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Automating Regulations in Open Multi-Agent Systems *

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Abstract. We propose, in this work, an approach for automating regulations in open multi-agent systems. This approach is founded on a top-down context modeling of laws and on a regulatory meta-ontology, and demonstrates that rules allied with inference techniques can be effective while composing regulatory contexts and automatically retrieving data (laws). We conducted an experimental study investigating the potentiality of the approach. In this study, we first classified some chosen laws according to modeling contexts. Then, we formalized the modeled laws creating an instance of the regulatory meta-ontology by using an ontology editor. Finally, we wrote rules for dynamic compositions of regulatory contexts. Applying the rules in the regulatory ontology instance, supported by a rule-based inference engine, it resulted in laws, from different regulatory contexts, composed and retrieved automatically. Thus, the study demonstrated the effectiveness of the applied approach and highlighted a straightforward method for automating regulations in open multi-agent systems.

Keywords: Contextual Regulations, Open Multi-Agent Systems, Inference, Rules, Ontologies.

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Table of Contents

1 Introduction

Agent-based computing is rapidly emerging as a powerful technology for the development of distributed and complex software systems. In a multi-agent system (MAS) there are several software agents, each one trying to achieve its own goals. An open MAS is a MAS with no centralized control in which agents can unrestrainedly enter or leave the system. Open systems are always subject to unanticipated interactions [14] caused by their members that do not conform to recommendations of right and wrong behaviors. This risk imposes the need for regulatory mechanisms to prevent malicious actions and to inspire trust for members of open systems.

Governance in open MAS is a challenging activity. Besides being inherently complex, this kind of system presents practical difficulties since they encompass heterogeneous agents, which have their own design and implementation. Key characteristics of open MAS are: agent heterogeneity, conflicting individual goals and limited trust [1].

Regulations in open MAS should be easily developed and deployed by their developers and they should be expressed in a well-defined model to permit agents' reasoning. Furthermore, regulatory dynamics should be supported. Seeking a solution which regards these requirements, we proposed, in a previous work [5], an approach for contextual regulations in open MAS.

Our approach was evolved with significant improvements in how automatically compose diverse combinations of laws, from different regulatory contexts, by using (few) rules. Moreover, the total numbers of possible combinations of laws, according to regulatory contexts, were discovered and presented by created formulas. These formulas describe the relation between rules and contextual compositions of laws. The evolved approach for automating regulations in open MAS is proposed in this work.

The remainder of this paper is organized as follows. In Section 2, our approach for contextual regulations in open MAS is briefly presented. In Section 3, our evolved approach focusing on the automation of regulations is explained. In Section 4, our case study is described. In Section 5, two main researches are outlined pointing directions for future works. Finally, in Section 6, we finished the paper offering our conclusions.

2 Regulations in open MAS

Multi-Agent Systems (MAS) are constituted, mainly, by environments, organizations, agents, agent roles and agent interactions [10]. Environments [21] 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 group of agents play roles inside it seeking to achieve their goals. Agent roles are abstractions that define a set of related tasks [19]. Agents interact with other agents, from the same or from different organizations and environments.

Environments, Organizations, Agent Roles and Agent Interactions suggest different contexts for regulations in MAS. Contexts are implicit situational information [4], i.e. contexts can be defined as pieces of information that can be used to characterize the situation of participants. Modular context refinements allow a more flexible regulatory system and provide a better support for developers in the tasks of maintenance and evolution of laws.

Context-aware systems use contexts to provide relevant information and/or services to their users, where relevancy depends on the users' tasks [4]. In our definition, regulated context-aware systems use contextual law information to provide the current enforcement of laws to their users. Deliberative normative agents [2] use this information to better adapt their behaviors according to the current system regulation.

Enforcement in MAS can be carried out a priori, avoiding law violation, or a posteriori, penalizing (punishing) infringing agents. A priori regulations guarantee law compliance while enforcing the system laws in all performed agent actions. However, they result in an extra overload for the system execution. A posteriori regulations do not guarantee law compliance, but they inhibit infringing agents with punishments.

In open MAS, a large number of heterogeneous agents enter and leave the system, without restraint. Consequently, a large number of agent actions are executed, reducing the effectiveness of a priori enforcement, because of excessive overloads for the system regulation. In order to provide a more effective regulation mechanism, we proposed in [5] an approach for a posteriori contextual enforcement of laws. This approach is based on a top-down context modeling of laws and on a regulatory meta-ontology, both briefly explained in the following sub-sections.

2.1 A top-down contextual modeling of laws

Contexts are tacitly understood for most people, but, in most cases, they are hard to elucidate. For developers of regulated systems, designing regulations according to a contextual modeling of laws eases the elucidation task, while better structuring information. However, sometimes, it is difficult to classify laws according to the defined regulatory contexts due to their subjectivity.

Researches in context-aware applications suggest top-down architectures for contextual modeling [15]. Following this direction, we addressed the following regulatory contexts of laws for open MAS: Environment, Organization, Role and Interaction. 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.

The boundaries of the environment, organization, role and interaction regulatory contexts are illustrated in Figure 1. There, are also illustrated (by arrows) distinct agents, with different roles, organizations and environments, interacting and regulated through laws from all regulatory contexts. Contextual regulations permit a more precise enforcement of laws. For instance, an agent from the environment in the right side of Figure 1 can interacts with an agent from the environment in the left side of Figure 1 regulated through interaction laws composed with specific environment, organization and role laws.

The proposed regulatory contexts of laws are not hierarchical, but they have different levels of abstraction. Laws from distinct regulatory contexts can be freely composed, during the system execution, restricting or relaxing the system current regulation. Nevertheless, laws composed from the same regulatory context can conflict, while addressing the same subject in opposite ways. It is not our intention here to make any assumption about how to resolve conflicts, however, we suggest enhance conflicted laws with priorities in order to minimize the problem.

We believe that the proposed regulatory contexts of laws are not targeted at a particular application domain, but rather represent a minimum set for contextual regula-

tions in open MAS. This set can be readily applied to regulate simple open MAS, from different application domains. For more complex MAS, this set can be improved with specifics domain regulatory contexts.

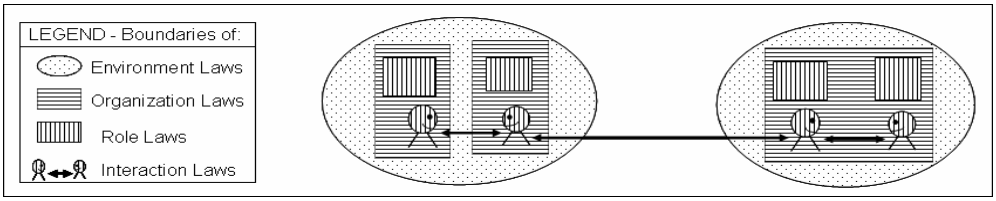

Figure 1. Interactions regulated through different composed regulatory contexts

2.2 A regulatory meta-ontology

In open MAS, regulations cannot be incorporated into the agents' code, since we do not have control over their development. A standard well-defined model should be used to express the proposed regulatory contexts and their data (the system modeled laws). Ontologies, i.e. conceptual models that embody shared conceptualizations of a given domain [9], can represent information in a meaningful way for agents to automatically process their contents [16].

A regulatory meta-ontology was designed to express information about contextual regulations in open MAS. This ontology (see Figure 2) has the six following related concepts: *Environment*, *Organization*, *Role*, *Norm*, *Penalty* and *Action*.

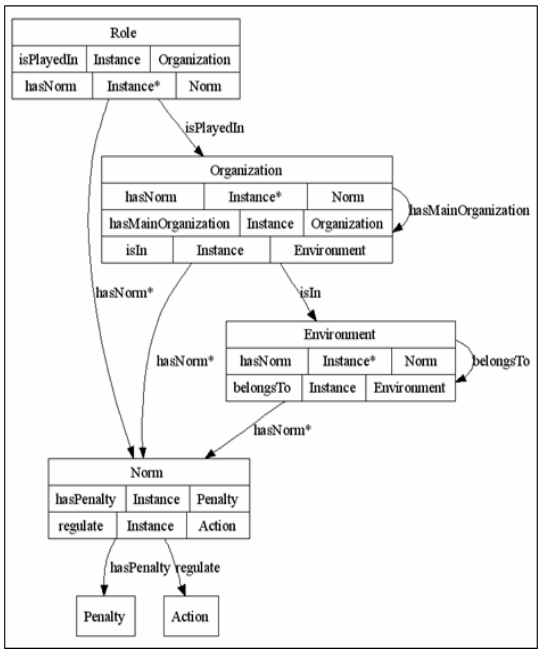

Figure 2. A regulatory meta-ontology

Each environment concept encompasses its norms (laws) and belonged environment (its owner environment). Each organization concept encompasses its norms, environment and its main organization. Each role concept encompasses the organization where it can be played in and its norms. Each norm concept encompasses its associated penalties and regulated action. Each penalty concept encompasses the penalties (pun-

ishments) to be given if its associated norm is violated. Each action concept encompasses the actions that must be regulated.

We believe that the six concepts from our regulatory meta-ontology represent a minimum set for contextual regulations in open MAS [6]. Regulatory contexts for particular domains can be represented extending the regulatory meta-ontology with new concepts. Thus, for consolidating regulations, the regulatory ontology (extended or not) has to be instantiated with the system laws, according to the regulatory contexts defined.

3 Automating regulations in open MAS

Context-aware systems can support three categories of features: (i) presentation of information and services to users; (ii) automatic execution of services for users; and (iii) tagging of context to information to support later retrieval [4].

Regarding feature (i), we expressed/formalized system modeled contextual laws into our regulatory ontology, supporting agents while automatically processing information.

Regarding features (ii) and (iii), we chose ontology-driven rules and rule-based inference engines. Ontology-driven rules allied with a rule-based inference engine and applied into a regulatory ontology instance permit automatic inference of composed contextual laws.

Putting together contexts, ontologies, ontology-driven rules and rule-based inference engines, induce we envision main assets of an approach for automating regulations in open MAS.

Figure 3 illustrates our envisioned approach. There, “Ontology” represents an instance of the regulatory meta-ontology. This instance expresses the regulatory contexts and their data (the system modeled laws). “Rules” represents ontology-driven rules, written based on ontology concepts and on concept relationships, specifying contextual compositions of laws. The inference engine illustrated automatically infers data, according to the defined rules applied in the regulatory ontology instance. The “Inferred Ontology” represents an inferred instance of the regulatory meta-ontology. This ontology has the regulatory contexts and the inferred data (the system modeled laws composed with the inferred contextual laws).

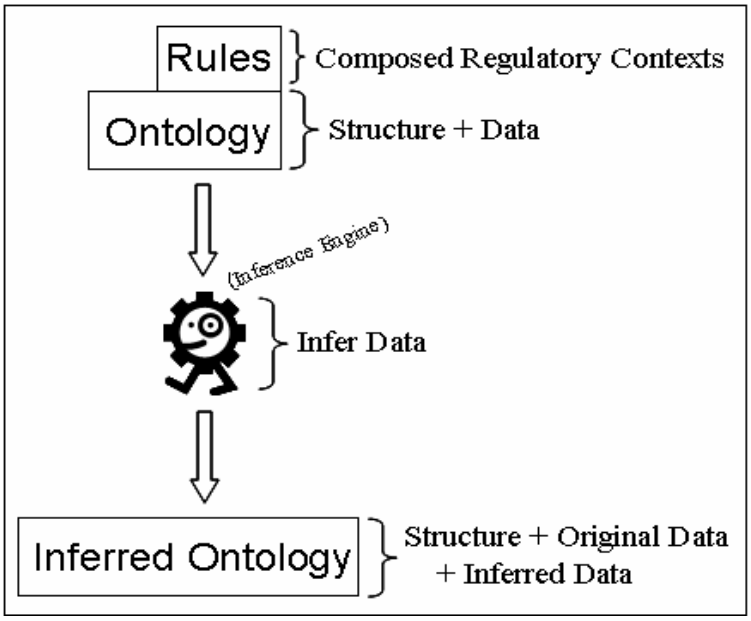

Figure 3. Automating regulations in open MAS

In our approach, rules can be manually updated, during the system execution, for different contextual compositions of laws. Consequently, the current system regulation is updated automatically, in run-time, by different inferred composed laws.

While composing laws, we are currently dealing with the four following regulatory contexts of laws: *Environment*, *Organization*, *Role* and *Interaction*.

Each environment can have its laws composed with just its Owner Environment laws, totalizing **one** contextual combination of laws.

Formula 1: Total of Contextual Combinations of Laws for each Environment instance = $\Sigma^{1}_{\iota=1}\ C^{1}_{\iota} = 1$

Each Organization can have its laws composed with contextual laws from the five following 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. These compositions totalize **thirty one** contextual combinations of laws (all illustrated in Figure 4).

Formula 2: Total of Contextual Combinations of Laws for each Organization instance = $\Sigma^{5}_{\iota=1}\ C^{5}_{\iota} = 31$

Each Role can have its laws composed with contextual laws from the six following 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. These compositions totalize **sixty three** contextual combinations of laws.

Formula 3: Total of Contextual Combinations of Laws for each Role instance = $\Sigma^{6}_{\iota=1}\ C^{6}_{\iota} = 63$

Legend of Abreviattions: Org.: Organization / OrgEnv.: Organization's Environment / OEnvOfOrgEnv.: Owner Environment of Organization's Environment / MOrg.: Main Organization / MOrgEnv.: Main Organization's Environment / OEnvOfMOrgEnv.: Owner Environment of Main Organization's Environment

C1	Org + MOrg.		**C16**	Org. + MOrg. + OrgEnv. + OEnvOfOrgEnv.
C2	Org. + OrgEnv.		**C17**	Org. + MOrg. + OrgEnv. + MOrgEnv.
C3	Org. + OEnvOfOrgEnv.		**C18**	Org. + MOrg. + OrgEnv. + OEnvOfMOrgEnv.
C4	Org. + MOrgEnv.		**C19**	Org. + MOrg. + OEnvOfOrgEnv. + MOrgEnv.
C5	Org. + OEnvOfMOrgEnv.		**C20**	Org. + MOrg. + OEnvOfOrgEnv. + OEnvOfMOrgEnv.
C6	Org. + MOrg. + OrgEnv.		**C21**	Org. + MOrg. + MOrgEnv. + OEnvOfMOrgEnv.
C7	Org. + MOrg. + OEnvOfOrgEnv.		**C22**	Org. + OrgEnv. + OEnvOfOrgEnv. + MOrgEnv.
C8	Org. + MOrg. + MOrgEnv.		**C23**	Org. + OrgEnv. + OEnvOfOrgEnv. + OEnvOfMOrgEnv.
C9	Org. + MOrg. + OEnvOfMOrgEnv.		**C24**	Org. + OrgEnv. + MOrgEnv. + OEnvOfMOrgEnv.
C10	Org. + OrgEnv. + OEnvOfOrgEnv.		**C25**	Org. + OEnvOfOrgEnv. + MOrgEnv. + OEnvOfMOrgEnv.
C11	Org. + OrgEnv. + MOrgEnv.		**C26**	Org. + MOrg. + OrgEnv. + OEnvOfOrgEnv. + MOrgEnv.
C12	Org. + OrgEnv. + OEnvOfMOrgEnv.		**C27**	Org. + MOrg. + OrgEnv. + OEnvOfOrgEnv. + OEnvOfMOrgEnv.
C13	Org. + OEnvOfOrgEnv. + MOrgEnv.		**C28**	Org. + MOrg. + OrgEnv. + MOrgEnv. + OEnvOfMOrgEnv.
C14	Org. + OEnvOfOrgEnv. + OEnvOfMOrgEnv.		**C29**	Org. + MOrg. + OEnvOfOrgEnv. + MOrgEnv. + OEnvOfMOrgEnv.
C15	Org. + MOrgEnv. + OEnvOfMOrgEnv.		**C30**	Org. + OrgEnv. + OEnvOfOrgEnv. + MOrgEnv. + OEnvOfMOrgEnv.
			C31	Org. + MOrg. + OrgEnv. + OEnvOfOrgEnv. + MOrgEnv. + OEnvOfMOrgEnv

Figure 4. All possibilities of contextual combinations for an organization instance

Each Interaction can have its laws composed with contextual laws from the following seven 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. Interaction compositions totalize two hundred and fifty four contextual combinations of laws.

Formula 4: Total of Contextual Combinations of Laws for each Interaction instance = $2^* \Sigma^{7}_{l=1} C^{7}_{l} = 254$

Summarizing, we can have **three hundred forty nine** combinations of laws while composing our four regulatory contexts. These combinations need to be expressed to be effectively utilized by inference engines. However, instead of writing all combinations, our approach offers a better automatic solution.

By activating and deactivating different combinations of rules, all possibilities of contextual combinations of laws are expressed. For instance, to achieve all combinations of laws for the Organization regulatory context (see **C1** to **C31** from Figura 4), rules 1, 2, 3, 4 and 5, from Table 1, need to be activated and deactivated, as presented in Table 2. Different combinations of these rules compose organization laws with laws from all its others possible five contexts.

Table 1. Rules for the Organization regulatory context

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)]

Following the same solution, to have all sixty three combinations of laws for the Role regulatory context, just six rules need to be activated and deactivated; to have all two hundred and fifty four combinations of laws for the Interaction regulatory context, just seven rules need to be activated and deactivated.

Thus, developers of regulations in open MAS can have three hundred forty nine contextual combinations of laws by just activating and deactivating a total of nineteen rules from our approach.

Table 2. Activating and deactivating rules for regulations

C1	Rule 1
C2	Rule 2
C3	Rule 3
C4	Rule 4
C5	Rule 5
C6	Rule 1 + Rule 2
C7	Rule 1 + Rule 3
C8	Rule 1 + Rule 4
C9	Rule 1 + Rule 5
C10	Rule 2 + Rule 3
C11	Rule 2 + Rule 4
C12	Rule 2 + Rule 5
C13	Rule 3 + Rule 4
C14	Rule 3 + Rule 5
C15	Rule 4 + Rule 5
C16	Rule 1 + Rule 2 + Rule 3
C17	Rule 1 + Rule 2 + Rule 4
C18	Rule 1 + Rule 2 + Rule 5
C19	Rule 1 + Rule 3 + Rule 4
C20	Rule 1 + Rule 3 + Rule 5
C21	Rule 1 + Rule 4 + Rule 5
C22	Rule 2 + Rule 3 + Rule 4
C23	Rule 2 + Rule 3 + Rule 5
C24	Rule 2 + Rule 4 + Rule 5
C25	Rule 3 + Rule 4 + Rule 5
C26	Rule 1 + Rule 2 + Rule 3 + Rule 4

C27	Rule 1 + Rule 2 + Rule 3 + Rule 5
C28	Rule 1 + Rule 2 + Rule 4 + Rule 5
C29	Rule 1 + Rule 3 + Rule 4 + Rule 5
C30	Rule 2 + Rule 3 + Rule 4 + Rule 5
C31	Rule 1 + Rule 2 + Rule 3 + Rule 4 + Rule **5**

4 Case study

The domain of multinational corporations is chosen for presenting our case study. 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 governance includes regulate 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 four roles: supplier, manufacturer, 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. Hpie Brazil is in Brazil, which in turn is in South America.

Normally, corporation laws are not public because they are strategically for the corporation businesses. Because of this, we created environment, organization, role and interaction laws based on some public laws collected from several corporate Web sites. The created laws were classified according to our four regulatory contexts.

1. **Examples of Environment Laws:**

   1.1. In North America, a finished good from every organization has its price added with a percentage of the price value (dependent of the seller location) as taxes if the deliver is immediately (carry-on) or if the deliver address is in North America.

   1.2. In USA, a finished good from every organization has its price added with 8% of the price value as taxes if the deliver is immediately (carry-on) or if the deliver address is in USA.

   1.3. In South America, every shipped order has its price added with 15% of the price value as taxes if the deliver address is outside South America.

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

   1.5. In Cuba, all negotiations have to be paid with 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 with 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 have to have detailed receipts.

   2.2. In Hpie Cuba, every organization's products have one year of warranty.

   2.3. In Hpie Brazil, every placed order has to 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 organization's products when substantial defects cannot be fixed in four attempts.

3.2. Hpie Cuba manufacturers have to provide, in until one month, refunds or replacements for each defective organization's product when its 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% of the price value as discount for orders paid with cash.

4. Example of an Interaction Law:

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

All laws presented above were formalized into an instance of our regulatory ontology and are illustrated in Figure 5.

Our case study was implemented in Java [8] using the Jena API [12] and JADE [11]. The Jena API was used as a programmatic environment for OWL [16] and as a rule-based engine. JADE was used to implement our agents and the behavior for contextual regulations. JADE containers were also used to represent environments and organizations, offering possible locations for mobile agents to go. USA, Cuba, Brazil, Hpie, Hpie Cuba and Hpie Brazil are examples of possible locations for mobile agents to go, all implemented as JADE containers.

In our implementation, once an agent migrates, its location attribute is updated. Our regulatory behavior always checks this attribute, getting the current agent location. For agents, the regulatory behavior informs the current contextual regulations of the system laws. Agents can use this information to automatically adapt themselves to better behaviors, increasing chances to achieve their goals. For the system, the regulatory behavior supports the task of law enforcement.

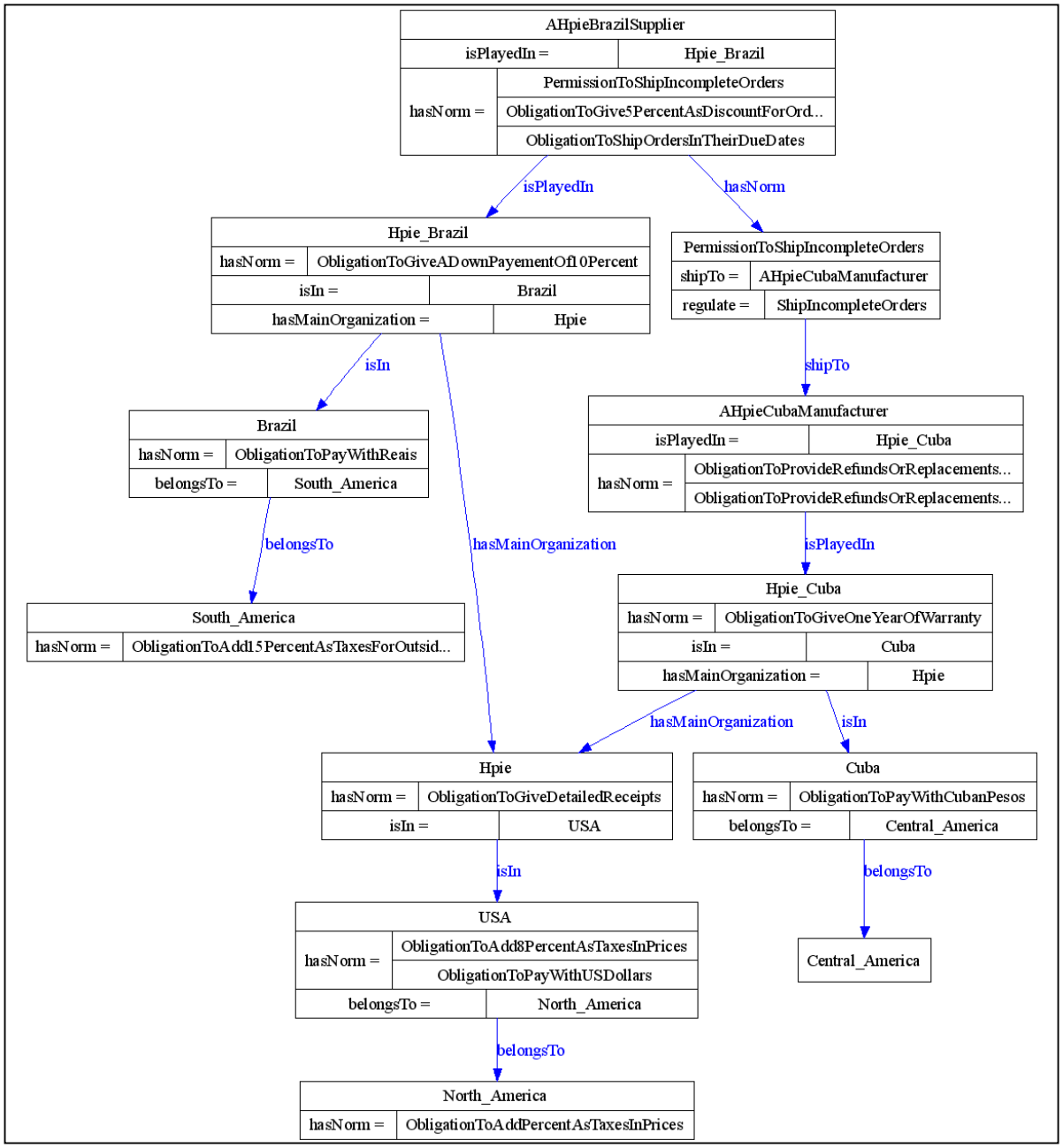

Figure 5. An example with our four regulatory contexts

In order to present our case study, a scenario is given by an Hpie Cuba manufacturer honoring its laws 3.1 and 3.2. In this scenario, the manufacturer needs to replace a defective product but an important part for the product's assembly is not found in Cuba. Thus, the Hpie Cuba manufacturer interacts with an Hpie Brazil supplier, looking for the specific product's part or, maybe, a product for replacement.

According to our approach, agents participating in a deal can have their negotiation regulated through composed laws from the four following regulatory contexts: *Environment Laws*, *Organization Laws*, *Role Laws* and *Interaction Laws*. Compositions of contextual laws can be done during the system execution, influencing the current enforcement of laws.

While the Hpie Cuba manufacturer is interacting with the Hpie Brazil supplier, the agents are regulated through the interaction law 4.1. This law states that the Hpie Brazil supplier is permitted to ship incomplete orders to the Hpie Cuba manufacturer.

While composing the interaction law with role laws, the interaction between the agents are influenced by the Hpie Brazil supplier laws 3.3 and 3.4. With the law 3.3, the Hpie Brazil supplier is obligated to ship orders, from the Hpie Cuba manufacturer, in their due dates. With the law 3.4, the Hpie Brazil supplier is permitted to give 5% of the price value as discount for orders, from the Hpie Cuba manufacturer, paid with cash.

While composing the interaction law with organization laws, the interaction between the agents are influenced by the Hpie Cuba law 2.2 and by the Hpie Brazil law 2.3. With the law 2.2, the Hpie Cuba manufacturer has to honor its laws 3.1 and 3.2 for just one year (the warranty period). With the law 2.3, every placed order, from the Hpie Cuba manufacturer, has to have a down payment of 10%. As Hpie is the main organization of Hpie Cuba and Hpie Brazil, its law 2.1 also influence the regulation between the agents. With this law, the Hpie Brazil supplier has to give detailed receipts for all paid orders from the Hpie Cuba manufacturer.

While composing the interaction law with environment laws, the interaction between the agents is influenced by the Brazil law 1.6. With this law, the Hpie Cuba manufacturer has to convert his CUP (national currency from Cuba) to R$ (national currency from Brazil) for the payment of his orders. As South America is the owner environment of Brazil, its law 1.3 also influences the regulation between the agents. With this law, every shipped order, from the Hpie Brazil supplier to the Hpie Cuba manufacturer, has its price added with 15% of the price value as taxes, because the deliver address is outside South America.

While composing the interaction law with role and environment laws, the interaction between the agents are influenced by the Hpie Brazil supplier laws 3.3 and 3.4, by the Brazil law 1.6 and by the South America law 1.3.

Several others compositions of laws can be done. According to **Formula 4**, from the previous section, the interaction law between the Hpie Cuba manufacturer and the Hpie Brazil supplier can be influenced by two hundred and fifty four contextual compositions of laws. This number of compositions is found by doubling the sum of the different combinations of laws from seven contexts. The duplication is because each interaction is performed by two players. The seven contexts for the player Hpie Brazil supplier are: Hpie Brazil supplier, Hpie Brazil, Brazil, South America, Hpie, USA and North America. The seven contexts for the player Hpie Cuba manufacturer are: Hpie Cuba manufacturer, Hpie Cuba, Cuba, Central America, Hpie, USA and North America.

In Figure 6 are illustrated the interaction regulatory context composed with some combinations of contexts from the Hpie Brazil supplier player (**C1** to **C10**) and with some combinations of contexts from the Hpie Cuba manufacturer player (**C11** to **C20**). Just because Hpie is the same main organization of Hpie Brazil and Hpie Cuba, then some combinations of their contextual laws are the same (such as **C5** and **C15**, **C6** and **C16**, **C7** and **C17**, etc.). Thus, the interaction law will be composed with less than the total of two hundred and fifty four contextual laws.

It is important to remark here that contextual compositions of laws influence the current system regulation. In our approach, all compositions of contextual laws are automatically achieved by rules allied with a rule-based inference engine. These basic rules, for regulations in open MAS, are offered enhanced in our approach, facilitating the law enforcement task for developers.

C1	Interaction + AHpieBrazilSupplier		**C11**	Interaction + AHpieCubaManufacturer
C2	Interaction + Hpie Brazil		**C12**	Interaction + Hpie Cuba
C3	Interaction + Brazil		**C13**	Interaction + Cuba
C4	Interaction + South America		**C14**	Interaction + Central America
C5	Interaction + Hpie		**C15**	Interaction + Hpie
C6	Interaction + USA		**C16**	Interaction + USA
C7	Interaction + North America		**C17**	Interaction + North America
C8	Interaction + AHpieBrazilSupplier + Hpie		**C18**	Interaction + AHpieCubaManufacturer + Hpie
C9	Brazil		**C19**	Cuba
C10	Interaction + AHpieBrazilSupplier + Brazil		**C20**	Interaction + AHpieCubaManufacturer + Cuba
	Interaction + AHpieBrazilSupplier + Hpie			Interaction + AHpieCubaManufacturer + Hpie

Figure 6. Possibilities of contextual combinations for the interaction regulatory context

5 Future work

The effectiveness we got in the presented case study, while regulating open MAS based on contexts, introduces assumptions about the success of both the chosen set of technologies and how these technologies are applied. We are planning to execute others case studies from different domains and increasing level of complexity in order to evaluate the new obtained results. More precisely, we aim to validate the set of regulatory: modeling law contexts, formalized related concepts and rules. The tradeoff between expressiveness and reasoning, i.e. the more expressive is a language, the harder is the reasoning in a finite computational time, should also be evaluated. Moreover, we are looking for domains where the applied regulation approach has better results than others, such as the approaches that regulate open systems just through the interaction regulatory level, e.g. [17] and [18].

5.1 Simulation of regulated open MAS

In this phase, we are planning to simulate open MAS with some (few) regulated entities, seeking a faster and an easier way to test our assumptions in other case studies, and to analyze the agents' reactions ahead both unexpected situations and new regulations.

To facilitate simulations, we are testing some JAVA open-source graphics engines (found in [3]), like the jME one [13], that can deal with our implemented solution of regulation. We expect to vary simulated systems' features and that agents adapt their behaviors according to these system modifications.

5.2 Use of a library of behaviors

In this phase, we are planning to use a library of behaviors to offer better options for agents adapt themselves ahead (few) simulated unexpected situations and new regulations. It is not our intention to implement behaviors, but use implemented *third-part* ones. We expect, from the utilized library, various specific behaviors propitious to different situations. For instance, agents should be adapted well, with a reactive behavior, ahead unexpected situations.

5.3 Simulation of regulated open MAS and Use of a library of behaviors

In this phase, we are planning to refine and to put together our solutions to simulate regulated open MAS and to use a library of behaviors. We expect, with both solutions, that agents will adapt their behaviors ahead different simulated situations (a number of possibilities close to 10^{100} for complex systems [20]).

6 Conclusion

Regulatory contexts better structure information, permitting several combinations of laws. These combinations are more precise and they are supported, in our approach, by an offered set of rules. These rules can be activated and deactivated, manually, during the system execution. Rules allied with rule-based inference engines and applied into a regulatory ontology instance permit automatic deduction of composed contextual laws. The granularity of our solution also permits developers to define separate sets of rules to regulate distinct group of agents. Furthermore, developers are assisted while maintaining and evolving laws, by decoupling information in particular regulatory contexts.

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