PUC

ISSN 0103-9741

Monografias em Ciência da Computação
n° 31/06

Toward a Normative Ontology for Implementing Contextual Regulations in Open MAS

Carolina Howard Felicíssimo   Carlos José Pereira de Lucena

Jean-Pierre Briot   Karin Koogan Breitman

Marco Antonio Casanova

Ricardo Choren

Departamento de Informática

PONTIFÍCIA UNIVERSIDADE CATÓLICA DO RIO DE JANEIRO

RUA MARQUÊS DE SÃO VICENTE, 225 - CEP 22453-900

RIO DE JANEIRO - BRASIL

Monografias em Ciência da Computação, No. 31/06 ISSN: 0103-9741
Editor: Prof. Carlos José Pereira de Lucena August, 2006

Toward a Normative Ontology for Implementing Contextual Regulations in Open MAS *

Carolina Howard Felicíssimo[1], Carlos José Pereira de Lucena[1], Jean-Pierre Briot[1,2], Karin Koogan Breitman[1], Marco Antonio Casanova, Ricardo Choren[3]

[1]Pontifícia Universidade Católica do Rio de Janeiro (PUC-Rio)

[2]Laboratoire d'informatique de Paris 6 (LIP6)

[3]Instituto Militar de Engenharia (SE/8 – IME)

{cfelicissimo, lucena, karin, casanova}@inf.puc-rio.br, jean-pierre.briot@lip6.fr and choren@de9.ime.eb.br

Abstract. We believe that the Semantic Web will be a huge machine-understandable open net composed of several information repositories plus intelligent cooperative entities, executing along the principles of multi-agent systems (MAS). Also, agents will be able to join and leave MAS freely, seeking to achieve their designed goals faster. In such scenario, some level of regulation is necessary. Along these lines, this paper presents our ongoing work for dynamic contextual regulations in open multi-agent systems – called DynaCROM. DynaCROM is based on a top-down modeling of contextual laws, on a normative meta-ontology for laws semantics and on a rule support for composing contextual laws. DynaCROM results in a straightforward method for regulations in open MAS, obtained with few ontology-based rules. For instance, with only 19 rules for 4 particular MAS contexts (environment, organization, role and interaction), DynaCROM permits a total of 349 customized compositions of contextual laws.

Keywords: Dynamic Contextual Regulations, Open Systems, Inference, Rules, Ontologies.

* This work has been sponsored by the Ministério de Ciência e Tecnologia da Presidência da República Federativa do Brasil

In charge for publications:

Rosane Teles Lins Castilho
Assessoria de Biblioteca, Documentação e Informação
PUC-Rio Departamento de Informática
Rua Marquês de São Vicente, 225 - Gávea
22453-900 Rio de Janeiro RJ Brasil
Tel. +55 21 3114-1516 Fax: +55 21 3114-1530
E-mail: bib-di@inf.puc-rio.br
Web site: http://bib-di.inf.puc-rio.br/techreports/

Table of Contents

1 Introduction

Following software engineering approaches for the Semantic Web (SW), we share Hendler's vision [11] stating that the SW will be a unique Web composed mainly of several small contextualized domain applications [3]. These domain applications will be, in our vision, Multi-Agent Systems (MAS) [14]. MAS have emerged as a promising approach to develop information systems that are composed of cooperative goal-oriented problem-solving entities [15], named agents. Agent-based computing is rapidly emerging as a powerful technology for the development of distributed and complex information systems.

A very dynamic, open and distributed domain (like the SW) is always subject to unanticipated events [12], caused by malicious agents that do not conform to recommendations of correct and incorrect behaviors. This risk imposes the necessity for regulatory mechanisms to prevent undesirable actions to happen, and to inspire trust for its members.

In open domains, no centralized control is feasible. Moreover, key characteristics of such domains are: agent heterogeneity, conflicting individual goals and limited trust [1]. Heterogeneity and autonomy rule out any assumption concerning the way agents are constructed and behave, meaning that an external control, dynamically created or modified, and not hard coded into agent implementations, is the only viable solution for regulations in open MAS [9].

This article focuses on the implementation level of an external control for open MAS, imperative to enable agent societies in the SW. This implementation level is based on our approach for dynamic contextual regulations in open MAS [6] – now called DynaCROM. DynaCROM uses norms to constrain agent actions and, consequently, to difficult malicious actions to happen.

Furthermore, we discuss here how to implement contextual regulations for open MAS with DynaCROM. More precisely, we describe here how to implement a regulated open MAS from a particular domain by following a top-down modeling of contextual laws, by extending (with domain concepts) and instantiating (with a set of user defined laws) a contextual normative meta-ontology, and by using rules and a rule-based inference engine for composing and deducing customized sets of contextual laws.

The remainder of this paper is organized as follows. In Section 2, DynaCROM is briefly presented. In Section 3, the implementation of a regulated open MAS with DynaCROM is explained with the help of an example. In Section 4, we compare DynaCROM with related works. Finally, in Section 5, we offer our conclusions and outline directions for future work.

2 Contextual Regulations

MAS are generally constituted by environments, organizations, agents, agent roles and interactions [16]. Environments [30] are discrete computational locations (similar to places in the physical world) that provide conditions for agents to inhabit it. Organizations [7] are social locations where groups of agents play roles, seeking to achieve their goals. Agent roles are abstractions that define a set of related tasks [26]. Agents interact with other agents, from the same or from different organizations and environments.

2.1 Motivation

Environments, organizations, agent roles and agent interactions suggest different contexts for regulations in open MAS. Contexts are implicit situational information [5] that might be used to characterize situations of participants. Modular context refinements allow a more flexible system and provide a better support for developers, while they are maintaining and evolving information.

Context-aware systems use contexts to provide relevant information and/or services to their users, where relevancy depends on the users' tasks [5]. In our definition, regulated context-aware systems use laws to provide to their users the information about the current system regulation.

Laws can be represented by norms, which should in some way influence or constrain the behavior of agents. Deliberative normative agents [4] use norm information to better adapt their behaviors, according to the current system regulation. Thus, norms should control environments, organizations, agent roles and agent interactions, defining which actions are permitted (allowed to be performed), obliged (must be performed), and prohibited (must not be performed).

Nevertheless, norms cannot be incorporated inside agent implementations because the control over their developments is not public. Moreover, regulatory mechanisms should be easy and flexible, while applying and evolving norms. Thus, we proposed in [6] an approach for dynamic contextual regulations in open MAS – now called DynaCROM. The main advantages of DynaCROM are: elucidate and consolidate user defined laws according to a top-down modeling; represent modeled laws in a meaningful way (i.e., with a common understanding) for agents; and permit dynamic changes (with different customized compositions of contextual laws) in the current system regulation, simplifying the regulation task for developers while they are evolving laws.

Figure 1 illustrates an overview of the DynaCROM process. The ontology explicitly represents regulatory contexts (by related concepts expressed in the ontology structure), and it also represents environment, organization, role and interaction laws (by instances expressed in the ontology data). Dynamic activations and deactivations of rules are used to manually specify customized compositions of contextual laws. A rule-based inference engine automatically deduces the composed contextual laws, according to the ontology, active rules and given actions, and expresses those laws into an inferred ontology.

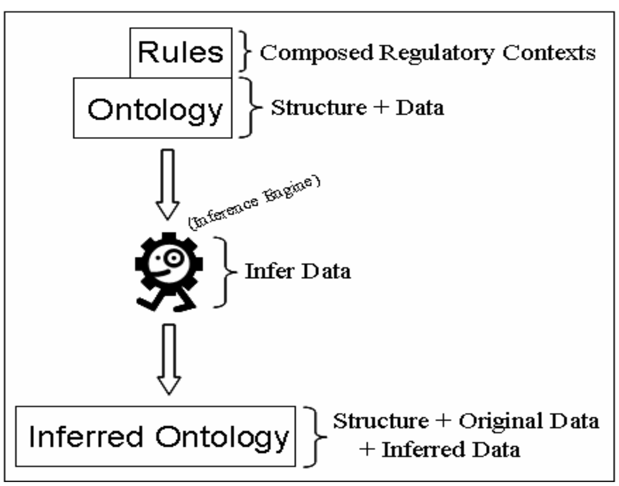

Figure 1. Implementing contextual regulations

2.2 A Top-Down Modeling of Contextual Laws

Contexts are tacitly understood by most people, but generally they are hard to elucidate. We believe that, classifying contextual laws according to a top-down modeling facilitates the developer tasks of elucidation and structuring information. However, we agree that sometimes it is difficult to classify laws according to defined contexts due their subjectivity.

Researches in context-aware applications suggest top-down architectures for contextual modeling [17]. Thus, we addressed in DynaCROM four regulatory contexts: Environment, Organization, Role and Interaction Laws. Environment Laws are applied to all agents from the regulated environment. Organization Laws are applied to all agents from the regulated organization. Role Laws are applied to all agents playing the regulated role. Interaction Laws are applied to all agents involved in the regulated interaction.

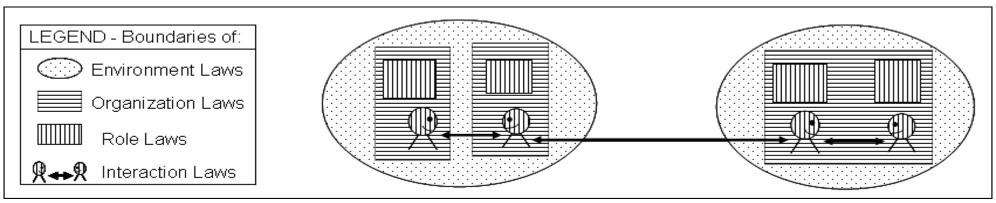

Figure 2. Interactions possibly regulated through different compositions of contextual laws

Figure 2 illustrates the boundaries of environment, organization, role and interaction laws. For instance, one agent from the environment on the right side interacts with an agent from the environment on the left side, both regulated through an interaction law. Moreover, these agents can also be regulated through customized compositions of environment, organization and/or role laws, for a more precise regulation.

DynaCROM regulatory contexts have different levels of abstraction, but they are not hierarchical. Laws from different regulatory contexts can be dynamically composed, restricting or relaxing the current enforcement of laws in regulated systems.

We believe that DynaCROM regulatory contexts are not targeted to a particular application domain, but they rather represent a minimum set for a general contextual regulation in open MAS. For more complex MAS, this set should be improved with additions and refinements of particular domain regulatory contexts.

2.3 A Contextual Normative Meta-Ontology

In DynaCROM, we consider Gruber's definition [10] stating that ontologies are conceptual models which embody shared conceptualizations of a given domain, and we also consider Bouquet et al.'s definition [2] stating that contextual ontologies are ontologies which keep their contents local (therefore, not shared with other ontologies). Moreover, we consider a contextual normative meta-ontology an ontology which has a minimum set of related meta-concepts, representing meta-regulatory contexts.

Figure 3 illustrates the DynaCROM contextual normative meta-ontology, which is composed of six related concepts. The Action concept encompasses all instances of the regulated actions. The Penalty concept encompasses all instances of the fines to be given in case norms are not fulfilled. The Norm concept encompasses all instances of norms from all regulatory contexts; however, each norm encompasses the permission, obligation or prohibition instance for its associated action and penalty. The Environment concept encompasses all instances of the regulated environments; however, each environment encompasses its associated norms and owner environment (the environment which it belongs to). The Organization concept encompasses all instances of the regulated organizations; however, each organization encompasses its associated norms, main organization (the organization which it is associated to) and environment. The Role concept encompasses all instances of the regulated roles; however, each role encompasses its associated norms and organization.

While regulating open MAS from particular domains, the DynaCROM meta-ontology should be instantiated with modeled laws and, probably, it should be extended with both domain concepts and interaction laws. Interaction laws should be implemented by following a representation pattern, from the Semantic Web Best Practices document [20], which defines that the relation object itself must be represented by a created concept that links the other concepts from the relation (i.e., reification of the relationship). In DynaCROM ontology, an interaction law should be represented by a new Norm sub-concept that links two Role concepts.

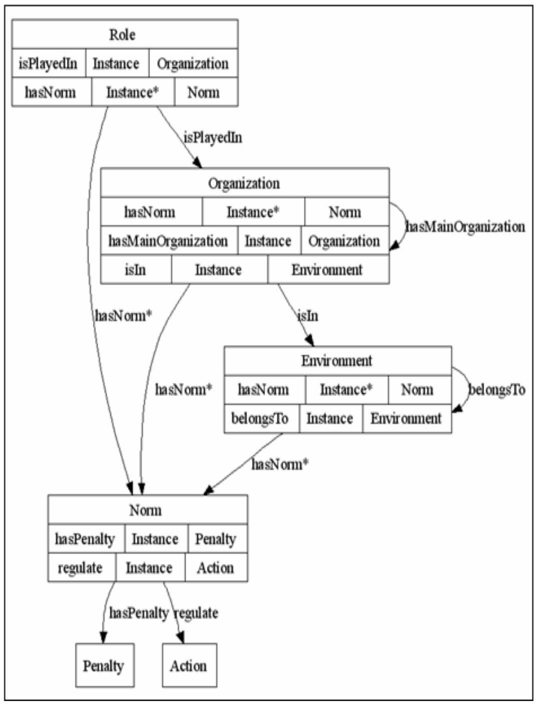

Figure 3. The DynaCROM Meta-Ontology

3 Implementing Contextual Regulations

The domain of multinational corporations is chosen to explain an implementation of contextual regulations in an open MAS with DynaCROM. A multinational corporation (organization) is an enterprise that manages production branches located in at least two countries. These branches can be in different regions across multiple continents. Corporate regulations include control all possible relationships among the many players involved.

Hpie is our created main organization and it has Hpie Cuba and Hpie Brazil as its branches. Hpie corporations have the following roles: manufacturer, supplier, distributor and customer. Hpie is in USA, which in turn is in North America; Hpie Cuba is in Cuba, which in turn is in Central America; and Hpie Brazil is in Brazil, which in turn is in South America.

3.1 Modeling Contextual Laws

Corporation laws are usually private because they are strategic for the corporation businesses. Thus, we created environment, organization, role and interaction laws based on public laws collected from several corporate Web sites. These laws were classified according to the DynaCROM top-down modeling.

1. **Examples of Environment Laws:**

   1.1. In North America, a finished good from every organization has its price increased by a percentage (dependent of the seller location) as taxes, for immediate delivery or if the deliver address is in North America.

   1.2. In USA, a finished good from every organization has its price increased by 8% as taxes, for immediate delivery or if the deliver address is in USA.

   1.3. In South America, every shipped order has its price increased by 15% as taxes, for immediate delivery or if the deliver address is outside South America.

   1.4. In USA, all negotiations have to be paid in American dollars (USD), the national currency. Negotiations outside USA have to have their values converted from USD to the national currency of the country where the buyer is.

   1.5. In Cuba, all negotiations have to be paid in Cuban pesos (CUP), the national currency. Negotiations outside Cuba have to have their values converted from CUP to the national currency of the country where the buyer is.

   1.6. In Brazil, all negotiations have to be paid in Reais (R$), the national currency. Negotiations outside Brazil have to have their values converted from R$ to the national currency of the country where the buyer is.

2. **Examples of Organization Laws:**

   2.1. In Hpie, all paid orders must have detailed receipts.

   2.2. In Hpie Cuba, every product has one year of warranty.

   2.3. In Hpie Brazil, every placed order must have a down payment of 10%.

3. **Example of Role Laws:**

   3.1. Hpie Cuba manufacturers have to provide refunds or replacements for every defective product when substantial defects cannot be fixed in four attempts.

   3.2. Hpie Cuba manufacturers have to provide, with one month, refunds or replacements for every defective product, when substantial defects cannot be fixed in four attempts.

   3.3. Hpie Brazil suppliers have to ship orders in their due dates.

   3.4. Hpie Brazil suppliers can give 5% as discount for orders paid in cash.

4. **Example of an Interaction Law:**

   4.1. Hpie Brazil suppliers have the permission to ship incomplete orders to manufacturers.

3.2 Instantiating DynaCROM Meta-Ontology

The DynaCROM meta-ontology was instantiated for the created environments, organizations and contextual laws of our example (see all in Figure 4). North America, Central America, South America, USA, Cuba and Brazil were created as instances of the

Environment concept. Hpie, Hpie Cuba and Hpie Brazil were created as instances of the Organization concept. Hpie manufacturer, supplier, distributor and customer roles were created as instances of Role sub-concepts (extending the DynaCROM meta-ontology), and were instantiated for each organization; two examples are the role instances "AHpieBrazilSupplier" from Hpie Brazil and "AHpieCubaManufacturer" from Hpie Cuba (both roles are linked by the "PermissionToShipIncompleteOrders" norm instance and the triple represents the interaction law 4.1).

Other contextual laws were also created as instances of the Norm concept and attached to their respective instances. Some examples are: the environment law 1.1 attached to North America; the environment law 1.4 attached to USA; the organization law 2.1 attached to Hpie; the organization law 2.3 attached to Hpie Brazil; and the role law 3.3 attached to the Hpie Brazil supplier. All these laws are also illustrated in Figure 4. The actions regulated by the presented laws were represented by action instances, and all these actions were associated to their respective penalties.

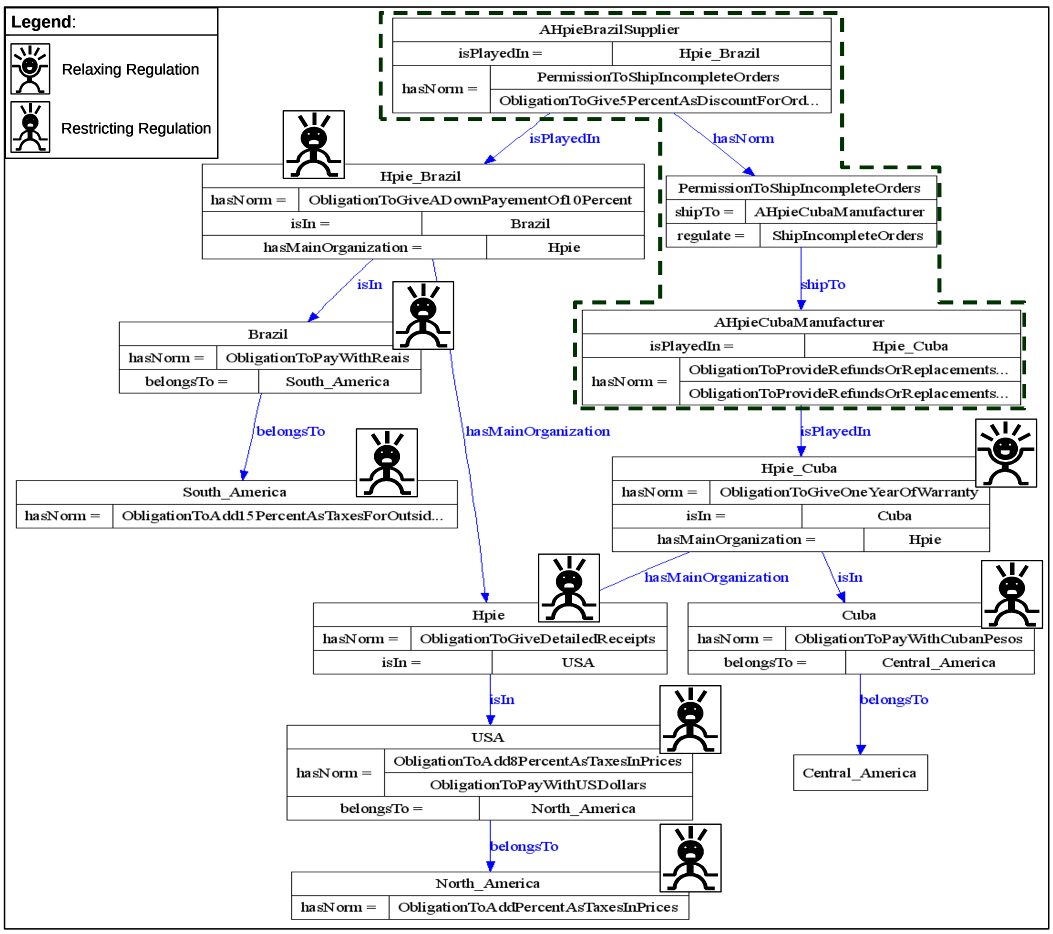

Figure 4. An example of a DynaCROM ontology instance with its four regulatory contexts

3.3 Restricting and Relaxing Contextual Laws

The main asset of organizing laws following a top-down modeling is to permit flexibility while enforcing different compositions of contextual laws. By doing so, the system regulations can be dynamically relaxed or restricted. Returning to our example, in different situations the current system regulations were relaxed and restricted by compositions of contextual laws, as illustrated with the particular icons from Figure 4.

An example where laws are relaxed is when Hpie Cuba manufacturers are also regulated by the Hpie Cuba organization law 2.2, stating that the warranty period is now limited to one year.

Examples where laws are restricted are: when the Hpie Brazil supplier is also regulated by the Hpie Brazil organization law 2.3, stating that every placed order now must have a down payment of 10%; when Hpie Brazil is also regulated by the Brazil environment law 1.6, stating that all negotiations in Brazil must be paid with Reais; when Brazil is also regulated by the South America environment law 1.3, stating that every shipped order to deliver addresses outside South America now must have its price increased by 15% as taxes; and, finally, when Hpie Brazil are also regulated by the Hpie organization law 2.1, stating that now all paid orders now must give detailed receipts.

Many others different compositions of contextual laws can be done, influencing current regulations. The compositions of contextual laws are according to the DynaCROM ontology structure, i.e. they are limited by the relations between the concepts (which represent the regulatory contexts where the laws are instantiated in).

Each environment can have its laws only composed with the laws of its owner environment, totalizing one composition of contextual laws. For instance, Brazil laws can only be composed with South America laws.

(1) Total of compositions of contextual laws
for each environment instance = $\Sigma^{1}_{=\iota}\ C^{1}_{\iota} = \mathbf{1}$

Each organization can have its laws composed differently with the laws from its five related concepts (Main Organization, Organization's Environment, Main Organization's Environment, Owner Environment of the Organization's Environment and Owner Environment of the Main Organization's Environment), totalizing thirty one compositions of contextual laws. For instance, Hpie Brazil laws can be composed with different combinations of laws from Hpie, Brazil, USA, South America and North America.

(2) Total of compositions of contextual laws
for each organization instance = $\Sigma^{5}_{1=\iota}\ C^{5}_{\iota} = \mathbf{31}$

Each role can have its laws composed differently with the laws from its six related concepts (Organization, Main Organization, Organization's Environment, Main Organization's Environment, Owner Environment of the Organization's Environment and Owner Environment of the Main Organization's Environment), totalizing sixty three compositions of contextual laws. For instance, "AHpieBrazilSupplier" role laws can be composed with different combinations of laws from Hpie Brazil, Hpie, Brazil, USA, South America and North America.

(3) Total of compositions of contextual laws
for each role instance = $\Sigma^{6}_{1=\iota}\ C^{6}_{\iota} = \mathbf{63}$

Each interaction can have its laws composed differently with the laws from its seven related concepts (Role, Organization, Main Organization, Organization's Environment, Main Organization's Environment, Owner Environment of the Organization's Environment and Owner Environment of the Main Organization's Environment, for each player), totalizing two hundred and fifty four compositions of contextual laws. For instance, the interaction law 4.1 between the "AHpieBrazilSupplier" and the "AHpieCubaManufacturer" can be composed with different combinations of laws from the Hpie Brazil Supplier, Hpie Brazil, Brazil, South America, Hpie Cuba Manufacturer, Hpie Cuba, Cuba, Central America, Hpie, USA and North America. However, only because Hpie Brazil and Hpie Cuba has the same main organization (Hpie), then, some combinations of their contextual laws are the same and, consequently, the number of different combinations is less than the total.

(4) Total of compositions of contextual laws
for each interaction instance = $2 * \sum^{7}_{i=1} C^{7}_{i} = \mathbf{254}$

In summary, for the four DynaCROM regulatory *meta*-contexts (environment, organization, role and interaction laws), a total of **three hundred and forty nine** compositions of contextual laws can be achieved (**1** from (1) **+ 31** from (2) **+ 63** from (3) **+ 254** from (4)). Furthermore, compositions of contextual laws from specific domain regulatory contexts can increase this total, if the domain contexts were created as extended concepts in the DynaCROM meta-ontology. Thus, the number of extra compositions of contextual laws, for each new domain context, is directly proportional to the number of concepts it is related to in the DynaCROM ontology (i.e. $\sum^{n}_{i=1} C^{n}_{i} = 2^{n} - 1$).

3.4 Restricting and Relaxing Contextual Laws Dynamically

Instead of implement the desired compositions of contextual laws inside agents' codes or inside any system's class, and have to change implemented code every time other compositions of contextual laws are required, DynaCROM offers a more flexible solution. Based on an instance of the DynaCROM ontology (where laws are expressed in) and on sets of rules (where compositions of contextual laws are defined in), DynaCROM uses a rule-based inference engine to automatically deduces the current composition of contextual laws an agent is bound to, while playing a regulated action (Figure 1 illustrates an overview of this process).

While simply activating and deactivating nineteen rules (one for the environment context, five for the organization context, six for the role context and seven for the interaction context), the total of three hundred and forty nine compositions of contextual laws from DynaCROM regulatory meta-contexts can be automatically achieved by the rule-based inference engine. Thus, developers have only to change rules to get new compositions of contextual laws an, moreover, can do that at run-time.

DynaCROM rules are ontology-based rules, i.e., they are created according to the ontology structure and they limited to the number of related concepts each concept has. For instance, Table 1 displays the five rules necessary for the rule-based inference engine automatically achieve the thirty and one compositions of contextual laws for the organization concept. Returning again to our example, when rule 1 is activated, organization laws are composed with their main organization laws (e.g., Hpie Brazil laws are composed with Hpie laws); when rule 2 is activated, organization laws are composed with their environment laws (e.g., Hpie Brazil laws are composed with Brazil laws); when rules 1 and 2 are activated, organization laws are composed with both their main organization and environment laws (e.g., Hpie Brazil laws are composed with both Hpie laws and Brazil laws); when rule 3 is activated, organization laws are composed with the laws from their environments (e.g., Hpie Brazil laws are composed with South America laws).

Rules can compose contextual laws from directly or indirectly related concepts from the same or different types. For instance, Table 1 illustrates compositions of contextual laws from directly related concepts from the same type (e.g., rule 1 composes organization laws with their main organization laws); from directly related concepts from different types (e.g., rule 2 composes organization laws with their environments laws); and from indirectly related concepts from different types (e.g., rule 3 composes organization laws with the laws from the owner environments of their environments).

Table 1. Rules for compositions of contextual laws

Rule 1- [ruleForOrgWithMOrgNorm:
(?Org *hasMainOrganization* ?MOrg)
(?MOrg *hasNorm* ?MOrgNorm)
-> (?Org *hasNorm* ?MOrgNorm)]

Rule 2- [ruleForOrgWithOrgEnvNorm:
(?Org *isIn* ?OrgEnv)
(?OrgEnv *hasNorm* ?OrgEnvNorm)
-> (?Org *hasNorm* ?OrgEnvNorm)]

Rule 3- [ruleForOrgWithOEnvOfOrgEnvNorm:
(?Org *isIn* ?OrgEnv)
(?OrgEnv *belongsTo* ?OEnvOfOrgEnv)
(?OEnvOfOrgEnv *hasNorm* ?OEnvOfOrgEnvNorm)
-> (?Org *hasNorm* ?OEnvOfOrgEnvNorm)]

Rule 4- [ruleForOrgWithMOrgEnvNorm:
(?Org *hasMainOrganization* ?MOrg)
(?MOrg *isIn* ?MOrgEnv)
(?MOrgEnv *hasNorm* ?MOrgEnvNorm)
-> (?Org *hasNorm* ?MOrgEnvNorm)]

Rule 5- [ruleForOrgWithOEnvOfMOrgEnvNorm:
(?Org *hasMainOrganization* ?MOrg)
(?MOrg *isIn* ?MOrgEnv)
(?MOrgEnv *belongsTo* ?OEnvOfMOrgEnv)
(?OEnvOfMOrgEnv *hasNorm* ?OEnvOfMOrgEnvNorm)
-> (?Org *hasNorm* ?OEnvOfMOrgEnvNorm)]

Figure 5 illustrates all possibilities of one-by-one (C1 to C5) and two-by-two (C6 to C15) compositions of contextual laws for Hpie Brazil. The one-by-one compositions of contextual laws are achieved by separately activating each of the rules from Table 1; the two-by-two compositions of contextual laws are achieved by activating pairs of the rules from Table 1, e.g., the composition C6 from Figure 5 is achieved when the rules 1 and 2 (from Table 1) are activated. The remaining possibilities for compositions of contextual laws (three-by-three, four-by-four and five-by-five) follows like wise.

C1	Hpie_Brazil	+	Hpie		
C2	Hpie_Brazil	+	Brazil		
C3	Hpie_Brazil	+	South_America		
C4	Hpie_Brazil	+	USA		
C5	Hpie_Brazil	+	North_America		
C6	Hpie_Brazil	+	Hpie	+	Brazil
C7	Hpie_Brazil	+	Hpie	+	South_America
C8	Hpie_Brazil	+	Hpie	+	USA
C9	Hpie_Brazil	+	Hpie	+	North_America
C10	Hpie_Brazil	+	Brazil	+	South_America
C11	Hpie_Brazil	+	Brazil	+	USA
C12	Hpie_Brazil	+	Brazil	+	North_America
C13	Hpie_Brazil	+	South_America	+	USA
C14	Hpie_Brazil	+	South_America	+	North_America
C15	Hpie_Brazil	+	USA	+	North_America

Figure 5. Hpie Brazil composed with some of its respective contexts

3.5 The DynaCROM Implementation

DynaCROM implementation is divided into three parts: the normative meta-ontology, created using the Protégé ontology editor [24]; the nineteen rules, written according to the Jena API [13] rule syntax; and the implementation of a JADE [27] behavior, responsible for enforcing composed contextual laws, implemented according to the DynaCROM process (illustrated in Figure 1).

It is important to remark here that the DynaCROM normative meta-ontology, all its rules and its normative behavior are available for implementing contextual regulations in open MAS.

Figure 6 shows part of the code for the DynaCROM behavior responsible for enforcements of composed contextual laws. More precisely, the result of the "getOntModel()" method (see the last line of Figure 6) is an instance of the DynaCROM ontology which explicitly represents the DynaCROM and user defined regulatory contexts (by related concepts expressed in the ontology structure), and also represents the user defined environment, organization, role and interaction laws (by instances expressed in the ontology data). Activations and deactivations of rules, used to specify the current compositions of contextual laws, have to be done, manually, in the "rulesToComposeNorms.rules" file (see the second line of Figure 6). The "reasoner" variable (see the fourth line of Figure 6) is the rule-based inference engine which, based on the ontology and active rules, automatically deduces the composed contextual laws and keeps these laws into the "inferredModel" variable (see the last line of Figure 6).

```
Model m = ModelFactory.createDefaultModel();
Resource configuration =  m.createResource();
configuration.addProperty(ReasonerVocabulary.PROPruleSet, ontologyDir.concat("rulesToComposeNorms.rules"));
Reasoner reasoner = GenericRuleReasonerFactory.theInstance().create(configuration);

InfModel inferredModel = ModelFactory.createInfModel(reasoner, this.getOntModel());
```

Figure 6. Applying dynamically compositions of contextual laws into a normative ontology

Developers of regulations in open MAS, aiming at the use of our DynaCROM approach, should complete the following four steps: (1) they must have to classify and organize user defined laws according to the DynaCROM top-down modeling; (2) they must have to extend the DynaCROM meta-ontology with particular domain concepts and explicitly represent all modeled laws into this extended ontology; (3) they must have to create rules, according to their domain concepts, and activate those (eliminating comments) or deactivate those (adding comments), for the automatic compositions of contextual laws from their particular domain; and, finally, (4) they must have to enhance their agents and systems with the DynaCROM behavior (totally free) for enforcement of composed contextual laws or implement a similar behavior.

Our case study from the domain of multinational corporations was implemented by following the above steps, i.e., we manually classified and organized user defined laws according to the DynaCROM top-down modeling and explicitly represented the modeled laws into an extended instance of the DynaCROM meta-ontology. The dynamics of DynaCROM for law evolution were perceived while creating, deleting and updating laws into the created ontology instance and while activating and deactivating new sets of rules for different customized compositions of contextual laws.

Our agents were implemented in JADE and enhanced with the two behaviors: a migratory behavior, which made them move randomly from one location (environment or organization) to another; and the DynaCROM behavior, for enforcing composed contextual laws. Figure 7 illustrates part of the world of our implemented case study, where environments and organizations are represented by JADE containers, and the "***MobileAgent", found in Hpie Brazil, is an example of an agent which has the migratory and normative behaviors.

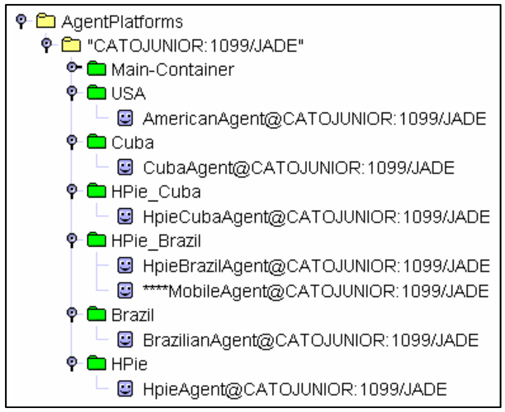

Figure 7. Environments, organizations and agents

4 Related Work

García-Camino et al. proposed in [8] a distributed architecture to endow MAS with a social layer, in which normative positions are explicitly represented and managed via rules. Every external agent from the architecture has a dedicated governor agent connected to it, enforcing the laws of executed events. DynaCROM also uses rules to manage normative agent positions, but executed actions are the focus of the regulation, instead of events. Besides this, DynaCROM provides a more precise mechanism for regulation, while enforcing customized compositions of contextual laws. Furthermore, enforcement can be done with few governor agents responsible for monitoring only the system regulated actions, instead of many agents monitoring all events executed in the regulated system.

Vázquez-Salceda et al. proposed in [29] the OMNI (Organizational Model for Normative Institutions) framework for modeling agent organizations. OMNI offers three levels of abstractions, with increasing implementation detail: the Abstract Level has the statutes of the organization to be modeled, the definitions of terms that are generic for any organization and the ontology of the model itself; the Concrete Level refines the meanings defined in the previous level, in terms of norms and rules, roles, landmarks and concrete ontological concepts; and, finally, the Implementation Level has the Normative and Organizational dimensions implemented in a given multi-agent architecture with the mechanisms for role enactment and for norm enforcement.

Comparing DynaCROM with OMNI, both define a meta-ontology with a taxonomy for norm regulations in open MAS. The use of norms can inspire trust in regulated MAS. One difference is that, in OMNI, enforcement is carried out by any internal agents from the system while in DynaCROM it can be carried out by trusted agents or by specific regulatory mechanisms from the regulated systems. A second difference, and the most important, is that, in OMNI, the idea of regulatory contexts is not explicit and separated in different levels of abstractions, especially for the environment and role regulatory contexts. DynaCROM is based on laws for the environment, organization, role and interaction contexts, to simplify the enforcement and evolution processes. For instance, the social structure of an organization in OMNI describes, at the same level of abstraction, norms for roles and groups of roles. Group of roles is used to specify norms that hold for all roles in the group. DynaCROM uses the organization regulatory context to specify organization norms that hold for all roles from an organization and uses the role regulatory context to specify role norms, both regulatory contexts from different levels of abstractions.

Paes et al. proposed in [22] XMLaw, a declarative language and a software implementation. The language supports a conceptual model for developing laws in open MAS. This model is composed of static and dynamic definitions. The implementation is to allow the enforcement of laws through the interception of agent interactions. In XMLaw, regulations take place at the level of interaction laws in order to achieve higher degrees of predictability.

Comparing DynaCROM with XMLaw, three main differences can be assessed. The first main difference between the works addresses the defined regulatory contexts. In XMLaw, just interaction laws are defined and regulations are based only on this level. In DynaCROM, interaction laws can be also composed with environment, organization and role laws for a more precise regulation. The second main difference between the works is how the enforcement is carried out when agents do not act according to the defined laws. In XMLaw, enforcement is carried out a priori, i.e. it intercepts messages and checks them to avoid law violations. In DynaCROM, enforcement is carried out a posteriori, i.e. laws are checked and if there was a law violation, its associated penalty (punishment) is assigned to the infringing agent. Thus, in DynaCROM the privacy of messages exchanged between agents is maintained and the overload, consequence of the interception process of all changed messages, does not exist. Finally, the third main difference is that in DynaCROM all regulated actions have to be known a priori and policed during the system execution, whereas in XMLaw it is not necessary because it does not police actions; XMLaw only intercepts messages while enforcing laws.

5 Conclusion

We strongly believe that the Semantic Web will be a unique Web composed mainly of several small contextualized open domain applications. These applications will have many goal-oriented entities (agents), joining and leaving it, and interoperating in order to achieve their objectives faster. However, to achieve this vision, we know that mechanisms to prevent malicious actions and to inspire trust for agents are essentials. These mechanisms should be external (i.e., not implemented inside agent codes) and flexible enough to easily permit regulatory dynamics.

In this paper, we presented our ongoing work for dynamic contextual regulations in open MAS – called DynaCROM, and how to use DynaCROM for particular domains. DynaCROM enables regulations to be dynamically relaxed or restricted by compositions of contextual laws, but it does not prevent norm-aware agents from executing actions that violate norms; it only penalizes infringing agents for doing so, leaving for them the autonomy to decide whenever obey laws. DynaCROM solution is based on a top-down modeling of contextual laws, on a normative meta-ontology for laws semantics, and on a rule support for composing contexts and retrieving ontology data (laws). The result is a straightforward method for smoothly apply and manage regulatory dynamics in open applications, like Semantic Web ones.

For future work, we are currently studying four main research lines: contexts and context-aware systems; specific ontologies for actions; simulations of regulated open MAS; and libraries of agent behaviors. The idea is to explore independently each of these research lines and to enhance DynaCROM, if good results appear.

Acknowledgments

This work was partially funded by the projects ESSMA (CNPq 552068/2002-0) and EMACA (CAPES/COFECUB 482/05 PP 016/04), and by CNPq individual grants.

References

[1] Artikis, A.; Pitt, J. and Sergot, M. Animated specifications of computational societies. In Proc. of AAMAS-2002, Part III, p. 1053-1061, Italy.

[2] Bouquet, P.; Giunchiglia, F.; van Harmelen, F.; Serafini, L.; and Stuckenschmidt, H.; C-OWL: Contextualizing Ontologies. In Proc. of ISWC-2003, LNCS vol. 2870, p. 164-179, Springer Verlag, 2003.

[3] Breitman, K.; Truszkowski, W.; Casanova, M.; Semantic Web Ontologies: Concepts, Technologies and Applications. Springer-Verlag London Ltd. Scheduled to be published in the fall of 2006.

[4] Castelfranchi, C.; Dignum, F.; Jonker, C.M. and Treur, J.; Deliberative Normative Agents: Principles and Architecture. In Proc. of ATAL-1999, USA.

[5] Dey, A. Understanding and Using Context. Personal and Ubiquitous Computing. Springer-Verlag, London, UK; Vol. 5, No.1, (2001) p. 4-7.

[6] Felicíssimo, C.; Lucena, C.; Briot, J.-P.; Choren, R.; An Approach for Contextual Regulations in Open MAS. In Proc. of AOIS@AAMAS-2006. Japan, 2006.

[7] Ferber, J.; Gutknecht, O.; Michael, F.; From Agents to Organizations: an Organization View of Multi-Agent Systems. In Proc. of the AOSE, 2003. Australia, 2003.

[8] García-Camino, A.; Rodríguez-Aguilar, J.A.; Sierra, C. and Vasconcelos, W.; A Distributed Architecture for Norm-Aware Agent Societies.

[9] Grizard, A.; Vercouter, L.; Stratulat, T.; and Muller, G.; A peer-to-peer normative system to achieve social order. In Proc. of COIN@AAMAS-2006. Japan, 2006.

[10] Gruber, T. R.: A translation approach to portable ontology specifications. Knowledge Acquisition, Vol. 5, Issue 2, p. 199-220. June, 1993. ISSN: 1042-8143.

[11] Hendler, J.; Agents and the Semantic Web. In IEEE Intelligent Systems & their applications, Vol. 16, No. 2, p. 30-37, March/April 2001

[12] Hewitt, C.; Open Information Systems Semantics for Distributed Artificial Intelligence. Artificial Intelligence. Vol. 47, Issue 1-3, p. 79-106. 1991. Elsevier Science Publishers Ltd. UK. ISSN: 0004-3702.

[13] Hewlett-Packard Development Company; Jena V. 2.3. In <http://jena.sourceforge.net/>. Accessed in 03, 2006.

[14] Huhns, M.N. and Stephens, L.M.; Multi-Agent Systems and Societies of Agents. G. Weiss (ed.), Multi-Agent Systems, ISBN 0-262-23203-0, MIT Press. 1999.

[15] Jennings, N.; Sycara, K. and Wooldridge, M.; A Roadmap of Agent Research and Development. Journal of Agents and Multi-Agent Systems, 1:p.7-38, 1998.

[16] Jennings, N. R.; On Agent-Based Software Engineering. Artificial Intelligence, 117 (2) p. 277-296. 2000.

[17] Khedr, M; Karmouch, A.; ACAI: Agent-Based Context-aware Infrastructure for Spontaneous Applications. Journal of Network & Computer Applications, Vol. 28, Issue 1, p. 19-44.

[18] Miller, G. WordNet: A Lexical Database for English. Communications of the ACM. Nov., 1995. pp.39-41

[19] Nile, I. and Pease, A.; Towards a Standard Upper Ontology. In Proc. of the FOIS'01. ACM Computer Press - October 17-19. Maine, USA. 2001.

[20] Noy, N; Rector, A. (Eds.). Semantic Web Best Practices and Deployment Working Group: Defining N-ary Relations on the Semantic Web: Use with Individuals. In <http://www.w3.org/TR/swbp-n-aryRelations/>.

[21] OpenCyc. In: <http://www.opencyc.org/>.

[22] Paes, R..; Carvalho, G.; Lucena, C.; Alencar, P.; Almeida, H.; Silva, V.; Specifying Laws in Open Multi-Agent Systems. In Proc. of ANIREM-2005, Utrecht, the Netherlands.

[23] Sowa, J. F.; Knowledge Representation: Logical, Philosophical and Computational Foundations. Brooks/Cole Books, Pacific Grove, CA – 2000.

[24] Stanford University School of Medicine: Protégé. In <http://protege.stanford.edu/>.

[25] SUO Information Flow Framework (SUO IFF). In: <http://suo.ieee.org/IFF/>

[26] Thomas, G. and Williams, A. B.; Roles in the Context of Multiagent Task Relationships. AAAI Fall Symposium "Roles, an Interdisciplinary Perspective: Ontologies, Programming Languages, and Multiagent Systems", FS-05-08. ISBN 978-1-57735-254-9. USA. 2005.

[27] Tilab Co. JADE. In: <http://jade.tilab.com/>.

[28] Tyrrell, T.; Computational Mechanisms for Action Selection. PhD thesis from the Edinburgh University. 1993. *The referred information is on page 125.

[29] Vázquez-Salceda, J.; Dignum, V. and Dignum, F.; Organizing Multiagent Systems. Journal of Autonomous Agents and Multi-Agent Systems, 11, p. 307-360, 2005.

[30] Weyns, D.; Parunak, H.V.D.; Michel, F.; Holvoet, T. and Ferber, J.; Environments for Multiagent Systems State-of-the-Art and Research Challenges. In Proc. of the E4MAS, 2005, p.1-47. ISBN 3-540-24575-8.