Contextualized Institutions in Virtual Organizations

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Abstract. Within a virtual organization, more than one institution might be involved in the regulation of actors' behavior. Each institution specifies a set of norms covering a specific aspect of the problem domain with a governance scope defining its remit. Together, they govern the participants and reflect the objectives of the organization. With actors' behavior being simultaneously regulated by more than one institution, normative conflicts can appear. In this paper, we formalize the notion of governance scope and propose a computational approach to identify weak and strong norm conflicts in virtual organizations. This is achieved by explicitly modeling the governance scopes of institutions through context models. We illustrate our approach by means of a case study concerning food security in international trade.

1 Introduction

Virtual organizations (VOs) [11] can employ various institutions to cover different aspects of regulating the behaviour of the participating actors in order to achieve the VO's goals. The norms that make up an institution inherently serve to restrict its applicability, but the variables, in terms of which those norms are expressed, are also typically intended to be restricted to specific, meaningful ranges within the domain being modelled. That is to say, some combinations of event and metadata are meaningful and others are not. We use the term *governance scope* to describe this set of concrete observable/exogenous events and associated values (event metadata) that can affect the state of an institution and hence characterize the situations (being particular combinations of contextual information such as time, location, weather, relations, and system states) in which a given institution has competence.

When an event occurs, several institutions might respond to regulate the behaviour. Regardless of the outcome of the individual regulation processes, we call this situation a *governance overlap*. The activation of multiple institutions can cause problems, in that a single event might be interpreted differently and could result in conflicting consequences. For example, when a Dutch citizen applies for a visa to the US, several institutions might be triggered, e.g., US embassy, Dutch government, and a conflict could exist between information requirements from the US embassy and privacy policies from the Dutch government. We contend that in VOs governed by multiple institutions, the existence of normative conflicts cannot be avoided just by defining mutually exclusive deontic expressions, since that would preclude any institutionally common event. Clearly, careful definition of institutional competence is needed and its overlap between different institutions is a necessary precondition for norm conflicts in VOs. Consequently, we regard the process of designing an institution as not only the definition of a set of norms but also the characterization of its governance scope, i.e., what kinds of situations are under control of the institution, since this is what gives the institution its 'footprint'. That is, the same set of norms with different governance scopes results in different *contextualized institutions*. Furthermore, the occurrence of external events, that fall within the governance scope of an institution, initiates state transitions for that institution. In this way, different sets of norms in the VO are activated to regulate behaviour.

This paper introduces an approach that: (i) formalizes the governance scope of an institution through context models and hence captures the relations between institutions, and (ii) provides a mechanism to analyze institutional governance scope, as a precursor to detecting norm conflicts. We operationalize our approach by adapting an existing computational model, which we then use to demonstrate how our proposal works using a case study.

The rest of the paper is organized as follows. In the next section, we present a simplified scenario concerning food security from the domain of international trade. In Section 3, we introduce the formal model of the *contextualized institution*. In section 4, we discuss the relations between *contextualized institutions* in VOs and define two categories of *norm conflict*. Section 5 presents an operational model of contextualized institutions, which is then used to identify norm conflicts through a case study in Section 6. Related work is discussed in Section 8. Finally, we conclude and identify directions for future work in Section 9.

2 Scenario

The World Customs Organization (WCO) has defined a framework called the Authorized Economic Operator (AEO) program [1] in order to address the tensions created by the simultaneous growth in international trade and requirements for increased security. The European Communities' implementation of AEO permits various customs administrations to grant AEO certificates to qualified companies under which they enjoy special privileges. Taking the scenario of importing food from a country outside the EU to the Netherlands, a number of governmental authorities and companies are involved, which together form a virtual organization. Such a virtual organization is governed by different sets of regulations concerning different aspects of the food importation process. For example, the EU has a set of general regulations in which one is that the food authority is *obliged* to carry out a food quality inspection. With the introduction of the AEO programme, the Dutch government introduced new regulations for the specific domain of AEO-certified goods in order to improve trading efficiency. For example, one regulation is that a food authority is *forbidden* to carry out a food quality inspection, if customs has already done so. Additionally, companies such as container terminals play an important role and bring their own regulations, e.g., a regulation at one container terminal is that carriers are *obliged* to transport their goods thence within two days after

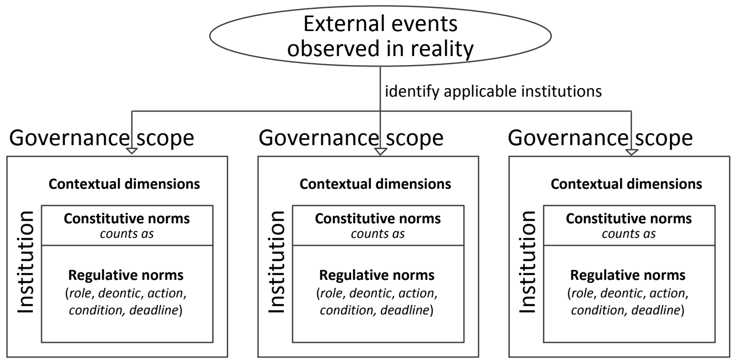

Fig. 1. Governance scopes in virtual organization.

unloading. Given these different sets of regulations, it is essential to capture not only their individual functionalities but also their interrelations concerning the governance of real world events.

3 Formal Model

The virtual organization in Figure 1 has three parts: (i) *external events* observed in the real world, each of which has associated contextual information (ii) *institutions* comprising sets of norms, in which *constitutive norms* translate external events into institutional events which are further mapped to institutional states, and *regulative norms* (permissions, obligations, prohibitions) react to the occurrence of institutional events and states, and (iii) *governance scopes* that delineate the control boundary of institutions through a set of contextual dimensions. With governance scopes, contextualized institutions are built, which facilitates the identification of applicable institutions for a given event. We now explain each of these components in more detail.

To capture the contextual information of events and the governance scope of institutions, we introduce the concept of *contextual dimension*.

Definition 1 (Contextual Dimension). *A contextual dimension D_i, $i \in \{1, \ldots, n\}$ is a situational variable whose values are from a value set V_i comprising a set of atomic values.*

Contextual dimensions concern, but are not restricted to, aspects such as individuality, activity, time, location, and relation [17]. The values of each contextual dimension are assumed to come from some structured domain. For example, we can have a contextual dimension of $D_i = Location$ with a value set $V_i = \{NL, France, Germany, ...\}$.

3.1 Events

We differentiate two kinds of events. One is external events observed in reality and the other is institutional events defined by institutions, which serve as the triggers of institutional evolution. A basic element of an event is an action and other contextual information, such as who, when and where the action is performed, can also be included to refine the occurrence of the event. Therefore, we define an event as an action associated with a set of contextual elements, which permits us to correlate events with the customized contextual dimensions of governance scopes.

Definition 2 (Event). *An event e is a tuple* $\langle action, c\rangle$ *where*

- *action indicates the fact or process of doing something,*
- $c \in \prod_i V_i, i \in \{1, \ldots, n\}$ *characterizes the situation where the event occurs, with respect to a flexible set of contextual dimensions.*

The contextual dimensions that are used to characterize the occurrence of an event is not fixed, i.e., c can relate to an arbitrary set of contextual dimensions. For example, given two dimensions $\{Location, Time\}$, an event could be e = ⟨*eat*, ⟨*McDonald's*, *12pm*⟩⟩, indicating that the action of eating occurs at the time of 12pm and at the location of McDonald's.

3.2 Governance Scope

Governance scopes are used to delineate the control boundary of institutions, determining which situations are under their control. To capture the governance scope of an institution, we adopt the context model proposed by Giunchiglia and Bouquet [8]. The model is based on three elements: a set of parameters, a value for each parameter, and a state of affairs or a domain, which draws a sort of boundary between what is in and what is out.

Correspondingly, we characterize a governance scope as a set of contextual dimensions. Different contextual dimensions indicate different ways of establishing the governance scope of an institution. For example, an institution can specify its governance scope by defining a contextual dimension of *Individuality*, indicating that as long as the entities evolved in an event belongs to a set of individuals, the institution has the right to govern the behaviour. Similarly for *Location*, an institution can indicate that as long as the observed location of an event belongs to a set of locations, the behaviour is in the governance scope of the institution.

Definition 3 (Governance Scope). *A governance scope gs is a tuple* ⟨ *Action, C* ⟩ *where*

- *Action is a set of actions,*
- $C \in \prod_i 2^{V_i}, i \in \{1, \ldots, n\}$*, relating to a flexible set of contextual dimensions.*

It can be seen that gs specifies a multi-dimensional space by assigning each contextual dimension a set of values it accepts. Note that we separate the set of actions from the contextual dimensions only to match the definition of event. A governance scope might have no constraint on a particular contextual dimension. In this case, a value of universal set denoted as U is assigned to that dimension and we consider the governance scope covers the whole value set of that contextual dimension. For example, a governance scope could be $\langle Action = \{import, export\}$, $\langle Location = \{NL\}, Time = U\rangle\rangle$.

3.3 Institution Model

Following Searle's notion of the construction of social reality [13], we differentiate two kinds of institutional norms, i.e., constitutive norms and regulative norms. Constitutive norms specify how an institution (and hence all of the members of the society associated with it) should interpret the events happened in reality, while regulative norms are used to regulate the behaviour of agents in terms of permissions, obligations and prohibitions.

Constitutive norms in our institution model are of two kinds. One is to translate external events to institutional events, denoted by function f_{CA}. The other is to derive institutional states from institutional events subject to certain institutional states, expressed by function $\mathcal{C}$. Adapted from [3], we use the concept of fluents $\mathcal{F}$, i.e., a set of facts, to characterize institutional states. Definition 4 gives the formalization.

Definition 4 (Constitutive Norm). *A constitutive norm is defined as* $n_c = \langle \mathcal{E}_{ex}, \mathcal{E}_{inst} \rangle |$ $\langle \mathcal{E}_{inst}, \Sigma_i, \Sigma_{i+1} \rangle$*, constructed from two functions:*

- *institutional mapping function* $f_{CA} : \mathcal{E}_{ex} \to \mathcal{E}_{inst}$ *which relates external events* $\mathcal{E}_{ex}$ *to institutional events* $\mathcal{E}_{inst}$*,*
- *institutional consequence function* $\mathcal{C} : \mathcal{E}_{inst} \times \Sigma_i \to \Sigma_{i+1}$ *in which* $\Sigma_i, \Sigma_{i+1} = 2^{\mathcal{F} \cup \neg \mathcal{F}}$ *respectively indicate the current and successor institutional states.*

Predicated on institutional events and states, regulative norms specify a set of dos and don'ts. Adapting the *ADICO* syntax proposed by Ostrom [12], we give the definition of a *Regulative Norm*.

Definition 5 (Regulative Norm). *A regulative norm is defined as a tuple* $n_r = \langle$*role, deontic, action, condition, deadline*$\rangle$ *such that:*

- *role indicates the type of entities to whom the norm applies;*
- *deontic indicates the deontic type of the norm, i.e., Permitted, Obliged or Forbidden;*
- *action specifies the particular institutional action to which the deontic is assigned;*
- *condition is expressed as* $\langle \Sigma, E \rangle$*, where* Σ *describes the states under which the norm holds and* E *is a sequence of events.*
- *deadline, expressed as an event, describes the latest time by which the norm (usually obligations) should be complied with otherwise a violation is generated.*

From the definition, we can see that a regulative norm is a conditional deontic expression with a deadline, which indicates that when the *condition* is fulfilled, agents enacting the *role* have a permission, obligation or prohibition to perform the *action* before the *deadline*. If a regulative norm does not specify a particular role, the default value is for all participants. Condition and deadline can also be empty, indicating the norm always holds under any conditions. Obligations may be assigned a deadline event, i.e. the *action* is obliged to perform before the deadline event occurs. In particular, obligations and prohibitions may have corresponding sanctions when the norms are violated. Sanctions are triggered when violations are detected. In this sense, the violation of certain norms serve as the conditions of other norms about sanctions.

Roles specified in regulative norms are enacted by real world actors. When an external event occurs, constitutive norms create a link between the actors in reality and the roles they enact in an institution. In this sense, the identity information of actors captured in the contextual information of external events are linked to institutional roles.

As stated before, institutions are not only a set of norms but also characterized by governance scopes which reflect their control boundaries. Therefore, we introduce the definition of *Contextualized Institution*.

Definition 6 (Contextualized Institution). *A contextualized Institution is defined as a tuple* $\mathcal{I} = \langle \Sigma_0, \mathcal{F}, gs, CN, RN \rangle$, *where*
- Σ_0 *indicates the initial state of the institution,*
- $\mathcal{F}$ *is a set of facts, characterizing institutional states,*
- gs *is the governance scope of the institution,*
- CN *is a set of constitutive norms,*
- RN *is a set of regulative norms.*

Each institution is assigned an initial state specifying where the institution starts. Associated with a governance scope, an institution identifies all the situations that are under its control. The set of constitutive norms CN, on the one hand, connects external events to the institution in the sense that external events *counts-as* institutional events constrained by the governance scope, and on the other hand, drives institutional state evolution. Given the institutional events and states, the set of regulative norms RN activates corresponding permissions, obligations and prohibitions so that the real world behavior can be regulated. Given an external event, we first use the values of its contextual dimensions to determine whether the event falls in the governance scope of an institution. If so, the event will be (partially) translated to institutional events since some of the contextual information might not be relevant for regulative norms and are only needed for the determination of governance scopes.

Given sequences of events occurring in reality, institutions relate the effects to the conditions of its regulative norms. In this way, institutions can respond to the real world behavior by initiating and terminating some of the regulative norms. Details about the dynamics of institutions will be explained in Section 5.

However, since regulative norms are based on institutional events, it is necessary to trace back the originating external events when determining the behavior in the real world that regulative norms refer to. Therefore, we defined *Reverse CountsAs Function* as below:

Definition 7 (Reverse CountsAs Function $\tilde{f}_{CA}$). *Given an institutional event* e' *and a set of constitutive norms* CN, $\tilde{f}_{CA}(e') = \{e | \langle e, e' \rangle \in CN\}$.

It can be seen that $\tilde{f}_{CA}$ maps the responses of the institution to the reality so that the real world behavior can be addressed and hence governed.

4 Institutions in Virtual Organizations

Individual institutions are designed originally for their own objectives and thus have specific governance scopes. As long as the institutions are internally consistent, they can successfully operate independently. In virtual organizations, however, when interactions are governed by multiple institutions, mutually exclusive norms might be provided from the institutions with overlapping governance scope. Therefore, we aim to detect such kind of conflicts in VOs.

4.1 Collective Institutions

Figure 2 shows how institutions evolve with a sequence of events occurred in a virtual organization. At the initial state Σ_0, each institution of the virtual organization is initialized. When an event occurs, the institutions whose governance scope covers that event will be activated.

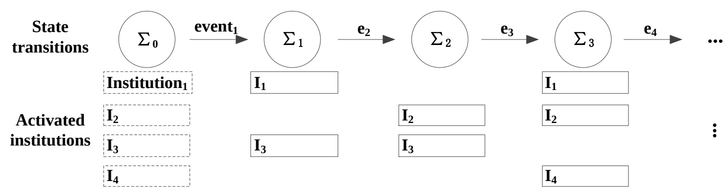

Fig. 2. Institutions.

We can see that at different time instants, there are different sets of institutions activated by the same event. That is, the contextual information of an event simultaneously maps to the governance scope of some institutions. To represent these simultaneously activated institutions, we introduce the concept of *Collective Institution Set* in Definition 8.

Definition 8 (Collective Institution Set). *In a virtual organization governed by a set of institutions* $\{\mathcal{I}_1, \ldots, \mathcal{I}_m\}$, $\mathcal{I}_j = \langle \Sigma_0^j, \mathcal{F}_j, gs_j, CN_j, RN_j \rangle, 1 \leq j \leq m$*, given an event e occurred at time instant k, a collective institution set is defined as* $\mathcal{V}_k = \{\mathcal{I}_j | action_e \in A_{gs_j}$*, and* $\forall D_i, \pi_{V_i}(c_e) \in \pi_{V_i}(gs_j), 1 \leq j \leq m\}$ *where* $\pi_{V_i}(c_e)$ *and* $\pi_{V_i}(gs_j)$ *respectively indicate the value (values) that the event e and the governance scope* gs_j *take for the contextual dimension* D_i.

At any time instant k, the set of all institutions whose governance scope covers the contextual information of the event that occurs at time k is called a collective institution set, indicating all the activated institutions given the occurrence of an event. The governance scopes of these institutions overlap with each other and thus they all have governance competence on the same event.

4.2 Governance Overlap

In a collective institution set, the overlap relation between governance scopes is indicated by the same substantive event covered by a set of institutions. Generally, the overlap relation is determined by the values of each contextual dimension with respect to different governance scopes. To represent the overlap between the governance scopes of different institutions, we introduce the concept of *Governance Overlap*.

Definition 9 (Governance Overlap). *Given two governance scopes* $gs = \langle A, C \rangle$, $gs' = \langle A', C' \rangle$*, the governance overlap between* gs *and* gs' *is defined as* $\Omega(gs, gs') = (A \cap A') \times \prod_i \pi_{V_i}(gs) \cap \pi_{V_i}(gs')$.

If $\Omega(gs, gs') \neq \varnothing$, we say gs and gs' have a non-empty overlap. Particularly, in a collective institution set $\mathcal{V}_k = \{\mathcal{I}_1, \ldots, \mathcal{I}_n\}$, $\forall \mathcal{I}_i \in \mathcal{V}_k, \forall \mathcal{I}_j \in \mathcal{V}_k, \Omega(gs_i, gs_j) \neq \varnothing$

4.3 Norm Conflicts

When an event simultaneously activates multiple institutions with overlapping governance scopes, these institutions should be consistent with each other. However, since the individual institutions are designed originally for their own use, there might be conflicting norms between them. The focus of this paper is on the conflicts between regulative norms that are simultaneously applied to the same agent possibly enacting different roles in different institutions, but associated with inconsistent deontic modalities. Definition 10 illustrates the concept of *Norm Conflicts* considered in this paper.

Definition 10 (Norm Conflict). *Within a collective institution set* $\mathcal{V}_k = \{\mathcal{I}_1, \ldots, \mathcal{I}_n\}$*, a norm conflict can be defined between any two institutions* $\mathcal{I}_i, \mathcal{I}_j \in \mathcal{V}_k$*,* $\mathcal{I}_i = \langle \Sigma_0^i, \mathcal{F}_i, gs_i, CN_i, RN_i\rangle$ *and* $\mathcal{I}_j = \langle \Sigma_0^j, \mathcal{F}_j, gs_j, CN_j, RN_j\rangle$ *iff*
$\exists\langle role_i, deontic_i, action_i, condition_i, deadline_i\rangle \in RN_i$,
$\exists\langle role_j, deontic_j, action_j, condition_j, deadline_j\rangle \in RN_j$*, such that*

- *both* $condition_i$ *and* $condition_j$ *are fulfilled,*
- *neither* $deadline_i$ *nor* $deadline_j$ *has expired,*
- $\tilde{f}_{CA}(e'_i) \cap \tilde{f}_{CA}(e'_j) \neq \varnothing$ *where* $e'_i = \langle action_i, v_{i1}, \ldots, v_{im}\rangle \in \mathcal{E}^i_{inst}$*,* $e'_j = \langle action_j, v_{j1}, \ldots, v_{jn}\rangle \in \mathcal{E}^j_{inst}$*,*
- *if* $deontic_i = P$ *and* $deontic_j = F$*, we term this conflict as a weak conflict,*
- *if* $deontic_i = O$ *and* $deontic_j = F$*, we term this conflict as a strong conflict,*

As expressed in the definition, given any two institutions $\mathcal{I}_i$ and $\mathcal{I}_j$ within a collective institution set, if their governance scopes overlap somehow and there are two norms initiated by two institutions simultaneously, both of which refer to the same event in reality, but associated with contradictory deontic modalities, we term this situation as a norm conflict.

Specifically, we differentiate two kinds of norm conflicts, i.e., weak conflicts and strong conflicts. A weak conflict is defined between a permission (P) and a prohibition (F), which *might* lead to violation. That is, if the action specified in both of the norms is performed, the prohibition is violated, while if not, there will not be any violation. A strong conflict is defined between an obligation (O) and a prohibition (F), which *must* lead to violation no matter the action specified in both of the norms is performed or not. That is, if the specified action is performed, the prohibition is violated, while if not, the obligation is violated. Therefore, weak conflicts might be avoided as long as the specified actions are not performed, but strong conflicts cannot.

5 Operational Model

We adapt ideas from the institutional action language $InstAL$ [3], to operationalize the normative framework of Section 3. For each individual institution, the modeling process defines an explicit governance scope and formalizes the norms (both constitutive and regulative) for each institution. Subsequent translation into a computational model allows users to verify the resulting institutional states against a sequence of external events.

The computational model is implemented by *Answer Set Programming (ASP)* [7], which is a declarative logic programming paradigm. $AnsProlog$ is chosen here to be the language because several efficient solvers exist for it. The fundamental elements of $AnsProlog$ are atoms assigned with truth values. Atoms can be negated by means of *negation as failure*. A literal in $AnsProlog$ is either an atom or a negated atom, and then constitute rules of the general form : $a : -b_1, ..., b_m, not\ c_1, ..., not\ c_n$ where a, b_i and $not\ c_j$ are all atoms. The rule can be read intuitively as *if all atoms b_i are known/true, and no c_j is known/true, then a must be known/true*. Of the form, a is referred as the head of the rule while b_i and $not\ c_j$ are the body. Additionally, there are two special forms of rules: *fact*s which have no body part and *constraint*s that have no head part. *Constraint*s are normally used to filter the results by specifying the undesirable features of solutions to the problem. A normal answer set program is denoted by a conjunction of rules. The results of the programs are represented by a set of answer sets. Each answer set is a minimal and consistent set of atoms assigned with truth values satisfying all the rules in the program and thus each answer set is a solution to the problem.

We build our operational model based on two basic elements fluents $\mathcal{F}$ and events $\mathcal{E}$. Fluents characterize institutional state, as a set of facts, and their presence denote that some facts are true, and their absence indicate the facts are false. Consequently, institutional states can be denoted by any combination of the fluents and their negated forms. Events, both external and institutional, are defined as a tuple and encoded as $\mathtt{ev}(\mathtt{a}, \mathtt{v1}, ...\mathtt{vn})$. For example, an event $\langle transport, terminal_a, AEO\ beef \rangle$ is encoded as $\mathtt{ev}(\mathtt{trans}, \mathtt{ta}, \mathtt{abf})$.

Governance scope gs has been introduced to build contextualized institutions. As defined in Section 3.2, the gs of an institution is represented as a tuple $\langle Action, C \rangle$. C is indicated by a set of contextual dimensions, each of which defines the set of values the contextual dimension can take with regard to this governance scope. Therefore, we model the gs of an institution by a set of $\mathtt{action}(\mathtt{a})$ indicating the governed actions, and a set of $\mathtt{scope}(\mathtt{i}, \mathtt{v})$ describing the corresponding values for a specific dimension with index i. In this way, the gs of an institution is explicitly defined by a multi-dimensional space. In order to examine whether an external event is within the gs of an institution, we assume that the event contains a full set of the contextual dimensions as defined in gs and specified in the same order. Whether a gs covers an event e is determined by comparing their attached value(s) regarding the same contextual dimension, and finally yields $\mathtt{governed}(\mathtt{A}, \mathtt{V1}, ..., \mathtt{Vn})$ if the event is covered by gs.

Institutional state transitions are driven by the occurrence of external events $\mathcal{E}_{ex}$ starting from a specified initial state Δ. The evolution of institutional states is based on both constitutive norms(CN) and regulative norms (RN): (i) CN interprets observed external events $\mathcal{E}_{ex}$ as institutional events $\mathcal{E}_{inst}$ subjected to the governance scope. Afterwards, the generated institutional events promote the transitions of institutional states. (ii) RN specifies norms at certain institutional states. If the conditions are satisfied, norms about permissions, prohibitions and obligation are activated. While the deadlines expire, the norms are deactivated.

$$
\begin{aligned}
s \in \Sigma &\Leftrightarrow \texttt{fluent(s)}.\\
e : \langle a, v_1, ..., v_n\rangle \in \mathcal{E}_{ex} &\Leftrightarrow \texttt{ev(a, v1, ..., vn)}.\\
e' : \langle ia, iv_1, ..., iv_n\rangle \in \mathcal{E}_{inst} &\Leftrightarrow \texttt{ev(ia, iv1, ..., ivn)}.\\
gs = \langle A, R1, ..., Rn\rangle &\Leftrightarrow \forall a \in A, \texttt{action(a)}.\ \forall v \in Ri, \texttt{scope(i, v)}.\\
&\quad\ \texttt{governed(A, V1, ..., Vn)}:-\texttt{action(A)},\\
&\quad\quad\quad \texttt{scope(1, V1)}, ..., \texttt{scope(n, Vn)}.\\
\forall \langle\langle a, v_1, ..., v_n\rangle, \langle ia, iv_1, ..., iv_n\rangle\rangle \in CN &\Leftrightarrow \texttt{occ(ev(ia, iv1, ..., ivn), T)}:-\texttt{obs(ev(a, v1, ..., vn), T)},\\
&\quad\quad\quad \texttt{governed(a, v1, ..., vn)}.\\
&\quad\ \texttt{countAs(ev(a, v1, ..., vn), ev(ia, iv1, ..., ivn), Inst), inst(Inst)}.\\
\forall \langle\langle ia, iv_1, ..., iv_n\rangle, \Sigma_t, \Sigma_{t+1}\rangle \in CN &\Leftrightarrow \texttt{holdsat(s, T + 1)}:-\texttt{occ(ev(ia, iv1, ..., ivn), T)}, \mathcal{X}(\Sigma, T).\\
&\quad\ \texttt{happened(ev(a, v1, ..., vn), T)}:-\texttt{obs(ev(a, v1, ..., vn), T)}.\\
&\quad\ \texttt{happened(ev(ia, iv1, ..., ivn), T)}:-\texttt{occ(ev(ia, iv1, ..., ivn), T)}.\\
\forall n_r \in RN, n_r = \langle r, perm, a, \langle \Sigma, E\rangle\rangle &\Leftrightarrow \texttt{norm(perm(a, r), T)}:-EX(\Sigma, T), \mathcal{H}(E, T), \texttt{action(a), role(r)}.\\
\forall n_r \in RN, n_r = \langle r, forb, a, \langle \Sigma, E\rangle\rangle &\Leftrightarrow \texttt{norm(forb(a, r), T)}:-EX(\Sigma, T), \mathcal{H}(E, T), \texttt{action(a), role(r)}.\\
\forall n_r \in RN, n_r = \langle r, obl, a, d, \langle \Sigma, E\rangle\rangle &\Leftrightarrow \texttt{norm(obl(a, r), T)}:-EX(\Sigma, T), \mathcal{H}(E, T), \texttt{not happened(d, T)},\\
&\quad\quad\quad \texttt{action(a), role(r)}.\\
\mathcal{H}(E, T), \forall e_i \in E &\Leftrightarrow \texttt{happened(ei, Ti), before(Ti, T)}.\\
\mathcal{X}(\Sigma, T) &\Leftrightarrow \forall s \in \Sigma,\ \texttt{holdsat(s, T)}.\ \forall s \notin \Sigma,\ \texttt{not holdsat(s, T)}.\\
EX(\Sigma, T), \forall s \in \Sigma &\Leftrightarrow \texttt{holdsat(s, T)}.\\
s_0 \in \Delta &\Leftrightarrow \texttt{holdsat}(\texttt{s}_0, \texttt{0}).
\end{aligned}
$$

Fig. 3. Operational Model in $AnsProlog$

In Figure 3, we illustrate the mapping from the formal model to $AnsProlog$ literals. The atoms `fluent(s)` and `ev(a, v1, ..., vn)` encode the fluents and events respectively. To operationalize CN, firstly the corresponding institutional event is generated (`occ`) by an external event (`obs`) if being covered by gs. At the same time, a literal `countAs` is generated to reflect the generation relation between external entities and institutional entities, including actions and other contextual entities carried with events. All the observed and occurred events are considered as happened events `happened(E, T)`. Moreover, CN also specifies the effects of institutional events. A state formula $\mathcal{X}(\Sigma, T)$ denotes the institutional states at time T, which is expressed by a set of `holdsat(s, T)` and `not holdsat(s, T)` . Regarding regulative norms RN, three literals are defined to encode Permissions (`norm(perm(a, r), T)`), Prohibitions (`norm(forb(a, r), T)`) and Obligations (`norm(obl(a, r), T)`), holding at time T. Certain conditions ($EX(\Sigma, T)$) have to be satisfied at time T to activate a regulative norm, which requires a sequence of happened events ($\mathcal{H}(E, T)$). The fluents holding at the initial states Σ_0 are translated into `holdsat(s0, 0)`.

6 Case Study

To demonstrate our approach, we formalize a specific case from the scenario described in Section 2. Based on the operational model, we further illustrate how to identify collective institution sets and detect norm conflicts in the case study.

6.1 Modeling Contextualized Institution

In this case study, we mainly consider three institutions $\{\mathcal{I}_1, \mathcal{I}_2, \mathcal{I}_3\}$, whose governance scopes are based on three contextual dimensions {*Individuality*, *Location*, *Food*}, and a set of actions *Action* that are specified by the regulative norms of the institutions. We use $RN_{action}(\mathcal{I}_i)$ to represent the set of actions that each institution defines in its set of regulative norms. *Individuality* refers to agents participating in the case study $\{ag, ag1\}$. *Location* is provided with a set of values $\{t_a, t_b, t_c, w_a\}$ in which the first three elements represent three container terminals and the fourth element represents a warehouse. *Food* also has a corresponding value set {AEO beef, non-AEO beef}. Note that in this paper we only consider parts of the value sets which are most relevant to our analysis. Table 1 gives the details of the three institutions.

As mentioned in Section 3.2, contextual dimensions are used to define the governance scope of an institution. We next discuss how governance scope can be formalized in our operational model. Each contextual dimension is encoded as a variable and the corresponding range of values is specified by a set of facts `scope` and `action`. Furthermore, the literal `governed` assures that the governance scope of an institution will be bounded by all these scopes. As illustrated in Table 1, the three institutions share three dimensions *Individuality*, *Location* and *Food*, which are constrained by different sets of values. For example, $\mathcal{I}_1$ governs all European terminals and warehouses when importing food to the EU countries. Therefore the scopes are initiated as ASP literals for $\mathcal{I}_1$: `scopeEU(1, ag; ag1)`, `scopeEU(2, ta; tb; tc; wa)`, `scopeEU(3, abf; nabf)`. $\mathcal{I}_2$ represents Dutch government, concerning importing AEO certified food via Dutch terminals and warehouses, e.g. t_a, t_b, w_a and AEO beef, while the terminal company $\mathcal{I}_3$ regulates all the food imports through terminal t_a only. All corresponding literals are defined and shown in Table 1. Different suffixes are attached with literal names to denote which institution the literal belongs to, e.g. `scopeEU` is for $\mathcal{I}_1$, `scopeNL` for $\mathcal{I}_2$ and `scopeTE` for $\mathcal{I}_3$.

Table 1. Institution Model for the case study

	gs	CN	RN
$\mathcal{I}_1$	$\langle RN_{action}(\mathcal{I}_1), \langle\{ag,ag_1\}$, $\{t_a, t_b, t_c, w_a\}$, {AEO beef, non-AEO beef}⟩⟩	transport food to EU *counts as* food passes border	O(food authority, inspect quality, after unloading), F(carrier, pass border, before inspection is finished), F(any food,choose inspection location)

	`scopeEU(1, ag; ag1).`
	`scopeEU(2, ta; tb; tc; wa).`
	`scopeEU(3, abf; nabf).`
		`occ(ev(inPass, carr, ta, abf), T)`
		`:-obs(ev(trans, ag1, ta, abf), T),`
		`governedEU(ag1, ta, abf).`
			`norm(obl(inInspect, foodAuth), T)`
			`:-happened(ev(informLoc, ag, ta, abf), K),`
			`not happened(ev(trans, ag1, ta, abf), T),`
			`before(K, T), role(foodAuth).`

$\mathcal{I}_2$	$\langle RN_{action}(\mathcal{I}_2), \langle\{ag,ag_1\}$, $\{t_a, t_b, w_a\}$, {AEO beef}⟩⟩	transport food to EU *counts as* food passes border	F(food authority, inspect quality, if customs did), F(carrier, pass border, before inspection is finished), P(AEO Food, choose inspection location)

	`scopeNL(1, ag; ag1).`
	`scopeNL(2, ta; tb; wa).`
	`scopeNL(3, abf).`
		`occ(ev(inPass, carr, wa, abf), T)`
		`:-obs(ev(trans, ag1, wa, abf), T),`
		`governedNL(ag1, wa, abf).`
			`norm(forb(inInspect, foodAuth), T)`
			`:-happened(ev(inInspect, customs, wa, abf), K),`
			`before(K, T),role(foodAuth; customs).`
			`norm(perm(inChooseLoc, carr), T)`
			`:-happened(ev(informLoc, ag, wa, abf), K),`
			`role(carr), before(K, T).`

$\mathcal{I}_3$	$\langle RN_{action}(\mathcal{I}_3)$, $\langle\{ag,ag_1\}, \{t_a\}$, {AEO beef, non-AEO beef}⟩⟩	transport food to EU *counts as* food leaves terminal	O(carrier, leave terminal, in 2 days after unload), O(carrier, pay fine, if food does not leave terminal after two days from unloading)

	`scopeTE(1, ag; ag1).`
	`scopeTE(2, ta).`
	`scopeTE(3, abf; nabf).`
		`occ(ev(inLeave, carr, ta, abf), T)`
		`:-obs(ev(trans, ag1, ta, abf), T),`
		`governedTE(ag1, ta, abf).`
			`norm(obl(inLeave, carr), T)`
			`:-happened(ev(waitForInsp, ag1, ta, abf), K),`
			`not happened(ev(deadline), T), before(K, T),`
			`role(carr).`

To operationalize the three institutions, we generate the computational model for each individual institution based on the rules in Figure 3. Due to space limitation, only the most significant rules are included in Table 1. The EU commission $\mathcal{I}_1$ specifies that transporting food to EU *counts as* passing the border, and food authorities are obliged to inspect the food before it passes the border. The relevant ASP programs are shown in Table 1. An external event is observed $\mathtt{obs(ev(trans, ta, abf), T)}$, which then generates an institutional event $\mathtt{occ(ev(inPass, ta, aeofood), T)}$ for $\mathcal{I}_1$ if all the dimensions are covered by the gs of $\mathcal{I}_1$. After informing the inspection location $\mathtt{happened(informLoc)}$, the obligation $\mathtt{norm(obl(inInspect, foodAuth), T)}$ is activated before the deadline event $\mathtt{trans}$ happens. $\mathcal{I}_2$ formalizes a regulative norm that after customs inspect the food $\mathtt{happened(inInspect(wa, abe\text{-}ef, customs))}$, food authorities are forbidden to inspect again $\mathtt{norm\ (forb(inInspect, foodAuth), T)}$, while the permission for passing border is granted. Besides, $\mathcal{I}_2$ permits carriers to choose inspection location when importing AEO food $\mathtt{norm(perm(inChooseLoc, carr), T)}$. $\mathcal{I}_3$ only considers those external events $\mathtt{ev(trans, ta, abf)}$ within its governance scope, which then trigger the institutional event leaving the terminal $\mathtt{ev(inLeave, ta, abf)}$. The obligation of leaving the terminal $\mathtt{norm(obl(inLeave, carr), T)}$ before a deadline is issued for all the food waiting for inspection at terminal ta.

6.2 Identification of Collective Institution Sets

As defined in section 4.3, conflicts are detected between institutions in a collective institution set. That is, given an external event, all institutions within the set can interpret the event (i.e. the event is covered by the gs of the institutions) and therefore are activated. The literal $\mathtt{governed/3}$ defined for each institution is used to examine whether all contextual values carried with the event are covered by the gs of an institution. For example, if an event $\mathtt{ev(inspect, ag, wa, abf)}$ is observed at time T and covered by the gs of $\mathcal{I}_2$, then $\mathtt{inst2}$ is added into the collective institution set at time T, $\mathtt{collectiveInstSet(inst2, T)}$. The corresponding ASP rules are as follows:

```
collectiveInstSet(inst2, T) :-
  obs(ev(inspect, ag, wa, abf), T),
  governedNL(ag, wa, abf).
```

6.3 Conflict Detection Mechanism

In this section, we present the computational mechanism for detecting norm conflicts between institutions. Because we modelled each institution by $AnsProlog$, the same technology can be adopted to detect norm conflicts between them. On the one hand, we can generate all the possible observed event traces to determine which traces will lead to conflicts. On the other hand, an deliberate event trace can be provided to test whether it would lead to any conflicts at any time instant. The ASP programs for detecting weak and strong conflicts are respectively shown as follows:

```
%% weak conflict
weakConflict(perm(AX, RX, InstX), forb(AY, RY, InstY), T) :-
  norm(perm(AX, RX), T), norm(forb(AY, RY), T),
  countAs(ev(A, V1, .., Vn), ev(AX, VX1, ..., VXn), InstX),
  countAs(ev(A, V1, .., Vn), ev(AY, VY1, ..., VYn), InstY),
  collectiveInstSet(InstX; InstY, T).

%% strong conflict
strongConflict(obl(AX, RX, InstX), forb(AY, RY, InstY), T) :-
  norm(obl(AX, RX), T), norm(forb(AY, RY), T),
  countAs(ev(A, V1, .., Vn), ev(AX, VX1, ..., VXn), InstX),
  countAs(ev(A, V1, .., Vn), ev(AY, VY1, ..., VYn), InstY),
  collectiveInstSet(InstX; InstY, T).
```

Following Definition 10, within a collective institution set, it is supposed that there is a permission(obligation) regarding an action AX performed by an agent enacting role RX at time T in one institution, and there is also a prohibition regarding action RY performed by an agent enacting role RY at the same time in another institution, if the institutional events associated with action AX and AY can be traced back to the same external event (i.e. including the same action and agent), a weak(strong) conflict is detected. We define two literals for weak and strong conflicts, `weakConflict` and `strongConflict`. Of these two literals, the first two arguments refer to the action and role to which the conflicts are related, and the third arguments indicate the two conflicting institutions. The literal `countAs` maps external events to institutional events, including actions and other contextual dimensions carried with them. `collectiveInstSet` constrains that the institutions are in the same collective institution set, which can be computed by the ASP programs proposed in Section 6.2.

(ta, abf)	strongConflict(obl(inLeave, carr, inst3), forb(inPass, carr, inst1), 5)
	strongConflict(obl(inLeave, carr, inst3), forb(inPass, carr, inst2), 5)
	strongConflict(obl(inInspect, foodAuth, inst1), forb(inInspect, foodAuth, inst2), 6)
	weakConflict(perm(inChooseLoc, carr, inst2), forb(inChooseLoc, carr, inst1), 3)
(ta, nabf)	strongConflict(obl(inLeave, carr, inst3), forb(inPass, carr, inst1), 4)
(wa, abf)	strongConflict(obl(inInspect, foodAuth, inst1), forb(inInspect, foodAuth, inst2), 6)
(tb, nabf)	none

Table 2. Norm Conflicts in the case study

Figure 4 shows a part of institutional evolutions in our case study. In general, when an external event occurs(denoted as the literals above/below arrows), the first task is to identify which institutions have governance competence, and then identify which norms in these institutions are triggered. It can be seen that at different time instants, there are different sets of institutions that are initiated concerning the occurrence of the event characterized by the attached contextual information. Each circle represents institutional states at a specific time, and a column of institution I_i above/below the circle indicates the collective institutions set at the time. For example, for the states Σ_3 and Σ_3', the activation of $\mathcal{I}_3$ depends on whether the location informed for inspection is within the governance scope of $\mathcal{I}_3$, i.e., the terminal t_a. Therefore, $\mathcal{I}_3$ is not activated at Σ'_3 when the informed location is t_b. While more than one institutions are activated, different sets of regulative norms from different institutions are triggered to constrain the behavior, which might cause conflicts. For example, three norms from the three institutions are triggered simultaneously at Σ_5, between which two strong conflicts occur. In this case study, there are in total five pairs of strong conflicts(indicated by a line with a cross) and one weak conflict (indicated by a line with a bullet) by providing four different event traces. Details about these conflicts are listed in Table 2. For example, a strong conflict is detected at time 5 between an obligation of the institutional event `inLeave` and a prohibition of the institutional event `inPass` because these two institutional events can be traced back to the same external event `trans` with regard to the reverse count-as function in Definition 7.

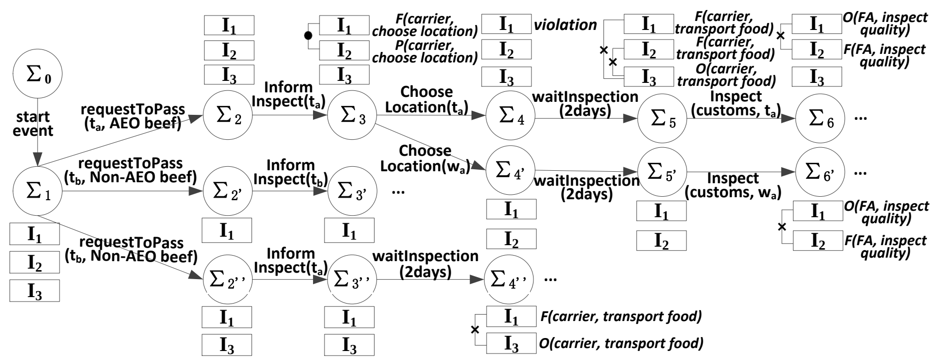

Fig. 4. Collective institution set and norm conflicts.

7 An Overview of Conflict Resolution

When the potential for norm conflict between the institutions of a collective are detected, an effective method of either preventing their actual occurrence, or a way of resolving those conflicts is needed. Unlike the approaches put forward in the literature [16, 6] in which the less important norm in a conflict pair is ignored or deleted, we take a finer-grain approach by revising the less important norm to be consistent with the other. We believe that such approach can actually resolve the conflicts by tracking and fixing the origins of them, rather than simply avoiding them. This approach to conflict resolution has been successfully applied to legal conflicts between cooperating legal systems [10] and because of the similarity, at the technical level, to the circumstances described here, we believe the same solution may be applied, perhaps save some minor details. By viewing each institution in a collective set (i.e. with overlapping governance scopes) as a participating legal specification – to use the terminology of our earlier work [10] – the procedure is able to compute automatically all possible revisions of the existing norms in the light of the detected conflicts. In order to keep this paper self-contained, we provide a brief introduction to the conflict resolution approach, but for more details of the approach, please refer to [10].

The approach uses the symbolic machine learning technique *Inductive Logic Programming*, through which the system is able to learn new norms or revisions to existing norms by generalising the given positive and negative examples. Those provided examples are the concrete reflection of the desirable and undesirable properties the resulting institutions should satisfy. Here we synthesize the negative examples by using the findings (i.e. conflict traces and conflicts) from conflict detection and feed them to the ILP learning system. We assume there is a strict total precedence order over the institutions in a (virtual) organization, e.g. EU $\succ$ NL $\succ$ TE,[1] which is then used to label the institutions in a given conflict pair, so that the one with lower precedence is referred to as the *revisable institution* and the other as the *background institution*. Keeping the background institution unchanged, the ILP learning system computes all possible revisions to the revisable institution that satisfy the properties of the examples, i.e. absence of conflict. Subsequently, it is necessary to select one of the proposed revision plans, for which criterion we use the plan with the minimum number of changes, in order to minimize the differences betwen the revised institution and the original. Each possible revision suggests a set of change operations, comprising:

- adding a new body condition to an existing norm, or
- removing a body condition from an existing norm, or
- forming a completely new norm.

The revision procedure, to which we refer above, is implemented in ASP, making it fully compatible with our modelling language for institutions and conflict detection. Given the operational models of the revisable institutions, we can construct the search space of all possible revisions with the help of *mode declarations* [4]. Consequently, an answer set solver (we use CLINGO), can generate a set of answer sets from: (i) the operational model of the background institution, using (ii) negative examples (i.e. conflict traces and conflicts) as constraints, and the (iii) revisable institutions. Each answer set is a candidate revision. We assign costs to each operation – the default is the unit cost for addition or deletion – and hence the total cost of a revision is then the number of operations included in the revision. The final step uses the *aggregate* technique in CLINGO to select the answer set with minimum cost. Following the application of the revision described in the answer set, the revised institution no longer causes the conflicts described in the learning examples.

8 Related Work

Interest has been steadily growing in the use of norms to regulate and coordinate agent behaviour in MAS, as a result of progress in two complementary areas: (i) institutional modeling, and (ii) norm conflict detection.

[1] EU, NL and TE refer to the three institutions in the case study: EU being European Union, NL the Netherlands and TE the terminal and warehouse.

We first review some representative research on normative modelling. Singh proposes the use of commitments to capture normative concepts in MAS and defines norms as a tuple of subject, object, context, antecedent and consequent [14], which provides an intuitive way to characterize the bounds of autonomy and interdependence between agents. Boella and van der Torre presented a logic architecture for a normative system and study logic relations between counts-as conditionals, institutional constraints, obligations and permissions [2]. This architecture gives a clear vision of how input/output operations correspond to the functionality of components that constitute normative systems. However, both of these studies are at the level of norms, while in contrast our work considers a set of institutions, each of which defines a set of norms, and their interrelations in the setting of virtual organizations.

We introduce the notion of *governance scope* and demonstrate how governance scope functions in institution modeling and conflict detection. The ideas presented in [16, 5] have some similarities. Vasconcelos et al.[16] define the *influence scope* of norms to constrain the effects of individual norms. This contrasts with our approach, where governance scope is defined at the level of institutions, with the aim of illustrating how *multiple* institutions can be situated within a virtual organization and how institutions are activated when responding to observed events. Elhag et al. [5] informally proposes the concept "world knowledge" that describes the context in which norms are intended to apply, along with the definition of key terminological concepts. The governance scope and constitutive norms defined in our work can capture the same concepts, but more importantly, governance scope is modeled explicitly and is operationalized in institutional reasoning.

We now turn to existing work on norm conflicts. Vasconcelos et al. [15, 16] consider both the detection and resolution of norm conflicts. They present an algorithm that uses *first-order unification* to determine substitutions, called *undesirable* sets, for the variables of norms that would lead to norm conflicts. Once the values are identified, conflicts can be avoided, by not allowing those values. In contrast, the conflict detection mechanism presented here is not only operationalized, but significantly, deals with conflicts that emerge through the interaction of institutions, which goes beyond the static analysis of individual norms. Using ideas similar to those in [15, 16], the practical reasoning agents of [9] include resolution mechanisms that enable them to handle conflicting norms themselves via negotiation with a norm issuer. An alternative resolution approach is proposed by García-Camino et. al [6], in which a simple priority mechanism is used to rank norms and hence resolve conflict by discarding lower priority norms.

9 Conclusions

Targeting virtual organizations, this paper presents a full illustration of *what* an institution consists of and *how* it evolves to the changes of reality. By explicitly incorporating the concept of governance scope, we know that an institution is not only a set of norms that are used to regulate the real world behavior, but is also characterized by the control boundary that determines what kinds of events are in the competence of the institution. Furthermore, the operational model provides a computational expression of institution dynamics, i.e., how institutions respond to the occurrence of external events.

The contributions of this paper are three-fold. First, governance scope is explicitly captured by institutions through context models, which facilitates the identification of applicable institutions in virtual organizations. Second, the relations between institutions are studied from the perspective of governance overlap. Third, based on our institution model, two definitions of strong and weak norm conflicts are proposed to the specific requirements of virtual organizations. To validate our proposal, we present an operational model, which enables an implementation of detecting strong and weak norm conflicts by a case study.

In this paper, we propose a framework for modelling institutions and their governance scopes. The framework not only provides the components for capturing the regulative properties of institutions but also their constitutive nature. Moreover, by explicitly modelling the governance scope of institutions, the framework enables a clear representation of the regulation boundaries of multiple institutions, which is an essential aspect that has to be considered for conflicts detection. Though the framework intends to provide a general approach for the problem undertaken, there are several issues that have to be considered when applying the framework:

- We assume that the ontologies used for contextualizing different institutions are aligned. That is, the contextual information is shared among different institutions. If this is not the case, additional work concerning ontology alignment needs to be done, which is itself a separate research topic.
- Sometimes, the governance scope of an institution is implicit and has to be derived from the description of its norms. In this case, one needs an overview understanding of the institution and generalize the contextual dimensions of its regulation boundaries.
- The conflict detection mechanism is dependant on the aligned semantics among institutions, i.e. the same entity has to be represented by the same logic notation in different institutions.

In future work, we intend to extend the institution model to multiple levels through hierarchical context models, and study how institutions are related from abstract to concrete. Furthermore, we will make refinement on different kinds of regulative norms and their relations, which will enrich the definition of norm conflicts and thus the detection mechanisms.

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