

Norm Contextualization

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Abstract. Agents interact with each other within a set of norms, which is expressed at different levels of abstraction that capture different contexts and operationalizations. Current normative frameworks deal with norm operationalization, yet few consider the contextual aspects of norms. Moreover, most frameworks are based on the independent evaluations of norms, which makes it difficult to evaluate interrelated effects of different norms and contexts. In this paper, we propose *norm nets* as a formalism to capture the structure of contextualized norm sets. This formalism will enable (1) the analysis of interrelations between norms, (2) the contextualization of normative statements, and (3) the verification of properties of related norms. We apply this framework to a case study taken from the domain of international trade.

1 Introduction

Open regulated Multi-Agent Systems (MAS) assume that agents are subject to norms (explicit or implicit) that regulate their behavior. A large number of research in normative agent systems focuses on how agents can decide whether to comply with norms (e.g., [12, 6, 8]). Another research area concerns consistency aspects of the normative structure in MAS (e.g., [9, 18, 14]). However, the traditional way of organizing norms does not emphasize their application environments or contexts at a large scale, which is very important in nowadays' business operations. For example, in the domain of international trade, different regulations would be applied if an importer imports the same kind of goods from different countries. The changes will result in cost if the importer could not follow the right set of regulations according to its situation. Moreover, focusing on operational aspects of norms makes it difficult to manage the huge amount of interrelated regulations at the fine-grained level.

In order to explore the interdependencies between norms and their application environments, this paper proposes an approach to represent and analyze sets of norms that takes into consideration both the interrelationships between different norms and the context of their application. This will reinforce the structure of relations between norms. More importantly, the explicit representation of institutional contexts on norms facilitates a contextual refinement normative structure, which supports norm design at multiple levels of abstraction. Our approach is different from those based on deontic reasoning, as we do not aim at identifying the deontic consequences of actions. Instead, we try to detail how

norms can be abstracted from reality and organized in a structured way to facilitate contextualization and compliance checking.

To illustrate our proposal, we show a scenario in the domain of international trade in which a trading network may include a variety of entities (e.g., software, organizations and people) that are largely autonomous, geographically distributed, and heterogeneous in terms of their operating environment, culture, social capital, and goals. In this domain, agents represent real interests and real entities, i.e., different agents have different owners, goals, interests, and preconditions for collaboration. For example, importers are motivated by profit and quality of products, while customs authorities are motivated by safety and security concerns. At any given moment, most agents will be conditioned by different regulations and norms, originating from different institutional contexts.

In general, our contributions are three-fold. First, we use *context* to organize norms in such a way that the interrelationships between norms and their application environments are structured at multiple abstraction levels. Second, we formalize a methodology of practicing contextualization, with which designers can easily build up their own context-aware normative models. Third, in order to ground the operational aspects of our framework, we design a mapping method which translates models of our framework to Colored Petri Nets (CPNs) that can be used for checking consistency of the designed models.

The rest of this paper is organized as follows. In the next section, we present a simplified scenario from the domain of international trade that will be used throughout the paper. In section 3, we introduce a norm net model, which is further extended to including refinement of contexts in section 4. Section 5 present the mapping from norm nets into CPNs. The mainstream studies are briefly discussed in Section 6. Finally, we conclude our work and raise directions for future work in section 7.

2 Scenario

In this section, we introduce a specific scenario in the field of international trade concerning the issues of *origin of goods* in importing and exporting under EU's regulation [1]. This scenario is used throughout the paper to explain our proposal.

Origin is the "economic" nationality of goods in international trade, which is generally required to be indicated in the export/import documents and governmental submissions when transporting goods from one country to another. This is checked in different ways. For example, certificates have to be presented when importing goods from a certain country. Such certificates usually contain the country of origin, the national goods code, etc. These should match the information that is listed on the invoice and the packing list. According to the characteristics of the trading goods, there are two types of origin: *non-preferential origin* and *preferential origin*. Regulations for non-preferential origin are used for all kinds of commercial policy measures such as anti-dumping duties, countervailing duties, trade embargoes, safeguard and retaliation measures, quantitative restrictions, but also for some tariff quotas, trade statistics, public tenders, and

origin marking etc. In addition, the EU’s export refunds in the framework of the Common Agricultural Policy are often based on non-preferential origin. Preferential origin is conferred on goods from particular countries, which have fulfilled given criteria. In order to obtain preferential origin, it is generally required that the goods be wholly obtained or have undergone specific processing activities. Preferential origin confers certain tariff benefits (entry at a reduced or zero rate of duty) on goods traded between countries which have agreed such an arrangement or where one side has granted it autonomously.

3 Normative Structure

Usually, norms are perceived as a set of dos and don’ts. For example, in sociology, a norm is considered as a rule or standard of behavior accepted by members within a society or group¹. In economics, a norm is a model of what should exist or be followed, or an average of what currently does exist in some context, such as an average salary among the members of a large group [7]. Formalized by E. Ostrom [16], a norm is defined in the ADICO syntax which describes who (Attribute) is obliged/forbidden/permitted (Deontic) to do or achieve what (aIm), when and where (Condition), otherwise (Or else) leading to consequences of violation.

To reflect the reality, many MAS variants tried to incorporate norms as a formal specification of deontic statements that aims at regulating the behavior of software agents and the interactions among them [2, 11, 12], which focus more on the operational level. While, the ADICO syntax is a natural expression of norms that (1) provides a clear description of opportunities and constraints that create expectations about actors’ behavior, and (2) makes it intuitive for the actors to understand their dos and don’ts. Therefore, we follow the ADICO syntax with adaptation to a MAS-integrable definition of norm, as shown in Definition 1.

Definition 1 (norm). A norm is defined as a tuple $n = (role, deontic, action, condition)$ such that:

- *role* indicates the organizational position to whom the norm applies;
- *deontic* is one of the three modal verbs “may” (Permitted), “must/should” (Obliged) and “must not/should not” (Forbidden);
- *action* specifies the particular action to which the deontic is assigned;
- *condition* describes when and where the norm holds.

If a norm does not specify a particular role or condition, the default value is for all participants, or at all times and in all places covered by that norm. The building blocks of our norm definition are expressed using lowercase (with or without subscripts). Corresponding expressions using uppercase indicate sets of a particular element, e.g., *ROLE* indicates a set of roles such that $role \in ROLE$.

¹ cf. Encyclopedia Britannica: <http://www.britannica.com/>

Norms (in particular, obligations and prohibitions) may have corresponding sanctions when the norms are violated. Sanctions are norms which will be triggered when violations are detected. Besides, the norms defined in an institution are not independent of each other. To model the possible relationships between norms, we introduce three logical operators *AND*, *OR*, and *OE* (representing Or else). The followings are examples of norm relationships taken from the scenario introduced in section 2.

- *AND*(n_1, n_2): both norms should be met.
 - (**ex1**) (n_1) [*role*: The customs authorities] [*deontic*: should] [*action*: grant to the approved exporter a customs authorization number]. *AND* (n_2) [*role*: The customs authorities] [*deontic*: should] [*action*: monitor the use of the authorization by the approved exporter].
- *OR* (n_1, n_2): choice between the two norms.
 - (**ex2**) (n_1), (n_2) [*role*: The customs authorities] [*deontic*: may] [*action*: exceptionally issue a certificate of origin] (n_1) [*condition*: after exportation of the products to which it relates, if the certificate of origin was not issued at the time of exportation because of errors]; *OR* (n_2) [*condition*: after exportation of the products to which it relates, if it is demonstrated to the satisfaction of the competent governmental authorities that a certificate of origin was issued but was not accepted at importation for technical reasons].
- *OE* (n_1, n_2) indicates the two norms are exclusive and conditional (only when n_1 is violated can n_2 be met).
 - (**ex3**) (n_1) [*role*: The approved exporter who makes frequent shipments of products originating in the Community] [*deontic*: should] [*action*: offers all guarantees necessary to verify the originating status of the products], [*condition*: irrespective of the value of the products concerned]. *OE* (n_2) [*role*: The customs authorities] [*deontic*: should] [*action*: withdraw the authorization] [*condition*: at any time where the approved exporter no longer offers the guarantees].

Furthermore, norms heavily depend on the institutional environments in which they are applied. This requires an explicit representation of *contexts* in normative structures that capture all the situational information [19] regarding what norms are involved. This paper does not focus on how to model contexts but explores an effective way of using contexts to organize norms. Therefore, we only give an abstract definition of context as follows.

Definition 2 (context). A context c is a set of states defined by predicates concerning aspects such as individuality, time, location, action, relations.

Note that the condition component of a single norm only indicates a local prerequisite of when and where the norm applies, e.g., (importers should submit importing declaration) [*condition*: before goods arrive at the EU boarder] is a specific description of when and where this norm holds, while a context characterizes the situation in which a set of interrelated norms apply and covers

situational information from a broader perspective, e.g., [*context*: preferential origin] characterizes the situation in which norms concerning beneficial treatments for certain countries are applied.

Putting all these together, we formalize a definition of *norm net* that not only represents the interrelationships between norms but also reflects their application environments.

Definition 3 (Norm Net). A Norm Net $NN = (c, NS)$, where

- c indicates the context of the norm net, and
- $NS = n$, or $NS = AND(NS_i, NS_j)$, or $NS = OR(NS_i, NS_j)$, or $NS = OE(NS_i, NS_j)$ where n is a norm, NS_i , NS_j , and NS are norm sets.

Each norm net is associated with an institutional context which describes all the situational elements that influence a normative structure. Making the context explicit enables actors to control the evolution of the norm net, to accommodate compliance and resolution of conflicts at higher-level views. A norm set NS can be a single norm or a nested structure composed of norms, which are connected by the three operators AND , OR , and OE in a certain context. The norms and their sanctions are exclusive and conditional, i.e., one either conforms to the norms or accepts the sanctions when violating the norms. This is reflected by the semantics of OE operator. (ex3) shows an example of this situation where an obligation is connected with its sanction.

Figure 1 shows a graphical construction of a norm net $NN_1 = (c_1, NS_1)$, represented as an oval. NS_1 , represented as a rectangle, is composed of two norm sets NS_2 and NS_3 connected by AND . Similarly, NS_2 is another AND connection of two sub norm sets NS_4 and NS_5 while NS_3 is an OR connection of two sub norm sets NS_6 and NS_7 . Connected by an OE , NS_8 with NS_9 as the consequence of not following NS_8 build up NS_4 . Specifically, we use dashed lines to indicate the consequence NS_9 . As can be seen, the proposed framework enables a clear representation of the relationships between norms in a specific context.

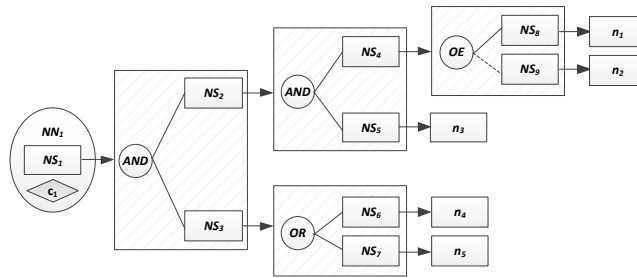


Fig. 1. An example of Norm Net.

4 Contextualization

Laws and regulations are a system of textual rules and guidelines that are enforced through social institutions to govern behavior. They are specified as a normative structure, which describes the expectations and boundaries for agent behavior. We have already presented the representation of norms using *norm net* in Definition 2 to capture the declarative meaning of the laws/regulations and also the relations between them. However, in real world domains, norms are not specified at a single level of abstraction. Usually, laws/regulations are first issued at a higher abstraction level stating the dos, don'ts and sanctions to regulate actors' behavior. Based on this abstract set of norms, elaboration will be conducted according to the specific characteristics and requirements of different situations, i.e. their application environments, which results into sets of contextual norms. This elaboration process facilitates detailed explanation of abstract norms in a concrete implementing environment. That is, the components (role, action, condition) in a norm are specified into a new norm net with more specific components and relationships between the norms.

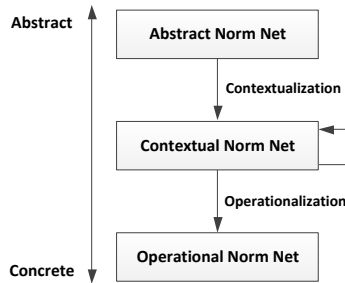


Fig. 2. Contextualization and operationalization

Our approach depicts three modeling layers of norms from abstract statements to concrete operations as shown in Figure 2. It starts from an abstract norm net which describes the expectations and boundaries for agent behavior in general. At this layer, specification of the norms is abstract and assumed to be stable throughout the life cycle of systems. The second layer uses contexts to organize the related norms in different application environments derived from the abstract norm net. That is, the abstract norm net refers to a set of contextual norm nets which give more specific information on the roles, actions, conditions and the relations between the elaborated norms. Moreover, a contextual norm net can again refer to sets of contextual norm nets in a recursive manner, which enables a flexible normative structure and facilitates norm designing at different abstraction levels. In this way, the contexts of these norm nets establish a refinement relation captured in Definition 4.

Definition 4 (context refinement relation). A context c' refines a context c , denoted as $c' \preceq c$ iff $c' \subseteq c$ when the ontologies of c' and c are unified.

Note that in a context refinement relation $c' \preceq c$, the ontology used in c' may be more concrete than that in c (e.g., where in c one may talk about *vehicles* while in c' one may talk about *cars*). The unification of contexts is done via “counts-as” [3, 7].

Given this context refinement relation, norm nets are connected through contextualization defined in Definition 5.

Definition 5 (contextualization). A norm net $NN' = (c', NS')$ is a contextualization of another norm net $NN = (c, NS)$, denoted as $NN' \trianglelefteq NN$ iff $c' \preceq c$.

Definition 4 and 5 are reflections of the laws/regulations in practice. In this sense, contextual norm nets describe what properties should the concepts have from the specification of the abstract norm net to the refined contexts. For example, whether a document should be considered as a required certificate in international trade depends on the context in which the concept of *certificate* is used. A required certificate for importing fruit from China to the EU might not count as a required certificate for importing textile.

In general, a norm net can have multiple contextualizations with respect to different contexts while different norm nets may be referred to in one contextualization. Moreover, there is no clear boundary between two contexts, i.e., the contexts of different norm nets may overlap, e.g., a context of the regulations for importing goods from Asia and another context of the regulations for importing textile products.

Finally, at the third layer, based on the contextual norm nets which contain enough information of the dos and don'ts in a specific situation, the norms will be extended with operational aspects to capture the operational meaning of the norms such as how the violation is detected (detection mechanism), and what can be done by the institution to repair the violation and minimize the negative influence[2]. In this paper, we mainly focus on the process from abstract norm nets to contextual norm nets and only give some basic ideas on the operational norm nets. The detailed operational norm nets are considered as future work.

Continuing with the scenario, Figure 3 shows how the normative structure described in the scenario is built into a set of norm nets in a hierarchy from general to specific through contextualization, which also results in a hierarchical structure of contexts. At the top level, the abstract norm net NN_1 specifies the regulations applied in the context of “origin of goods in the EU” marked as c_1 . The norms at this level consist of coarser-grained components and have a broader view of the domain. Then according to the differences and specific requirements in the two sub contexts “non-preferential origin in the EU” and “preferential origin in the EU” marked as c_{11} and c_{12} , NN_1 refers to two contextual norm nets NN_{11} and NN_{12} whose contexts do not overlap in this case. Furthermore, with the refinement of c_{11} to the context “certain agricultural products subject to special import arrangements in the EU” marked as c_{111} , the norm net NN_{11}

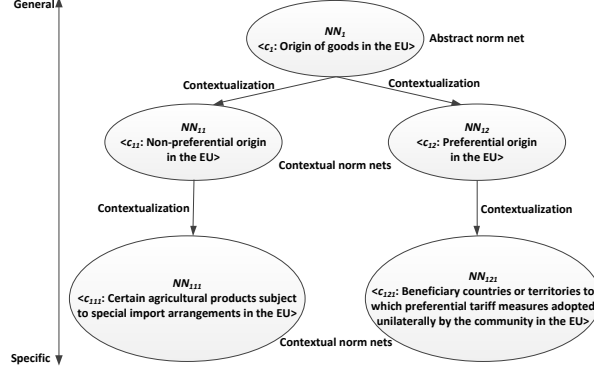


Fig. 3. Contextualization in the scenario.

is further contextualized into NN_{111} . Similarly for the regulations of the preferential origin in EU, more specific norms are presented in the context “beneficiary countries or territories to which preferential tariff measures adopted unilaterally by the community in the EU” marked as c_{121} .

This norm refinement relation through contextualization is not only a natural reflection of how norms are evolved in real life but also makes it easier for actors to recognize their dos and don’ts according to their runtime environments. Moreover, norm nets are distributed into well-defined reusable components and enable hiding of details in a consistent way.

Based on the normative structure shown in Figure 3 and the practical regulations in the EU, we illustrate the contents of the norm nets abstracted from the scenario, which has been partially shown as *ex1*, *ex2*, *ex3* in Section 3. However, due to space limitations, we can only present a small part for explanation.

$NN_1 = (c_1, NS_1)$ where

- $c_1 =$ “origin of goods in the EU”,
- $NS_1 = AND(AND(n_1, n_2), OE(n_3, n_4))$, where
 - n_1 : [role: Exporters] [deontic: should] [action: apply for certificate of origin] [condition: when exporting goods to the EU].
 - n_2 : [role: The customs authorities] [deontic: should] [action: issue certificate of origin to the qualified applicants].
 - n_3 : [role: Importers] [deontic: must] [action: present Customs with a specific origin documents] [condition: at the moment of import].
 - n_4 : [role: The customs authorities] [deontic: should] [action: reject the import] [condition: when the origin documents cannot be presented].

$NN_{11} = (c_{11}, NS_{11})$ where

- $c_{11} =$ “non-preferential origin in the EU”,
- $NS_{11} = OE(AND(AND(n_{a1}, n_{a2}), OR(n_{a3}, n_{a4})), n_{a5})$, where

- n_{a1} : [*role*: The certificate of origin] [*deontic*: should] [*action*: measure 210×297 mm].
- n_{a2} : [*role*: The certificate of origin] [*deontic*: should] [*action*: allow a tolerance of up to minus 5 mm or plus 8 mm in the length].
- n_{a3} : [*role*: The certificate of origin] [*deontic*: should] [*action*: be printed in one or more of the official languages of the Community],
- n_{a4} : [*role*: The certificate of origin] [*deontic*: should] [*action*: be printed in any other language] [*condition*: depending on the practice and requirements of trade].
- n_{a5} : [*role*: The certificate of origin] [*deontic*: should not] [*action*: be approved] [*condition*: when it is not in the prescribed format].

$NN_{12} = (c_{12}, NS_{12})$ where

- c_{12} = “preferential origin in the EU”,
- $NS_{12} = AND(AND(n_{b1}, ex1), AND(ex2, ex3))$, where
 - n_{b1} : [*role*: The competent governmental authorities of the beneficiary country] [*deontic*: should] [*action*: ensure that certificates and applications are duly completed].

$NN_{111} = (c_{111}, NS_{111})$ where

- c_{111} = “certain agricultural products subject to special import arrangements in the EU”,
- $NS_{111} = OE(AND(AND(n_{a1}, n_{a2}), n_{a3}), n_{a5})$

From the description above, we can see that the norms in NN_1 only give a general idea about the regulations concerning the origin of goods in the EU. While in NN_{11} and NN_{12} , more specific norms are given in terms of descriptions about roles, actions and conditions such as the format of certificate of origin, the expected behavior of the approved exporter and under which conditions the customs should withdraw the authorization. Specifically, we can find the similarities and differences between the norms in NS_{11} and NS_{111} , which indicate that contextualization may not only add detailed information but also make changes.

5 Verification

To enable consistency and compliance checking of norm nets, we introduce a verification based on the mapping to the Colored Petri Nets.

5.1 Colored Petri Nets

CPN is a graphical language for modeling and validating distributed systems or systems in which concurrency plays a major role [13]. Not only do CPNs model the states of a system and the events that change the system from one state to another, but also replace tokens by data objects of programming languages.

Definition 6 (CPN). A CPN is defined as a tuple $(\Sigma, P, T, A, N, C, G, E, I)$ where: Σ is a finite set of non-empty types, also called color sets; P is a finite set of places; T is a finite set of transitions; A is a finite set of arcs; $P \cap T = P \cap A = T \cap A = \Phi$; N is a node function defined from A into $P \times T \cup T \times P$; C is a color function defined from P into Σ ; G is a guard function defined on T ; E is an arc expression defined on A ; I is an initialization function defined on P .

5.2 Mapping to CPNs

Norm Mapping The mapping makes use of correspondences between the components in norms and the elements in CPNs.

$$ROLE \rightarrow \Sigma, \quad ACTION \rightarrow T, \quad CONDITION \rightarrow G$$

Roles in norms are mapped to the color sets in CPNs so that colored tokens correspond to role enacting agents in MAS. Actions in norms are mapped to the transitions in CPNs while conditions in norms are mapped to the guard functions in CPNs. Thus, only when the condition of a norm holds can the corresponding action specified in the norm be permitted, obliged or forbidden. Places in CPNs indicate the states of the role enacting agents, i.e., their behavior status in terms of norms. For the three deontic representations in norms, we use different building blocks with special places and transitions shown in Figure 4.

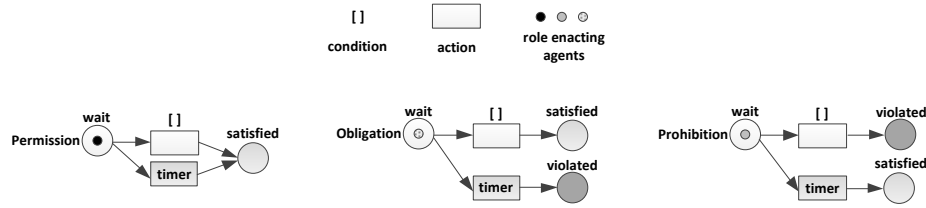


Fig. 4. Basic components in norms mapping to CPN.

The CPN of a norm starts with a place of *wait* which indicates the activation of the norm and has a color set indicating the role in its norm. Once the condition of the norm is satisfied, the agents in that place are able to perform the specified action. Permissions specify what may be done and won't lead to sanctions. Therefore, no matter the actions specified in the permissions are performed or not, the final state of permissions will be *satisfied*. Obligations and prohibitions specify the actions that must and must not be done otherwise sanctions may be imposed, in the sense that the final state will either be *satisfied* or *violated*.

However, we cannot determine that someone does not follow a norm by simply saying that the action specified in the norm is not performed. In practice, whether a norm is satisfied or violated is normally determined within a certain period of

time, e.g., the life cycle of an interaction scene. That is, the state of the norm is changed either because of the action specified in the norm is performed or the norm expires for this time. For this purpose, we adopt a special kind of transitions called *timer* that can be used to change the state of the norm when it expires and at the same time the action specified in the norm is not performed.

For permissions, both the action of the norm and the timer are connected to the place of *satisfied*, indicating that there are two ways to this state: either the permitted action is performed by the agent or the timer is fired (i.e., the permitted action has not been performed when time is up).

Obligations indicate that agents should perform the specified actions and if this is the case, the token moves to the place of *satisfied*. But when the obliged action in the norm is not performed and the timer is fired, the token moves to the place of *violated*.

Prohibitions are a reverse logic of obligations. If the forbidden actions are performed, the corresponding tokens will move to the place of *violated*. But when the forbidden actions are not performed during the specified period of time, the corresponding tokens will move to the place of *satisfied*.

The description above only captures the mapping of individual norms. For the norm nets which require a mechanism of representing different relationships between norms, we use extra elements for the mapping.

Norm Net Mapping As an example, we model the norm net NN_1 of the scenario as shown in Figure 5. When the corresponding CPN is instantiated, all the tokens, i.e., all role enacting agents, are in the place of *input*. There are three role enacting agents in this example, a Chinese company enacting the role of exporter, a Dutch company enacting the role of importer, and the Dutch Customs enacting the role of customs. Then the *initialization* transition will be unconditionally triggered and all the tokens are moved to the following places of *wait* according to the arc expressions.

Each place of *wait* specifies the color sets (role types) from its corresponding norm in the norm net and the arc expression related to the place selects the agents that match the color sets based on their roles. For example, the role of $norm_1$ is *exporter*. Therefore, the color set for the wait place in $norm_1$ and the related arc expression both try to match *exporter*, indicating that only agents enacting the role of exporter can move into this part of the net. Note that a token is only a reference to a role enacting agent and tokens representing the same agent can be in multiple places simultaneously, in the sense that the agent relates to a set of different norms. For example, the tokens representing the Dutch Customs are distributed to the places of both $norm_2$ and $norm_4$ since both norms involves the Dutch Customs. When the condition of a norm is satisfied and the agent in the place of *wait* performed the related action, the corresponding token will move to the state of *satisfied* or *violated* according to the types of norms.

The *AND* (*OR*) relation between norms is mapped to *AND* transitions (*OR* transitions) in CPNs. However, for norms connected by *OE* operators, a special structure is used to indicate the exclusive and conditional relation between them.

For example, the *violated* place of $norm_3$ and an additional *wait* place are joined at an *AND* transition which is then connected to the *wait* place of $norm_4$, indicating that only when $norm_3$ is violated can $norm_4$ be triggered. In this way, the “conditional” part of the relation between two norms connected by an *OE* operator is captured. For the “exclusive” part of the relation, we use *XOR* transition to connect the two norms, indicating that only one of the two norms can be satisfied. For instance, after the importer in the Netherlands presents the Dutch Customs with the specific origin documents, the state of $norm_3$ changes to *satisfied* while $norm_4$ has no chance to be triggered. However, when the action in $norm_3$ is not performed before the required date, the state of $norm_3$ changes to *violated* and at the same time $norm_4$ is imposed as a sanction. Since the example is only a part of the EU regulations, the sanction to the violations of the norms in Figure 5 is not fully pictured. Finally, the corresponding CPN ends with a token at the *output* place which indicates the compliance of an instance of a norm net.

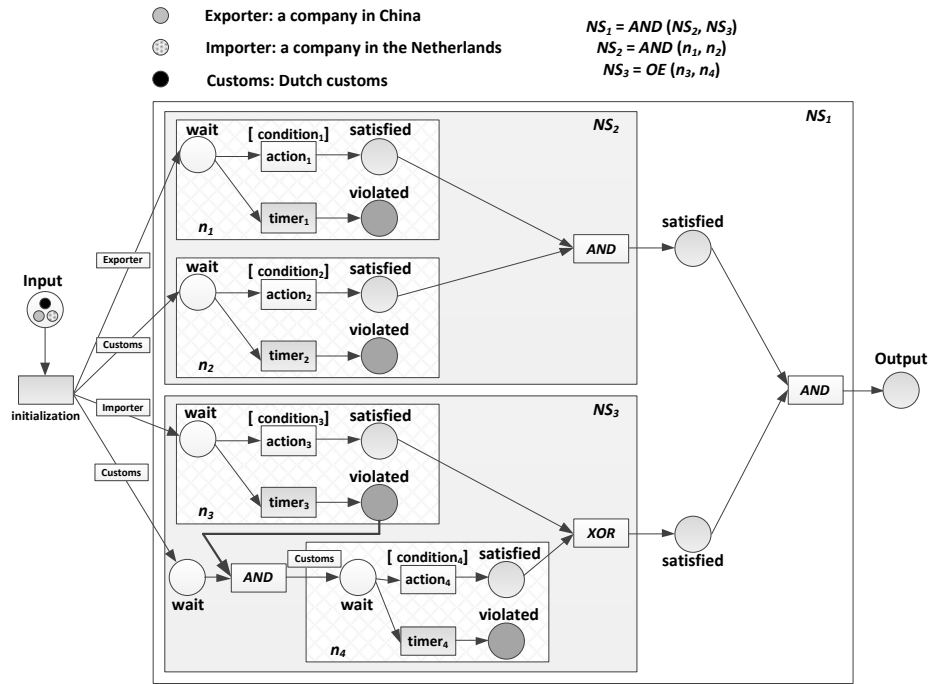


Fig. 5. Norm nets mapping to CPN.

Note that mappings illustrated in this section is currently dedicated to a single norm net within a specific context. The mapping of hierarchical contextual norm nets is left as our future work.

5.3 Verification properties

Based on the norm net mapping, the properties of CPNs can be linked to our normative structure, which facilitates consistency and compliance checking on norms.

- **Reachability** indicates that, given a set of norms organized in a norm net, whether there is a possible way to comply with those norms, i.e., a path through the norm net (CPN) that is norm compliant at all steps. This property can be used to identify the inconsistencies between the norms.
- **Liveness** indicates that, given a set of norms organized in a norm net, whether some of the norms are impossible to comply with, i.e., no reachable path through the norm net (CPN) that includes those norms. This property can be used to identify the norms that are redundant or wrongly positioned.

Therefore, given a set of norms in MAS, we can first model them using our normative structure, and then map the resulted norm nets to CPNs by which we can perform compliance checking on the norms.

6 Related Work

There is a growing interest in the research of norms to regulate and coordinate agents' behavior in MAS. Fruitful results have been achieved from different perspectives such as norm compliance, norm conflict resolution, norm contextualization, etc. [15] presented a formal normative framework intended to be used by agents that reason about why norms must be adopted and complied with, in which the relations between norms are represented as interlocking norms. The framework proposes that norms are applied in particular circumstances or within a specific context, but without considering the refinement relation of contexts, it is at a single level of analysis on norms. Munindar P. Singh proposed to use commitments to capture normative concepts in MAS and define norms as a tuple including subject, object, context, antecedent and consequent [17]. This approach provides a natural way to characterize the bounds of autonomy and interdependence between agents, but the contextual aspects of norms are not considered.

In [12], a formalism called Process Compliance Language (PCL) is proposed for the expression of violation conditions and the reparation obligations which is very important for formalizing norms to determine the compliance of a process with the relevant norms. PCL enables to represent exceptions as well as to capture violations and the obligations resulting from the violations, but it does not take a broader view on norm sets where relationships other than reparation of violation exist between norms. In order to regulate the behavior of agents in open and regulated MAS in a distributed manner, [11] presents a normative structure based on the propagation of normative positions as consequences of agents' actions and provides a mapping into Colored Petri Nets for conflict resolution.

The normative structure models norms in normative scenes and builds connections between the scenes by transition rules, which focuses more on the causal relations between norms other than conjunction, disjunction and implication.

Since norms are usually specified at different levels of abstraction, there is a need to relate the abstract concepts used in the specification to concrete ones used in practice, which necessitates the research on norm contextualization. In [3], counts-as statements are used to provide the concrete concepts their institutional and organizational meaning according to different contexts and enable agents to reason about norm compliance by the context they are in. A context-based institutional normative environment is proposed in [5], which enables the use of norms within a hierarchical context structure and norm inheritance as a mechanism to facilitate contract establishment. Another perspective on contextual normative structure, presented in [10], models norms of MAS according to four levels of abstraction: Environment, Organization, Role and Interaction contexts. However, these contextual normative frameworks all concentrate on the effects of individual norms but ignore their relations.

Due to the changing nature of norms, conflicts or inconsistencies may occur. To solve this problem, different approaches have been proposed such as [18], [9], [4]. Eventhough, we do not focus on checking the consistency of normative structures, but since the building blocks (norm nets) are organized in such a way that they can be mapped to CPNs, inconsistencies will be easy to identified using CPNs formal analysis methods and tools.

7 Conclusions

In this paper, we proposed a normative structure that not only captures the characteristics of a single norm but also the relationships between norms. Given that agents in MASs interact with each other to achieve certain goals, the inter-related effects of norms on their behavior are very important for both individuals and the system. Therefore, the connections between norms should be explicitly indicated in a structural way. Moreover, contexts play an important role in the construction of norms, in the sense that the application of a norm heavily depends on its institutional context and a norm may have different interpretations in different situations. To this end, the concept of norm net in this paper expresses how a set of recursive norm sets organize in a hierarchy of contexts.

Most importantly, this paper presents a norm net contextualization process that describes norms from general to specific. This enables a modular approach for building normative structures that improves both reusability and flexibility. Furthermore, following this contextualization process, actors can have a better understand of their dos and don'ts with the evolution of contextual norm nets. To verify the proposal, we map norm nets to CPNs and incorporate agents/actors as colored tokens in the analysis, which presents the state transition process of norm nets and provides a potential approach for compliance checking on norms.

In future work, the normative structure will be extended to the operational level for the implementation of norm enforcement. Furthermore, we intend to

build a complete mapping for contextual norm nets from general to specific using advanced Colored Petri Nets. That is, linking the CPNs of abstract norm nets with that of contextual norm nets in a recursive manner and reflecting the contextualization process from the whole structure. Moreover, we would be interested in implementing simulation of norm nets for compliance checking on norms on the basis of CPN analysis tools and agent based simulation techniques.

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