3, 5, tom), 1), obl^{sa3:sa}(tom, delivery(tom, r3, 5, sam), 3),$ $fulf^{sa3:sa}(tom, delivery(tom, r3, 5, sam), 2), obl^{sa3:sa}(sam, payment(sam, 5, tom), 4)\}$

Now, suppose context *sa3*:*sa* includes the following norms.

$$\begin{aligned} N_1^{sa3:sa} = {} & ifact^{sa3:sa}(order(A1, Res, Qt, jim), T)\wedge \\ & supply\text{–}info^{sa3:sa}(jim, Res, Upr) \wedge Qt > 99 \\ & \rightarrow \\ & obl^{sa3:sa}(jim, delivery(jim, Res, Qt, A1), T + 5)\wedge \\ & obl^{sa3:sa}(A1, payment(A1, Qt * Upr, jim), T + 2) \end{aligned}$$

This norm expresses the fact that agent *jim*, when receiving orders with more than 99 units, has an extended delivery deadline.

$$\begin{aligned} N_2^{sa3:sa} = {} & ifact^{sa3:sa}(order(sam, Res, Qt, A2), T)\wedge \\ & supply\text{–}info^{sa3:sa}(A2, Res, \_) \\ & \rightarrow \\ & obl^{sa3:sa}(A2, delivery(A2, Res, Qt, sam), T + 2) \end{aligned}$$

$$\begin{aligned} N_3^{sa3:sa} = {} & fulf^{sa3:sa}(A2, delivery(A2, Res, Qt, sam), T)\wedge \\ & supply\text{–}info^{sa3:sa}(A2, Res, Upr) \\ & \rightarrow \\ & obl^{sa3:sa}(sam, payment(sam, Qt * Upr, A2), T + 2) \end{aligned}$$

These two norms express the higher position of agent *sam* who, as opposed to other agents, only pays after receiving the merchandise. Suppose we have the following founding contextual info for context *sa3*:*sa*:

$$supply\text{–}info^{sa3:sa}(jim, r1, 1)$$
$$supply\text{–}info^{sa3:sa}(sam, r2, 1)$$
$$supply\text{–}info^{sa3:sa}(tom, r3, 1)$$

Table 1 shows what might happen in different normative states. Lines labeled with *Conflict* in the first column show what norm activation conflicts come about (and how they are resolved) when the institutional reality elements of their previous line (labeled with NS) are present. Lines labeled with NS' show the normative state after applying the defeating norm activation. Notice that in the second example there is no conflict, since norm $N_1^{sa3:sa}$ is not activated because of a variable restriction.

Observe that the model is very flexible, allowing us to specify different contracting situations where the concept of norm activation defeasibility is useful.

5 Conclusions and Related Work

Our model of Electronic Institution [3][4] is based on an environment with a hierarchical normative structure, including norm inheritance as a mechanism to facilitate contract establishment. This paper formalizes such an environment.

We rely on a common normative structure applicable to several "social systems", where the institution is prior in existence to the specific social relationships (which are mapped to contexts). A different perspective is taken in [9], where an electronic institution is coupled (situated) with a previously existing social system. The authors also explore the possibility of autonomic adaptation of the institution's rules to enhance performance. In our case, adaptability is addressed by having a normative environment that agents can exploit and adapt to fit their purposes.

The idea of *context* for normative reasoning has been studied before. However, in most cases the notion of context comes from the 'counts-as' relation [10][11]: "X counts-as Y in context C". For instance, in [12][13] a context gives an interpretation to abstract norms of a broader context. There is a leveled structuring of contexts, which broadly contemplates institutions, sub-institutions and organizations, from the most abstract to the most concrete level. However, concrete norms (refined as rules and implemented as procedures) are used to model preexistent organizations. Concept abstraction is studied in [14]. In this case, it is not the norm that is abstract, but instead the concepts in which it is expressed. A norm based on abstract concepts may be further specified in a more specific context. Our approach has a different concern: we use the context structure for designing a model of defeasibility for norms, which may be added to the system at runtime. We do not tackle with abstraction.

The "contextualization" of contracts within higher normative structures has also been advanced in [15]. In this case, a contract is modeled as an institution itself (see also [16]), and can be governed by another (super) institution. This relationship is expressed through a mechanism of empowerment. States are described by fluents and evolve according to rules expecting events. Empowerments are defined by normative fluents allowing the creation of events and the initialization or termination of fluents. With this approach, a rule defined in an institution may operate on another institution's state if the rule's effects are explicitly empowered. In our approach, contracts are modeled as contexts within a single institution. Norms can also operate in contexts other than the one where they are defined, but this property is based on a structured normative framework, and not on a discretionary basis that may be cumbersome to express.

From the law field, three normative conflict resolution principles have been defined and traditionally used. The *lex superior* is a hierarchical criterion and indicates that a norm issued by a more important legal entity prevails, when in conflict with another norm (e.g. the Constitution prevails over any other legal body). The *lex posterior* is a chronological criterion indicating that the most recent norm prevails. The *lex specialis* is a specificity criterion establishing that the most specific norm prevails. While not firmly adopting any of these options, our approach resembles more the *lex specialis* principle. However, the defeating norms are more specific in the sense that they are *defined at* (as opposed to *applied to*) a more specific context (a kind of "lex inferior"). The *lex specialis* flavor comes from the fact that in most cases a defeating norm should apply to a narrower context-set.

These properties of our norm defeasance approach result from the fact that the original aim is not to impose predefined regulations on agents, but instead to help them in building contractual relationships by providing a normative background (which can be exploited in a partial way). A feature of our approach that exposes this aim is that all norms are defeasible. In this respect we follow the notion from law theory of "default rules" [6]. We leave for future work the possibility of defining non-defeasible norms, that is, norms that are not to be overridden.

This notion of "default rules" might be misleading; it has not a direct correspondence with default logic formalizations [17]. We do not handle the defeasibility of conclusions of default rules in that sense, but instead model defeasibility of the application of the rules themselves (which are called norms).

From a theoretical logical stance, norm defeasibility has been addressed in, e.g., [18][19][20]. Typically, deontic reasoning guides these approaches, and thus conflicts regard the deontic operators themselves. Our approach is centered instead on the applicability of norms, not on their conclusions.

The work in [21] addresses the issue of conflict resolution in a structured setup of compound activities. These resemble our context and sub-context relationships. However, they model deontic conflicts (e.g. an action being obliged and prohibited), while we model norm (activation) conflicts. They study the inheritance of normative positions (obligations, permissions, prohibitions), based on an explicit stamping of each one of them with a priority value and a timestamp; the specificity criterion is based on the compound activities' structure. We address the inheritance of norms and provide a means to override norm activations based on their defeasibility.

Our approach of context and sub-context definitions, together with the presented norm defeasibility model, is similar to the notion of *supererogatory defeasibility* in [22]. They model defeasibility in terms of role and sub-role definitions. In fact, they also consider *express defeasibility*, which is based on the specificity of conditions for norm applicability, but this approach has been followed by several others.

The problem of normative conflict resolution has been also studied in more practical approaches. The application of business rules in e-commerce has been addressed in [23], where courteous logic programs allow for an explicit definition of priorities among rules. An extension based on defeasible and deontic logic has been advanced in [24] for the representation of business contracts (and not merely business rules). However, this approach does not consider defeasibility of norms between a contract and an underlying normative framework. Finally, [25] also addresses defeasible reasoning in the e-contracts domain, based on the translation of contracts from event calculus to default logic, and on the definition of dynamic priorities among rules (by using domain-dependent criteria). Conflics are, in this case, based on the normative positions of agents.

We should also point out that [26] presents a grammar for rules that combines both our rule and norm definitions. However, our concern is to distinguish *a priori* rule definition as a normative state maintenance issue from norm definition as a contracting activity. Furthermore, in [26] there is no attempt to solve any disputes related with possibly conflicting norms.

From a software engineering perspective, we envisage the development of different "enterprise agents" that encapsulate the private interests of the electronic institution participants, and that engage in (partially automated) negotiations in order to obtain mutually beneficial contracts. We have a working platform that incorporates the needed infrastructure for the concepts introduced in this paper, based on Jess [27] – a very efficient rule engine based on the Rete algorithm for pattern matching. Another major effort concerns the knowledge engineering of norms applicable to different business contexts, in order to maximize the usefulness of the normative background.

Some open issues in our research include, as already mentioned, the possibility of defining non-defeasible norms, which might be important in certain contract domains. The development of multiple-inheritance mechanisms within our contextual framework is also an interesting issue, although it poses additional problems regarding norm defeasibility.

Acknowledgments. The first author is supported by FCT (Fundação para a Ciência e a Tecnologia) under grant SFRH/BD/29773/2006.

References

1. Arcos, J.L., Esteva, M., Noriega, P., Rodríuez-Aguilar, J.A., Sierra, C.: Environment engineering for multiagent systems. Engineering Applications of Artificial Intelligence 18(2), 191–204 (2005)

2. Artikis, A., Pitt, J., Sergot, M.: Animated specifications of computational societies. In: Castelfranchi, C., Johnson, W.L. (eds.) International Joint Conference on Autonomous Agents and Multi-Agent Systems, Bologna, Italy, pp. 1053–1062. ACM Press, New York (2002)
3. Lopes Cardoso, H., Oliveira, E.: Electronic institutions for b2b: Dynamic normative environments. Artificial Intelligence and Law 16(1), 107–128 (2008)
4. Lopes Cardoso, H., Oliveira, E.: A contract model for electronic institutions. In: Sichman, J.S., Padget, J., Ossowski, S., Noriega, P. (eds.) COIN 2007. LNCS (LNAI), vol. 4870, pp. 27–40. Springer, Heidelberg (2008)
5. Lopes Cardoso, H., Oliveira, E.: Institutional reality and norms: Specifying and monitoring agent organizations. International Journal of Cooperative Information Systems 16(1), 67–95 (2007)
6. Craswell, R.: Contract law: General theories. In: Bouckaert, B., De Geest, G. (eds.) Encyclopedia of Law and Economics. The Regulation of Contracts, vol. III, pp. 1–24. Edward Elgar, Cheltenham (2000)
7. Dignum, F., Broersen, J., Dignum, V., Meyer, J.J.: Meeting the deadline: Why, when and how. In: Hinchey, M.G., Rash, J.L., Truszkowski, W.F., Rouff, C.A. (eds.) FAABS 2004. LNCS (LNAI), vol. 3228, pp. 30–40. Springer, Heidelberg (2004)
8. Emerson, E.A.: Temporal and modal logic. In: van Leeuwen, J. (ed.) Handbook of Theoretical Computer Science. Formal Models and Sematics, vol. B, pp. 995–1072. North-Holland Pub. Co./MIT Press (1990)
9. Campos, J., López-Sánchez, M., Rodríguez-Aguilar, J.A., Esteva, M.: Formalising situatedness and adaptation in electronic institutions. In: Hubner, J.F., et al. (eds.) COIN 2008. LNCS (LNAI), vol. 5428. Springer, Heidelberg (2008)
10. Searle, J.R.: The Construction of Social Reality. Free Press, New York (1995)
11. Jones, A., Sergot, M.: A formal characterisation of institutionalised power. Logic Journal of the IGPL 4(3), 427–443 (1996)
12. Vázquez-Salceda, J., Dignum, F.: Modelling electronic organizations. In: Mařík, V., Müller, J.P., Pěchouček, M. (eds.) CEEMAS 2003. LNCS (LNAI), vol. 2691, pp. 584–593. Springer, Heidelberg (2003)
13. Grossi, D., Dignum, F.: From abstract to concrete norms in agent institutions. In: Hinchey, M.G., Rash, J.L., Truszkowski, W.F., Rouff, C.A. (eds.) FAABS 2004. LNCS (LNAI), vol. 3228, pp. 12–29. Springer, Heidelberg (2004)
14. Grossi, D., Dignum, F., Meyer, J.J.C.: Contextual taxonomies. In: Leite, J., Torroni, P. (eds.) CLIMA 2004. LNCS (LNAI), vol. 3487, pp. 33–51. Springer, Heidelberg (2005)
15. Cliffe, O., De Vos, M., Padget, J.: Specifying and reasoning about multiple institutions. In: Noriega, P., Vázquez-Salceda, J., Boella, G., Boissier, O., Dignum, V., Fornara, N., Matson, E. (eds.) COIN 2006. LNCS (LNAI), vol. 4386, pp. 67–85. Springer, Heidelberg (2007)
16. Boella, G., van der Torre, L.: Contracts as legal institutions in organizations of autonomous agents. In: Jennings, N., Sierra, C., Sonenberg, L., Tambe, M. (eds.) Third International Joint Conference on Autonomous Agents and Multi Agent Systems, vol. 2, pp. 948–955. ACM Press, New York (2004)
17. Reiter, R.: A logic for default reasoning. Artificial Intelligence 13(1/2), 81–132 (1980)
18. Royakkers, L., Dignum, F.: Defeasible reasoning with legal rules. In: Brown, M., Carmo, J. (eds.) Deontic Logic, Agency and Normative Systems (Workshops in Computing), pp. 174–193. Springer, Heidelberg (1996)

19. Sartor, G.: Normative conflicts in legal reasoning. Artificial Intelligence and Law 1(2-3), 209–235 (1992)
20. van der Torre, L.: Violated obligations in a defeasible deontic logic. In: Proceedings of the Eleventh European Conference on Artificial Intelligence (ECAI 1994), pp. 371–375. John Wiley and Sons, Amsterdam (1994)
21. García-Camino, A., Noriega, P., Rodríguez-Aguilar, J.A.: An algorithm for conflict resolution in regulated compound activities. In: Seventh Annual International Workshop Engineering Societies in the Agents World (ESAW 2006) (2006)
22. Ryu, Y.U.: Relativized deontic modalities for contractual obligations in formal business communication. In: 30th Hawaii International Conference on System Sciences (HICSS), Hawaii, USA. Information Systems Track - Internet and the Digital Economy, vol. 4, p. 485 (1997)
23. Grosof, B.N.: Representing e-commerce rules via situated courteous logic programs in ruleml. Electronic Commerce Research and Applications 3(1), 2–20 (2004)
24. Governatori, G.: Representing business contracts in ruleml. International Journal of Cooperative Information Systems 14(2-3), 181–216 (2005)
25. Giannikis, G.K., Daskalopulu, A.: Defeasible reasoning with e-contracts. In: IEEE/WIC/ACM International Conference on Intelligent Agent Technology, pp. 690–694 (2006)
26. García-Camino, A., Rodríguez-Aguilar, J.A., Sierra, C., Vasconcelos, W.: Norm-oriented programming of electronic institutions: A rule-based approach. In: Noriega, P., Vázquez-Salceda, J., Boella, G., Boissier, O., Dignum, V., Fornara, N., Matson, E. (eds.) COIN 2006. LNCS (LNAI), vol. 4386, pp. 177–193. Springer, Heidelberg (2007)
27. Friedman-Hill, E.: Jess in Action. Manning Publications Co. (2003)