Extending the Framework TAO with Norms for Multi-Agent Systems

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Abstract. *The increasing complexity of systems poses a challenge to Software Engineering. The existence of Normative Multi-Agent Systems, where the agents' behavior is governed by norms, promotes the need for an ontology capable of defining these related concepts. In this context, we highlight TAO, a conceptual framework for (representing) MAS, used as a foundation to the MAS-ML modeling language. However, the support for representing of the norm concepts is limit. This paper describes the extending the TAO through of the creation of new abstraction norm and its relationships. Additionally, the structure of some abstractions defined in the previous version was changed because of the inclusion of the norm concepts. Through a case study, we demonstrate the use of the proposed extension to represent the elements of a virtual marketplace.*

1. Introduction

An adequate definition of the conceptual framework is critical to understand the business (conceptual modeling) and elaborate a coherent solution (computer modeling) in the context of the development project of complex systems [Dieste et al., 2001]. The focus of the conceptual modeling is to provide the domain understanding related to the described problem. Conceptual models describe the problem found out by the user and describe the way of a software system to solve the problem [Dieste et al., 2001]. In order to produce a solution, computational models can be generated based on conceptual models.

Computational models describe how a software system solves a problem. Because the existence of different concepts proposed to Multi-Agent Systems (MAS) entities the conceptual frameworks are important to establish a base for modeling languages or agent oriented frameworks. The Taming Agents and Objects (TAO) [Silva et al., 2003] is a conceptual framework which provides the basis for software engineering methods based on agents and objects. It is the basis of the modeling language MAS-ML [Silva, Choren and Lucena, 2008], that allows the modeling of all the entities and their properties and relationships defined in TAO. In Addiction, MAS-ML has a support tool called MAS-ML tool [Gonçalves et al., 2011]. This tool allows the modeling of the static diagrams defined in the language.

In order to cope with the heterogeneity, autonomy and diversity of interests among the different members, governance (or law enforcement) systems have been defined. The

governance systems define a set of norms (or laws) that must be followed by the system entities. Norms provide a means for regulating the agents' behavior by describing their permissions, prohibitions and obligations [Figueiredo and Silva, 2010].

Norms are used to regulate the behavior of the agents in MAS by describing the actions that can be performed or states that can be achieved (permissions), actions that must be performed or states that must be achieved (obligations), and actions that cannot be performed or states that cannot be achieved (prohibitions). They represent a way for agents to understand their responsibilities and the responsibilities of the others. Norms are used to cope with the autonomy, different interests and desires of the agents that cohabit the system [López y López, 2003].

In TAO, the modeling of the norms concepts is limited to: (i) allow to regulate the behavior of agents, sub organizations and organizations that inhabit an environment, (ii) define what system resources that will have their access restricted and (iii) specify sanctions that apply if the norms are violated or fulfilled. Thus, there is a need to adapt the concepts of TAO in order to support norm concepts. However, TAO allows the modeling of all the typical entities and their properties that compose a MAS.

This paper proposes the extension of TAO for the representing of norm concepts. The extension is done through the creation of the norm abstraction and its relationships. Additionally, the structure of some abstractions defined in the previous version was changed because of the inclusion of the norm concepts. The representation of these abstractions and their relationships are done through of the templates. The paper is structured as follows: the TAO and the norms for MAS are described in Section 2. Section 3 presents the related work. The extension of the TAO is presented in Section 4. Section 5 presents a case study involving the proposed extension. Finally, conclusions and future work are in Section 6.

2. Background

2.1. Taming Agents and Objects (TAO)

The framework TAO (Taming Agents and Objects) provides an ontology that covers the fundamentals of Software Engineering based on agents and objects. With that is possible to support the development of MAS in large-scale [Silva et al., 2003]. This framework elicits an ontology that connects consolidated abstractions, such as objects and classes, and "emergent" abstractions, such as agents, roles and organizations, which are the foundations for agent and object-based software engineering. TAO presents the definition of each abstraction as a concept of its ontology, and establishes the relationships between them. The Figure 1 shows the abstractions and relationships of TAO. The abstractions of TAO are defined as follows:

- Object: It is a passive or reactive element that has state and behavior and can be related to other elements.
- Agent: It is an autonomous, adaptive and interactive element that has a mental state. Its mental state has the following components: (i) beliefs (everything the agent knows), (ii) goals (future states that the agent wants to achieve), (iii) plans (sequences of actions that achieve a goal) and (iv) actions.

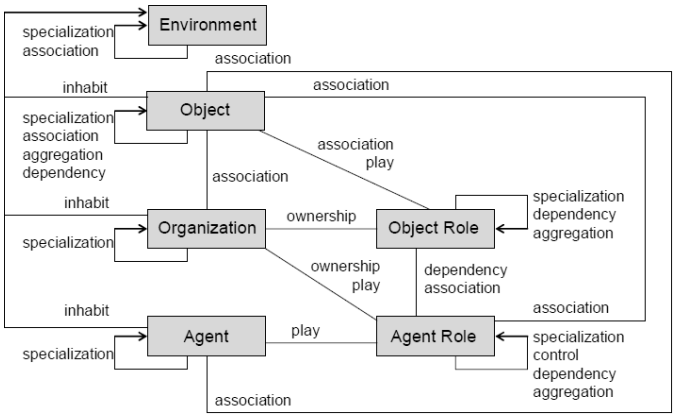

Figure 1. The abstractions and relationships of TAO [Silva et al., 2003].

- Organization: It is an element that groups agents, which play roles and have common goals. An organization hides intra-characteristics, properties and behaviors represented by agents inside it. It may restrict the behavior of their agents and their sub-organizations through the concept of axiom, which define the actions that must be performed.
- Object Role: It is an element that guides and restricts the behavior of an object in the organization. An object role can add information, behavior and relationships the object instance that executes.
- Agent Role: It is an element that guides and restricts the behavior of an agent in the organization. An agent role defines (i) duties that define an action that must be performed by an agent, (ii) rights that define an action that can be performed by an agent and (iii) protocol that defines an interaction between an agent role and other elements.
- Environment: It is an element that is the habitat for agents, objects and organizations. An environment can be heterogeneous, dynamic, open, distributed and unpredictable [Omicini, 2001].

Additionally, Silva et al. (2003) defined the following relationships in TAO: Inhabit, Ownership, Play, Specialization/Inheritance, Control, Dependency, Association and Aggregation/Composition.

2.2. Norms for Multi-Agent Systems

The norms are used to restrict the behavior of agents, organizations and sub-organizations during a period of time, and set sanctions applied if violated or fulfilled [Silva, Braga and Figueiredo, 2010]. Thus, the norms should be associated with an environment, an organization, a sub-organization or an agent role. The following are the main elements that compose the norm based on a survey conducted by [Figueiredo, 2011].

- Deontic concepts: deontic logic refers to the logic of requests, commands, rules, laws, moral principles and judgments [Meyer and Wieringa, 1993]. In MAS, such concepts have been used to describe the constraints for the behavior of agents in the form of obligations (what the agent must execute), permissions (what the agent can execute) and prohibitions (what the agent cannot execute).

- Involved Entities: provided that the norms are always set to restrict the behavior of entities, identification of affected entities is essential. The norm may regulate the behavior of individuals (for example, a particular agent, or an agent, while playing a particular role), or the behavior of a group of individuals (for example, all agents playing a particular role, groups of agents, groups of agents playing roles or all agents in the system).
- Actions: Once a norm is used to restrict the execution of the entities, it is important that the action being regulated is clearly specified. Such actions may be communication, usually represented by sending and receiving a message, or non-communicative actions (such as access and modify a resource, get in an organization, move to another environment, etc.).
- Activation Constraints: The norms have a period in which its restrictions must be fulfilled, but only when they, the norms, are active. Norms may be activated by a constraint or a set of constraints that can be: the execution of actions, specifying time intervals (before, after or in between), the realization of system states or temporal aspects (such as dates) and also the activation / deactivation of other norm and fulfillment / violation of a norm.
- Sanctions: When a norm is violated the entity may suffer a punishment, and when a norm is fulfilled, the involved entity may receive a reward. Rewards and punishments are called for sanctions and should be reported to the specification of the norm.
- Context: the norms are usually defined in a determined context that determines the application area. The norm may, for example, be described in the context of a particular environment and must be filled only by agents in execute in the environment. Similarly, in the context of an organization.

3. Related Work

Some conceptual frameworks and organization models have been proposed for MAS, however they provide limited support to the norm concepts. Our aim is analyze the conceptual frameworks and organization models considering the provided support to the modeling of the typical entities of the MAS along their properties and their relationships. Also, the support given to the modeling of the norm concepts (Section 2.2) will be analyzed. We analyze three conceptual frameworks and two organization models.

The proposed framework by d'Inverno and Luck (2001) defines a hierarchy composed by four layers having entities, objects, agents and autonomous agents. However, it presents the following limitations: (i) in this framework the environment entity has only structural features without transactions, (ii) no dynamic aspect associated with the proposed entities is defined and (iii) it does not provide elements to define correctly the agent norms.

Yu and Schmid (2001) propose a conceptual framework for the definition of role-based agent-oriented MAS. Agents are showed as an entity playing roles within any organization. As weak points we highlight the following aspects: (i) Although agents are defined as an entity playing roles, this conceptual framework does not define the agent properties and relationships between agents and roles, (ii) Although the authors confirm that roles are played in organizations, the proposal does not define the organization properties and the relationship among them and roles, (iii) Neither it defines the environment entity in which

they contain agents and organizations, (iv) it does not allow to describe the elements of norms and (v) it only restricts the agent's behaviour in context of a role.

According to [Dardenne, Lamsweerde and Fickas, 1993], KAoS is a conceptual framework that defines abstractions, such as entities, relationships and agents, as object extensions. An entity is an autonomous object independently of other objects. A relationship is a subordinated object. An agent is an object that has a choice and behavior, and defines beliefs, goals and actions. We can mention some weak points for this framework: (i) KAoS does not consider organizations, roles and environments; (ii) it does not explain in a satisfactory way, the distinction between an entity and an agent; (iii) it does not describe the object features or explains how it is extended by other abstractions; (iv) it does not define any dynamic aspect associated with the described entities and (v) it describes only policies to restrict the access to properties of its abstractions.

The organization model Moise+ [Hübner, Sichman and Olivier, 2002] is based in model Moise [Hannoun, 2002] that presents an organization-centred view considering three forms to represent the organizational restricts (roles, plans and norms). Moise+ has two central notions to represent the organization: (i) organizational specification, that agent group adopts to create an (ii) organizational entity, that its action is designed to achieve a goal. Moise+ allows the description of permission and prohibition norms for roles in context of an organization. However, only non-communicative actions can be restricted by the norm. This model presents the following weak points: (i) it does not allow the environment specification. Thus, the modelling agents moving from one environment to another is not possible; (ii) it does not define the agent properties; (iii) it does not allow the norm specification for agents and environments and (iv) it does not support the definition of sanctions.

The organization model OperA [Dignum, 2004] is a framework that allows the specification of MAS through of the distinction between the characteristics (structure and behaviour) of the organization model and the behaviour of the agents in this model. This framework has the models: organizational, social and interaction for the modelling of organizations and their components. The model describes the organizational structure of the society along with the roles and interactions defined by stakeholders of the organization. OperA allows the description of norms of obligation, permission and prohibition for agents, agent roles and agent groups in context of organization. Additionally, it allows the definitions of restrictions for norm activation. However, this organizational model: (i) it does allow the modeling the structural aspects of agents and environments, (ii) it does not support the definition of reward, only punishment and (iii) it does not restrict the agent behaviour in context of an environment.

4. Extending Framework TAO

The extension of TAO is based in the inclusion of the elements that compose the norms. These elements are presented in the section 2.2. Thus, in TAO are defined the entity Norm and four relationships: Context, Restrict, SanctionReward and SanctionPunishment.

The creation of the abstraction Norm is necessary because it has a state, behavioral properties and specific relationships. Additionally, the following relationships are defined for allow the association of norms with the entities defined in TAO: (i) Context, that is responsible for identification of the context that the norm will be applied; (ii) Restrict, that identifies the entities that will be restricted by the norm; (iii) SanctionReward, that

identifies the rewards of the determined norm and (iv) SanctionPunishment, that identifies the punishments of the determined norm. The Figure 2 shows the extension of TAO along with the new abstraction Norm and its relationships. In the next Sections, this abstraction and its relationships are described and their representations are done through templates.

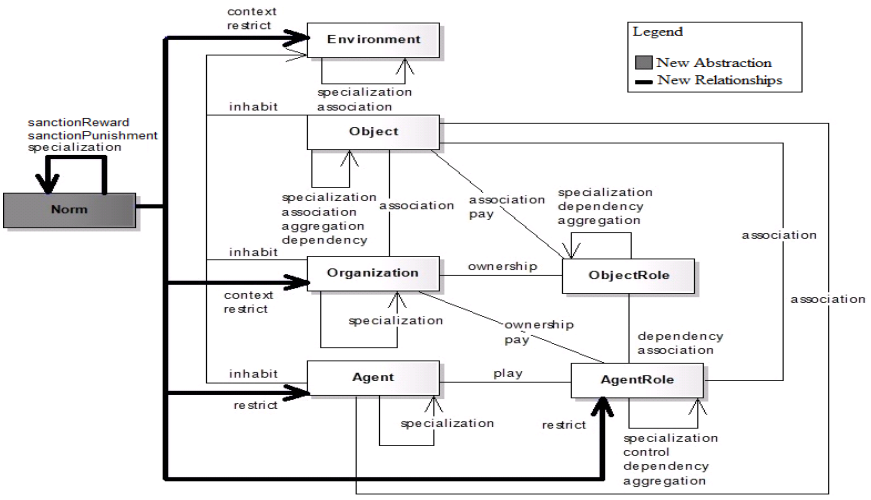

Figure 2. New abstractions and relationships in TAO.

4.1. Norm: A New Abstraction

Norm is an element that restricts the behavior of agents, agent roles, organizations and sub-organizations. A norm restricts the behavior of entities during a period of time and it applies sanctions when violated or fulfilled [Silva, Braga and Figueiredo, 2010].

A norm is an element with state and behavior properties, and its relationships. The state of a norm stores the resource to be restricted. According to [Silva, Braga and Figueiredo, 2010], the resource may be restricted by the norms can be an entity or a property of an entity. The entities that can be governed by norms include: (i) an agent, (ii) an agent role, (iii) an organization, or (iv) an environment. In adding, the restricted properties include: (i) a goal, (ii) a belief, (iii) an attribute, (iv) a method, (v) an action, (vi) a plan, (vii) a protocol, (viii) an association or (ix) a message.

The behavior of a norm is defined based on its characteristics. The characteristics of norms are based in deontic concepts and activation constraints. The deontic concepts define the restriction type of the norm. A norm may be obligation (what the agent must execute), permission (what the agent can execute) and prohibition (what the agent cannot execute). The activation constraints define a period in which the norms are active. A norm may be activated by a constraint or a set of constraints that can be: (i) the execution of actions, (ii) specifying time intervals (before, after or in between), (iii) the realization of system states or temporal aspects (such as dates) and also (iv) the activation / deactivation of other norm and fulfilment / violation of a norm.

The relationships of a norm describe (i) the context that determines the application of norm, (ii) the entity that has its behavior restricted and (iii) the reward or punishment that may be received by the entity that has fulfilled or has violated the norm. These relationships are extensively described in Section 4.2. The norm template presents a norm class. A norm class

defines its state as the resource to be restricted, the behavior of its instances as a set of its properties and a set of relationships that are common to all norm instances.

Norm

Norm_Class Norm_Class_Name
Restriction_Type Deontic_Concept_Name
Resource <Element_Class_Name.property >
Activation_Constraint setOf{Constraint_Type Constraint _Type_Name : (<Element_Class_Name_First> and/or <Element_Class_Name_Second>) or <date> or <Element_Class_Name.property : Operator = (Element_ Class_Name.property) or value)>}Relationships setOf {Relationship_Name}
End Norm_Class

4.2. Norms Relationships

This Section presents the relationships between the elements of the conceptual framework with new abstraction Norm. Three new relationships are introduced to indicates others properties of norms.

Let **A** be a set of agents, **a** ϵ **A**, **E** be a set of environments, **e** ϵ **E**, **N** be a set of norms, **n** ϵ **N**. and **O** be a set of objects, **o** ϵ **O**. Let **Org** be a set of organizations, **org**, **subOrg** ϵ **Org** and **subOrg** always represents a sub-organization. Let **R** be a set of roles, **R** = **RObj** U **RAg** where **RObj** is a set of object roles and **RAg** is a set of agent roles, **r** ϵ **R**, **ro** ϵ **Robj** and **ra** ϵ **RAg**. For each one relationship presented below, we present its definition, its classification and the elements that are linked through it.

- Context (C): C(context, norm): C(e, n), C(org, n), C(subOrg, n) – Norm requires the definition of the application context. The context relationship defines that the environment, organization or sub-organization are application context of norm. The behavior of all the elements related to the environment, organization and sub-organization will be governed by the norms.
- Restrict (R): R(element, norm): R(a, n), R(e, n), R(org, n), R(subOrg, n), R(ra, n) – The restrict relationship defines which entity will have their behavior constrained by the norm. If the entity fulfills or violates the norms, the sanction will be applied.
- SanctionReward (SR): SR(reward, norm): S(n, n) – The sanctionReward relationship specifies the reward that can be received by the entity that has fulfilled the norm.
- SanctionPunishment (SP): SP(punishment, norm): S(n, n) – The sanctionPunishment relationship specifies the punishment that can be received by the entity that has violated the norm.

The relationship template is used to define the links between the elements. For each relationship type, the template identifies the elements and its roles in the relationship.

Relationship

Relationship Relationship_Name
CONTEXT : context, norm
| RESTRICT : element, norm
| SANCTION_REWARD : reward, norm
| SANCTION_PUNISHMENT : punishment, norm
End Relationship

4.3. Inclusion of Norm in TAO's Abstraction

In addition to setting the new element Norm and their relationships, adaptations on the already existent abstractions are necessary. According to [Silva et al., 2003], an agent role guides and restricts the behavior of an agent since the goals, beliefs, duties, rights, protocols and commitments associated with the role characterize the agent while playing the role. In the original conception, the concept of right and duty are used to define the actions that can and must be executed by agents. These concepts can be considered semantically equivalent to the deontic concepts of permission and obligation defined in the norms. Thus, the concepts of right and duty have been replaced by norm concepts in the Agent Role template.

Agent_Role

Agent_Role_Class Agent_Role_Class_Name
Goals setOf{Goal_Name}
Beliefs setOf{Belief_Name}
Actions setOf{Action_Name}
Protocols setOf{Interaction_Class_Name}U setOf{Rule_Name}
Commitments setOf{Action_Name}
Relationships setOf{Relationship_Name}
End Agent_Role_Class

An organization defines a set of rules and laws that agents and sub-organizations must obey. The rules and laws are used to characterize the global constraints of the organization [Silva et al., 2003]. Considering that the concept of norm includes rules and laws features, in the new configuration, these concepts was removed and substituted by norm in organization.

Organization

Organization_Class Organization_Class_Name
Norms setOf{Norm_Name}
Actions setOf{Action_Name}
Relationships setOf{Relationship_Name}
end Organization_Class

In TAO, the environment abstraction incorporates the access restrictions associated with theirs services and resources [Silva et al., 2003]. In other hand, the norm concept considers the definition of access restrictions related with services and resources in the environment. Therefore, the concepts of services and resources have been removed and replaced by the norm concept in the environment.

Environment

Environment_Class Environment_Class_Name
Norms setOf{Norm_Name}
Behavior setOf{Properties}
Relationships setOf{Relationship_Name}
Events generated: setOf{Event_Name}, perceived: setOf{Event_Name}
end Environment_Class

5. Case Study

This section presents the modeling of the virtual marketplace [Silva, 2004] using the proposed extension of the TAO addressing the norm concepts related to the entities in MAS.

5.1. Virtual Marketplace

Virtual markets are markets located on the Web useful to the users buy and sell items. Each one consists of a main market where the users can negotiate any type of item. In addition, the market defines two main types: (i) markets for special products that negotiate expensive and high quality items, and (ii) markets for used product that negotiate low quality and low price items. The users can: (i) buy items on the main market, in markets with special products and used products, and (ii) sell its items in markets for used product. In the main market and markets with special products, the users buy the items available on the market. The main market calculates the profits, so the markets with special products and used product must send the information relating to sales to the main market.

5.2. Identification of Virtual MarketPlace Entities

In Virtual Marketplace environment is possible to identify the main organization General Store and its two sub-organizations, Imported Bookstore and Second-hand Bookstore, performing the roles, Market of Special Goods and Market of Used Goods, respectively. The modeling of the environment Virtual Marketplace is shown below.

Virtual_Marketplace

Environment_Class Virtual_Marketplace
Norms setOf{N1}
Behavior setOf{Open, Heterogeneous}
Relationships setOf{Inhabit_VirtualMarketplace _GeneralStore,
Inhabit_VirtualMarketplace _Imported Bookstore,
Inhabit_ VirtualMarketplace_ user agent, ...}
Events perceived: setOf{Group_Forming}
end Environment_Class

The modeling of the organization General Store is shown below.

General_Store

Organization_Class General_Store
Norms setOf{N2, N3, N4, N5}
Relationships setOf{Ownership_GeneralStore_ImportedBookstore,
Ownership_GeneralStore_SecondhandBookstore, ... }
end Organization_Class

Moreover, in this system two types of agents are identified: user agent, which can play the buyer role and the store agent, which can play the manager and seller roles. These roles were defined by the main organization, along with the object roles desire and offer. Instances of these roles are played by the instances of the Book class, which inherits from the Item superclass and has two subclasses, SecondHandBook and ImportedBook. The modeling of the agent role Buyer is shown below.

Buyer

Agent_Role_Class Buyer
Goals setOf{ buy_products }, Beliefs setOf{ Offer, Product }
Actions setOf{ payGood, buyGood, finderSeller, reportStatusOffer}
Protocols {FIPA_Protocol}, Commitments {pay_for_Product}
Relationships {Association_Buyer_Seller, Association_Buyer_Manager, ... }

End Agent_Role_Class

5.3. Definition of Norms to Virtual MarketPlace

For the defined virtual Market in [Figueiredo, 2011], were established the following norms along with their respective modeling:

- N1: All Virtual Market's seller has permission to update stock of good.
- N2: General Store organization's buyers are required to pay for items they bought.
- N3 (Punishment): Buyers that have violated N2 norm are forbidden to buy items.

N1

Norm_Class N1
Restriction_Type Permission
Resource Good.updateQuantity
Relationships setOf{Context_VirtualMarketPlace_N1, Restrict_Seller_N1}
End Norm_Class

N2

Norm_Class N2
Restriction_Type Obligation
Resource Buyer.payGood
Activation_Constraint {after : Buyer.buyGood}
Relationships setOf{Context_GeneralStore_N2, Restrict_ Buyer _N2, Sanction_N3_N2}
End Norm_Class

N3

Norm_Class N3
Restriction_Type Prohibition
Resource Buyer.buyGood
Relationships setOf{Context_GeneralStore_N3, Restrict_ Buyer _N3}
End Norm_Class

Additionally, for the proposed definition and modeling in [Silva, Braga and Figueiredo, 2010], the entities Market of Special Goods, General Store, Imported Bookstore, Second-hand Bookstore, Buyer and Seller define constraints on the agent and sub-organization behaviors. This role determines that the agents playing the role have an obligation (duty) to search for buyer agents and the right to accept or reject a proposal submitted by a selling agent. Now, these concepts are modeled by two new norms:

- N4: Buyer agents linked to Buyer roles must look for seller agents.
- N5: Buyer agents linked to Buyer roles can send messages about the proposal situation to a seller agent proposal.

N4

Norm_Class N4
Restriction_Type Obligation
Resource Buyer.finderSeller
Relationships setOf{Context_GeneralStore_N4, Restrict_ Buyer _N4}
End Norm_Class

N5

Norm_Class N5

Restriction_Type Permission
Resource Buyer.reportStatusOffer
Relationships setOf{Context_GeneralStore_N5, Restrict_ Buyer_N5}

End Norm_Class

5. Conclusion and Future Works

The TAO represents a basic ontology defining the core set of abstractions for large-scale MAS. However, the support related to norms is restricted since the deontic concepts are partially supported in TAO. This paper presents the extension of the TAO in order to enable the integration between their entities with the concepts related to norms, along with deontic concepts, entities involved, actions, activation restrictions, sanctions and context.

The extension proposed involves the creation of the Norm abstraction and three relationships: (i) context, (ii) restrict and (iii) sanction. These relationships allow to indicate others properties of norms. The properties of each abstraction and relationships are specified through templates. Additionally, adjustments in the templates of already existent abstractions are proposed in order to include the concepts related to norms. In (i) agent role abstraction, were removed from the concepts related to duty and right, (ii) organization abstraction, was removed the concept related to axiom and (iii) environment abstraction, were removed from the concepts related to the restriction of services and resources. Thus, the extended TAO allows the modeling of all the concepts present in Section 2.2. The case study is centered on the modeling of a Virtual Market through the use of templates, aiming to illustrate the adequacy of the proposed extension.

As future works we consider the following aspects: (i) the formalization of the proposed templates, (ii) the integration of the agents' internal architectures defined in [Russell and Norvig, 2004] and norms elements and (iii) a new TAO extension considering the setting made in (ii).

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