Norm Compliance Checking

(Extended Abstract)

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ABSTRACT

In multi-agent systems, norms are used to regulate agents' behavior so that the objectives of the systems can be realized in a predictable way. Therefore, it is important to check whether agents can comply with the norms imposed on them. However, when norms are interrelated, verification of norm compliance cannot be achieved by checking compliance of each norm separately as done traditionally. To this effect, this extended abstract introduces an approach which first models a set of interrelated norms as *Norm Nets*, and then map them to *Colored Petri Nets* (CPNs), by which compliance checking of both individual agents' behavior and the collective behavior of the system can be performed automatically. With CPNs, it is also possible to identify under which conditions the norms can be complied with.

Categories and Subject Descriptors

I.2.11 [**Artificial Intelligence**]: Distributed Artificial Intelligence—*Languages and structures*; I.2.11 [**Artificial Intelligence**]: Distributed Artificial Intelligence—*Multiagent systems*

General Terms

Design, Theory, Verification

Keywords

Norm Compliance, Multi-agent Systems, Colored Petri Nets

1. INTRODUCTION

Norms like obligations, permissions and prohibitions have been proposed to deal with coordination and security issues in multi-agent systems. They specify the (un)desired behavior for agents participating in a system so that the overall objective of the system can be ensured. However, on the one hand, agents might violate the norms and cause unwanted results to the system, and on the other hand, the design of the norms itself might have inconsistencies. In this sense, not only do we need to check norm compliance of agents' behavior but also verify the consistencies of the norms specified in a system.

In this extended abstract, we use the normative structure *Norm Nets* [3] with the intention of compliance checking of agents' behavior against a set of norms specified in a regulated system. A Norm Net models a set of norms through an elaboration of single norms and the interrelations between the norms. We propose a mapping from Norm Nets to Colored Petri Nets (CPNs) which not only gives operational semantics to Norm Nets but also facilitates norm compliance checking by making use of standard features and tools of CPNs. Furthermore, the consistency verification of a set of norms can be achieved by using the state space analysis techniques of CPNs to check whether there are paths in the CPN model of a Norm Net that are norm compliant at all steps.

2. NORM NETS

Targeting sets of norms, Norm Nets not only have a representation of singles norms, but more importantly capture the interrelations between the norms. The building blocks of Norm Nets are *role-actions pairs* which describe the actions available for role enacting agents. Constructed from a set of role-action pairs, a single norm defines that a combination of role and action is permitted/obliged/forbidden before a *deadline* given a *precondition*. The precondition and deadline of a norm can be empty, indicating that the norm holds in all cases and at all times.

Based on the model of single norms, Norm Nets represent two kinds of interrelations between norms. One is that the norms might contain similar components, e.g., pertaining to the same role, constraining the same action, under the same condition, with the same deadline. The other concerns the compliance states of norms, i.e., whether a norm is complied with will influence the state of other norms. A typical example of the latter is between a norm and its sanction, indicating that only when the norm is violated its sanction can be initiated.

The first kind of interrelation is reflected in the construction of a Norm Net through a common set of role-action pairs. That is, if two norms have shared components, the same role-action pairs will be found in their models. The

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second kind of interrelation is captured by introducing three logical operators between two norms, i.e., *AND*, *OR*, and *OE*. *AND* indicates that both norms should be complied with. *OR* indicates a choice between the two norms. *OE* indicates that the two norms are exclusive and conditional, i.e., only when the first norm is violated can the second norm be activated. Putting all these together, a Norm Net is a nested structure composed of norms connected by *AND*, *OR*, and *OE*.

3. MAPPING TO CPNS

CPNs is a graphical yet formal language for modeling and validating concurrent systems [2]. A CPN is a network of places connected by transitions. A transition can fire if all its input places contain a token and the constraints on the transition are satisfied. By firing, the transition consumes the tokens from the input places and deposits a token in all output places. Tokens in CPNs are assigned "colors", which means that they have a data type and thus can be distinguished and changed.

The basic elements of a norm are *roles* and *actions* which respectively map to the *colors* and *transitions* in CPNs. Each place in a CPN is assigned a specific color, indicating that only agents enacting specific roles (represented as colored tokens) can reside in. Each transition in a CPN represents an action that the role enacting agents may perform. The connections between the places and transitions indicate which actions are relevant to which roles and their temporal relations specified in a norm.

In a CPN model, the places are used to represent the state of the modeled system. Each place can hold one or more tokens, and each token has a data value attached to it. It is the number of tokens and their data values on the individual places that together represent the state of the system, which is called a *marking* of the CPN model. The transitions are used to represent the events that can occur in the system. Reflected in normative systems, the events are the actions performed by role enacting agents which will trigger state transitions of the systems. Therefore, we use *markings* of CPNs to represent states of the normative systems and *the firing of transitions* in CPNs to represent the occurrence of events in normative systems.

For each norm, two places are added in its CPN model, respectively indicating the complied and violated state of the norm. The difference between an obligation and a prohibition is that the transition of the governed action will lead to a complied place for an obligation, while lead to a violated place for a prohibition. The deadline works the other way around. As we have stated, norms are interrelated with each other in two ways. Regarding shared components, the CPN model of the norms will partially have the same constructions. For compliance relations, the complied and violated places of the norms are connected by different CPN patterns according to the type of the relation (*AND*, *OR*, and *OE*). Whether a Norm Net is complied with is derived from that of all the norms that constitute the Norm Net according to their compliance relations. Similarly for a Norm Net, there are two places that respectively indicate its complied and violated state. As a result, when a norm or Norm Net is not violated, there are no tokens in the corresponding violated place, as such we can easily detect whether the norm or Norm Net is complied with.

4. COMPLIANCE CHECKING

In a normative system, agents enact roles and perform actions, leading to sequences of events. For each event, there may be several transitions being triggered in the CPN model of the normative system, indicating that the event is regulated by several norms in the system. If a transition fires with the occurrence of an event, the state of the normative system will transit to another marking accordingly. Given sequences of events, we can trace the changes of the marking of the CPN model to check whether the Norm Net is complied with. More specifically, it is the change of the marking of the violated place of the Norm Net that reflects whether the Norm Net is in the complied state.

Furthermore, it is necessary to know the possible ways that can achieve full compliance in a normative system. This is realized by traversing the state space of the CPN model and find those paths that are norm compliant at all steps, i.e., no violation has been detected in the violated places of the Norm Net. If we cannot find such a way of achieving full compliance in a Norm Net, it means that there are inconsistencies in the design of the normative system.

To evaluate our approach, we use the CPN tools [1] to show how compliance checking of Norm Nets is realized. There are three steps: (1) generate the CPN model of a Norm Net, (2) calculate the state space of the CPN model, and (3) make compliance queries in the state space by either providing a sequence of events or two different markings. With a sequence of events, we can check whether the Norm Net is complied with subject to each event. With two different markings, we can check whether there are paths between them that are norm compliant at all steps.

5. CONCLUSIONS

In this extended abstract, we identify the correspondences between Norm Nets and CPNs, and propose a mapping between the two formalisms. With CPNs, compliance checking of interrelated norms is facilitated by the CPN tools. From the perspective of norm representation, Norm Nets provide a modular way of modeling norms and their interrelations, which capture the regulation of both individual agents' behavior and the collective behavior of the system. From the perspective of norm verification, Norm Nets serve as a basis for compliance checking in normative systems, and the mapping to CPNs not only gives operational semantics to Norm Nets but also makes it possible for us to use the available analysis methods and tools of CPNs.

For future work, we intend to develop an automatic translator from Norm Nets to CPNs in a way that we can easily make use of the CPN tools to analyze the properties of normative systems. Moreover, we will make use of other properties of CPNs and explore their significance in terms of Norm Nets, such as boundedness, liveness, deadlocks.

6. REFERENCES

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