

Representing Organizational Structures in an Enterprise Architecture Language

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Abstract

Enterprise Architecture (EA) promotes the establishment of a holistic view of the structure and way of working of an organization. One of the aspects covered in EA is associated with the organization's "active structure", which concerns "who" undertakes organizational activities. Several approaches have been proposed in order to provide a means for representing enterprise architectures, among which the ArchiMate, an EA modeling language. In this paper, we present a semantic analysis of the fragment of the ArchiMate metamodel related with the representation of active structure. In addition, we present a proposal to extend the metamodel based on a well-founded ontology for the organizational domain. Our objective is to enrich the language with important capabilities to represent organizational structures using a principled ontology-based approach.

Introduction

Enterprise Architecture (EA) promotes the establishment of a holistic view of the organization in order to provide organizations with the ability to understand its structure and way of working. As defined in [1], the description of an EA usually "takes the form of a comprehensive set of cohesive models that describe the structure and functions of an enterprise". The majority of EA frameworks considers an organization as a system whose elements include: (i) organizational activities structured in business processes and services; (ii) information systems supporting organizational activities; (iii) underlying information technology (IT) infrastructures, and (iv) organizational structures (organizational actors, roles and organizational units).

This last domain of elements is also called "active structure" [2] and concerns "who" undertakes organizational activities. Active structure focuses on the business agents that perform tasks and seek to achieve goals, encompassing the definition of business roles, authority relationships, communication lines, work groups, etc. The relevance of organizational structure is clear from a management perspective in that it defines authority and responsibility relations between the various elements of an enterprise. Further, from the perspective of enterprise information systems, organizational actors can be considered as system owners, system maintainers, system users or simply system stakeholders in general, affecting the usage and evolution of such systems [3]. Our ultimate goal is to produce EA models that represent organizational reality faithfully and thus serve for the purposes of EA documentation, analysis and communication.

In this paper, we are particularly interested in the modeling of the active structure domain in the widely employed EA modeling language ArchiMate [2]. A strength of this language is the broad coverage of a wide number of aspects of EA, and the possibility to describe relations between the various aspects. Nevertheless, the emphasis on providing an overview of relations seem to have led to a less sophisticated treatment of some aspects, and that includes the active

structure domain. As a consequence, some shortcomings have been identified by the ontology community [4][5], such as limitations on its conceptual coverage and lack of clear real-world semantics for some of its constructs. The limitations in the coverage of concepts affect the language's ability to represent important organizational phenomena (affecting expressiveness, or what is called "completeness" in [6]). The absence of a well-defined real-world semantics opens space for interpretations not originally intended by a language user, resulting in ambiguous and inaccurate representations and ultimately in problems of communication between users.

Our primary goal is to address these limitations by proposing means to represent more sophisticated organizational structures in ArchiMate. We address this task with a principled approach. We first define a reference ontology for the active structure domain. Our objective for this reference ontology is to focus on core aspects of this domain in accordance with dominant themes in the management literature. Having this reference ontology enables us to analyze the capacity of ArchiMate to represent information about the active structure domain. We point out the problems and their consequences for the generation of high-quality EA models. Finally, we present a proposal to extend the language metamodel to address the identified issues and contribute to the increase of the expressiveness and clarity of the language.

This paper is structured as follows: Section 1 reviews basic organizational concepts in order to set minimum requirements for the representation of the active structure of organizations. Section 2 introduces the OntoUML Org Ontology (O3). Section 3 introduces ArchiMate active structure constructs briefly. Section 4 the analysis and revision of ArchiMate using the notions of O3. Section 5 discusses related work. Finally, Section 6 presents our conclusions.

1 Basic Notions in the Organizational Literature

In the organizational literature, some basic organizational notions are frequently referred to in order to characterize organizations. In this section, we discuss these notions, as they form basic requirements of expressiveness of organizational structure. We do not aim at exhausting all relevant aspects concerning organizational structure. We focus on three dominant themes in the management literature: (i) division of labor, (ii) social relations and (iii) types of structuring units.

1.1 Division of Labor

We, as human beings, have limitations on processing information and on accomplishing tasks [7]. Division of labor manages our human limitations and coordinates us to achieve organizational goals. Fayol defined in [8] that the division of labor aims to produce more and better, with the same effort, in addition to reducing the number of objectives upon which the attention and effort should be applied.

In a top-down view, organizations can be considered as systems composed of subsystems, each of which can be nested into subsystems recursively [9]. Division of labor consists in the top-down view of dividing an overarching organizational mission into specialized goals or tasks allocated to distinct well-defined units of work in order to increase efficiency. The creation of working groups aggregating individuals with heterogeneous skills that pursue a common purpose represents the definition of these subsystems (which we will call here Organizational Units). In a bottom-up view, "we are confronted by the task of analyzing everything that has to be done and determining in what grouping it can be placed [...] Workers may be easily combined in a single aggregate and supervised together" [10].

The division of labor in its highest degree of specialization is represented by defining "positions". At this level of granularity, the tasks are distributed among the various positions as official duties. This infers a clear division of labor between positions, as defined in [11]. Positions also allow the formalization of the organization based on descriptions of duties, rights, requirements and social relations assigned to reusable organizational roles and not directly on the actors who play them.

1.2 Social Relations

Within the universe of a formal organization, social relations of power and communication are of great relevance. Concerning power relations, [8] defines that authority is the right to command and the power to be obeyed. Without authority, i.e., without explicit formal organization in upper and lower positions, where the superiors have more power than the lower, the organization ceases to be a coordinated entity [12]¹. Apart from power relations, communication relations allow the definition of interactions between business actors without requiring the establishment of relations of authority. The existence of a relationship of authority between organizational actors implies the existence of a relationship of communication between them, but the contrary is not always true.

¹ This reveals our interest specifically in organizations that are, to a certain extent, hierarchical

1.3 Types of Structuring Units

The working groups that compose organizations have different natures. Different structuring principles (functional, line-staff, divisional, matrix and flat organizations) lead to different types of structuring units like departments, divisions, line units, staff units, teams and task forces.

In organizations structured following the line-staff model, one of the main distinctions is between line and staff units. The line units comprise the functional organization and represent the specialization of division of labor in functional/production units following different criteria of aggregation of individuals. The line units can relate through relationships of authority and are composed of other line units [13]. In contrast, staff units are units without administrative authority, who have the responsibility of advising the production units to perform actions and do not have full responsibility for the execution of tasks [14]. The “staff authority is subordinate to line authority, and they tend to identify line with managers or administrators and staff with experts and specialists” [14].

Other types of working groups present in organizations that adopt the matrix model are the teams and task forces [15], which are units with dual authority relationship, where the relationship of power is balanced between formal authority and technical authority [15]. Teams and task forces aggregate employees belonging to different departments/divisions/line units and can have limited lifetime. In addition, these types of structuring units put together in a single unit the authority and information necessary for performing tasks [15]. The main difference between teams and task forces lies in the fact that task forces are used to solve temporary problems, while teams are used to solve recurring problems [15].

2 The Reference Domain Ontology

The basis of the semantic analysis of ArchiMate performed in this paper is a reference domain ontology which we call OntoUML Org Ontology (O3). It covers the organizational domain, focusing on the themes discussed in the previous section. In order to represent this reference ontology, we employ OntoUML, a UML profile that incorporates the foundational distinctions of the Unified Foundational Ontology (UFO) using UML stereotypes. Thus, our domain ontology employs and specializes the more general domain-independent notions of objects, types, events, social entities, etc. (A brief description of the required UFO concepts is given below in sections 2.1 and 2.2. See [6] and [16] for thorough presentations.) Our choice for UFO is based on the key role it has played in previous efforts in domain ontology engineering [16], harmonization of semantic models [17][18] and evaluation and revision of enterprise languages [3][19]. By specializing UFO, O3 provides an ontologically well-grounded view that covers the basic notions of the organizational domain.

2.1 Basic Entities

We start with the basic distinction in UFO between Individuals and Universals. Individuals are entities that exist in reality instantiating one or more universals and possessing a unique identity. Universals (more specifically *first-order* universals) are patterns of features that can be realized in a number of individuals. Roughly speaking, individuals can be viewed as elements and first-order universals as their types.

Substantials are individuals that do not need others individuals to exist, i.e., are existentially independent (e.g., a car, an apple, Bill Gates). Moments are particularized properties inherent to an individual and are existentially dependent on the individuals on which they inhere. Moments can be intrinsic or relational. Intrinsic moments apply to a single subject (e.g., an apple’s color, someone’s headache). Relational moments are called relators and depend on various relata (e.g., an employment contract relating an employee and an employer, a marriage contract between husband and wife) [6].

The stereotypes in OntoUML correspond to ontological distinctions for universals of UFO, enabling us to use class diagrams to represent ontologies that employ the distinctions of UFO. For instance, a class stereotyped as `<<category>>` represents a rigid concept, i.e., a class that applies necessarily to its instances (throughout their entire existence). A class stereotyped as `<<kind>>` also represents a rigid concept but one that supplies a principle of identity to its instances (e.g., Person). A class stereotyped as `<<role>>` (or `<<role mixin>>`), in turn, is an anti-rigid concept, applying contingently to its instances (e.g., a Person is only an Employee contingently and can cease to play that role and still exist). A role is also relational dependent, i.e., it defines contingent properties exhibited by an entity in the scope of a relationship (when an individual instantiates a role universal, it is thus connected to at least one other individual through a relator).

2.2 Intentional and Social Aspects

UFO includes a social layer that specializes its core with distinctions to account for intentionality and social reality [16]. An important distinction in this layer is that between agentive and non-agentive objects. Agentive objects (agents) can perform actions and have mental/intentional moments (intentions, desires and beliefs). Agents are differentiated in

physical agents (e.g., a person) and social agents (e.g., an organization). Objects are passive entities that can be used, consumed, destructed, modified and created by agents. Objects are partitioned into physical objects (e.g., a computer, a pen) and social objects (e.g., a piece of legislation, a language).

Normative descriptions are social objects that define rules/norms recognized by agents. Normative descriptions can define nominal universals, such as social objects (e.g., the crown of the King of Spain) and social roles (e.g., IT Analyst, surgeon).

2.3 OntoUML Org Ontology (O3)

O3 has been defined by extending the social concepts of UFO, such as social role, social agent and physical agent. In this paper we present fragments of O3 focusing on the concepts required for the purpose of this paper, namely, the analysis and revision of the ArchiMate active structure elements. We discuss the ontology following two points of view: (i) organizational structure (section 2.3.1) and (ii) roles (section 2.3.2).

2.3.1 Organizational Structure

Figure 1 presents the fragment of O3 related with the organizational structure concepts. The top-most concept is organization, specializing the UFO notion of Social Agent. As defined in [12], organizations are (artificial) social units built with the explicit intention of pursuing specific goals. In another definition, organizations are defined as "collectivities that have been established for the pursuit of relatively specific objectives on a more or less continuous basis" [20]. Human resources are among the major means used by organizations to achieve its goals [12]. In healthy organizations, the organizational goals are assimilated by its human resources in combination with its personal goals. Organizations include corporations, armies, hospitals and churches, but exclude tribes, ethnic groups, families and groups of friends. Organizations are characterized by division of labor, presence of one or more power centers that control the combined efforts of the organization and coordinate activities to achieve goals. Members of an organization can be replaced or relocated to other functions without the organization ceasing to exist. An organization may be structured into other social agents that together contribute to the operation or behavior of the whole, defining thus what is called a functional complex in [6]. (See [19] for a discussion on the whole-part relation of UFO applied at the organizational context.)

We specialize organizations into formal organizations and organizational units. Formal organizations are formally recognized by the external environment. Their creation is determined by normative descriptions or speech acts which are recognized by the normative context in which formal organizations exist. Examples of formal organization include Microsoft Inc., the UK Government and the Fed. University of Espirito Santo.

Organizational units are those organizations that are only recognized in the internal context of a formal organization and represent the working groups of a formal organization. An organizational unit can be a structural unit or a missionary unit. Structural units are closely related to functional structure of the organization, including line units and staff units. A line unit has authority relationships with other line units (upper or lower). Such relationships result in a hierarchy of authority. Furthermore, it may be composed of other line units, resulting in a relationship of authority (represented by the relationship "manages") between parts. The justification for the structuring of line units through two distinct relationships (whole-part and authority) lies in the fact that the whole-part relationship (in the organizational domain) naturally implies power, but power does not imply a whole-part relation. Examples of line unit include a Marketing Department, a Board of Directors and a Sales Division. As seen in Section 1, a staff unit is a "counselor" unit, which has no administrative authority, thus it is not part of line hierarchy composed by line units. Although they have no line authority, staff units relate to line units through the relation "staff of", which determines the line unit to which a staff unit responds. Examples of staff unit: a Group of Financial Advisors and an Internal Audit Group. Missionary units represent teams and task forces related to the matrix structure of the formal organization, such as a project group and a task force to deliver a product to the market in the schedule. A feature of this type of work group is the aggregation of actors belonging to different line units. Examples of missionary unit include an ERP Project Team, an Audit Committee and a Financial Task Force.

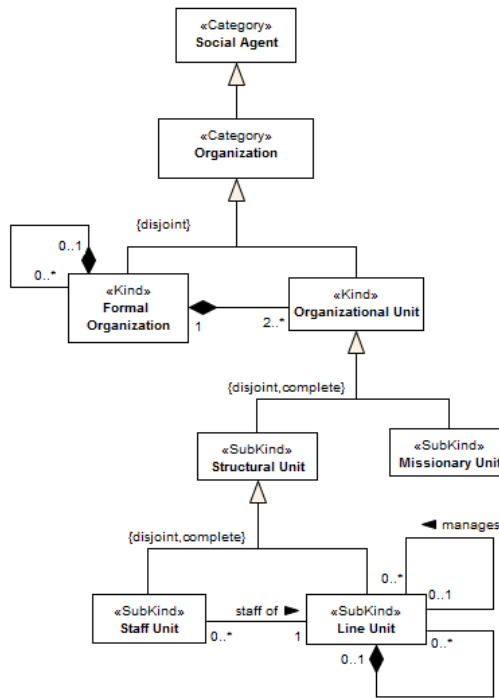


Figure 1: Fragment of OntoUML Org Ontology related with organizational structure.

2.3.2 Organizational Roles

Figure 2 presents the concepts related with the agents that compose the organization and the types of roles they may play. We are concerned in this fragment with the roles persons play, first of all as a member of a formal organization (formal organization member), and then when they are given more specific places in the power structure, either in a structural (line or staff) unit (structural unit member) or in missionary units (missionary unit member). (For the sake of brevity the diagram omits the <<relator>> classes that connect the individuals playing the roles and the formal organization, structural and missionary units.) Note that in order to play a particular role in an organizational unit, a person needs to be a formal organization member first.

In the scope of each organization, different specializations of these more general roles are required. For example, in a university, employee types such as “Professor” and “Secretary” become relevant, while in a hospital employee types such as “Doctor” and “Nurse” may be defined. Therefore, O3 includes the second-order notions of employee type and other business roles. They are to be instantiated in particular settings creating thus specific roles. The instances of employee type specialize formal organization member, and the instances of business role specialize either structural unit member or missionary unit member. We represent them by following UML’s “powertype” representation pattern with the second-order concept stereotyped <<hou>> (for higher-order universal), highlighted in gray. Specific employee types define the set of roles (business roles) that a typified employee can occupy in the organization (see “cover” relationship). Business roles defines more specific capabilities, duties and prerogatives possibly in the scope of organizational units. An employee allocated to a structural unit plays a structural business role; employees assigned to missionary units play missionary business roles. Authority relations between these types of business roles can be define through the relationships “is superior to”.

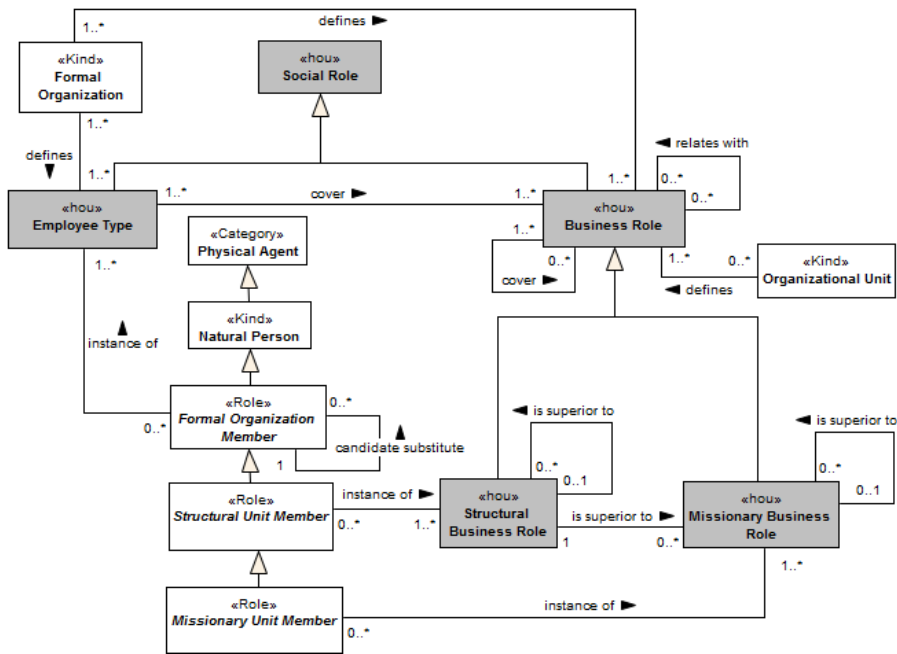


Figure 2: Fragment of OntoUML Org Ontology related with organizational roles.

3 An Overview of Active Structure in ArchiMate

For the purposes of this paper, we focus on the active structure aspects of ArchiMate’s business layer, whose abstract syntax metamodel is presented in Figure 3.

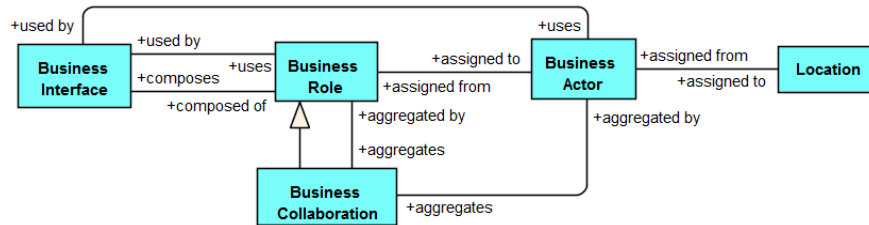


Figure 3: ArchiMate metamodel fragment and relations between active structure elements. Adapted from [2].

In the ArchiMate specification, a *Business Actor* is defined as “an organizational entity that is capable of performing behavior” [2]. It can represent an individual entity or a group entity, as a department, for example. Examples of *Business Actors* are: “John”, “Customer” and “Marketing Department”. A *Business Role* is the “responsibility for performing specific behavior, to which an actor can be assigned” [2]. Examples of *Business Role* include “Project Manager”, “Secretary” and “Sales Consultant”. In ArchiMate, a *Business Role* can be assigned to a *Business Actor* through a relation called “assignment”. The *Business Collaboration* construct represents the interactions between two or more *Business Roles*. The *Business Collaboration* does not have an official status within the organization and can be temporary [2]. An example of *Business Collaboration* is a “Supply Chain” collaboration performed between two organizations, which one plays the role of “Customer”, and the other plays the role of “Supplier”. A *Business Interface* exposes the functionality of a business service to *Business Roles* and *Business Actors*, or expects functionality from other business services. The exposed interface is a channel that provides means to interaction, e.g., “Internet”, “Mail”, “Telephone” and “Care Unit”. Finally, *Location*, in the scope of Business Active Structure, allows the definition of the distribution of the *Business Actors*. A *Location* “is defined as a conceptual point or extent in space” [2]. (In addition to the relations shown in Figure 3, all elements in ArchiMate can be related with other elements of the same type through the generic relations of composition, aggregation, association and specialization.)

Figure 4a presents an example of an ArchiMate model concerning business active structure. In this example, two *Business Actors* (“Insurance Department” and “Customer”), play the *Business Roles* of “Insurance Seller” and

“Insurance Buyer”, and interact through a telephone interface. Figure 4b presents an example of nested business actors, representing a composition or aggregation of actors in ArchiMate.

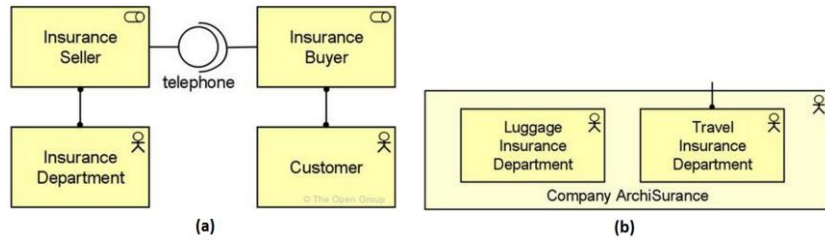


Figure 4: Examples of ArchiMate model with active structure elements [2].

4 ArchiMate Analysis and Revision

Using O3 as a semantic background, and based on the ArchiMate specification and official examples, a number of observations can be made with respect to the expressiveness of ArchiMate in the specification of organizational structures. First of all, we can note that the *Business Actor* construct is used indistinctively to model both social agents and natural persons. Absence of such distinction prevents the specification from elaborating on rules for the language’s syntax, e.g., aggregation (a whole-part relation) may be used inadvertently by language users to relate business actors representing natural persons (e.g., Mary as part of John).

Another point of attention identified is related with the inability to indicate that a business role is pertinent to an organizational unit. Despite the absence of such possibility in the current version of ArchiMate, this type of relationship was possible in earlier versions, as explained in [5]. In addition, it is not possible to represent the relation between staff units and line units, a basic notion of organization charts.

There is further no explicit construct for representing missionary units. Although there is a *business collaboration* construct, it is unclear whether *business collaboration* results in the definition of a new social agent. Finally, observing the ArchiMate metamodel (Figure 3), *business collaboration* seems to hide several problems: we can see that *business collaboration* can aggregate *business actors* without the intermediary of roles. Moreover, because it is a *business role*, *business collaboration* inherits all relationships of the *business role* construct, thus, an actor can “play” a collaboration. These situations defy a clear interpretation of the business collaboration construct as is.

Considering these shortcomings, we propose a revision of the metamodel, as shown in Figure 5. Classes marked with darker colours represents constructs added.

The constructs *natural person*, *organizational unit*, *formal organization*, *staff unit*, *line unit*, *missionary unit* and *employee type* of the revised metamodel have a direct mapping to the corresponding O3 concepts. The *business actor* construct is partitioned in three sub-categories: *formal organization*, *organizational unit* and *natural person*. The specialization of *business actor* comes in response to the overload of constructors present in the original meta-model.

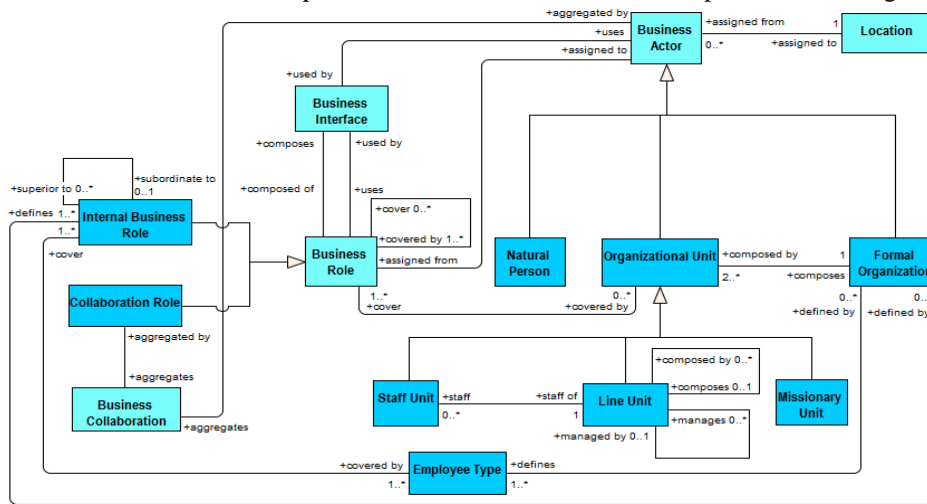


Figure 5: Extended metamodel of ArchiMate.

Besides the constructs added to the metamodel, we have added or removed some of the relationships between the constructs of the original metamodel. We modify extensively the *business role* construct, including a different proposal of semantic interpretation, which eliminates the semantic overload existing between a role in an internal context (played by an employee) and a role in an interaction context, e.g., between a supplier and an organization. In the revised metamodel the *business role* construct is thus specialized into: *internal business role* and *collaboration role*.

An *internal business role* defines more specifically than *employee type* the capabilities, duties and privileges of an employee who plays a certain role. Moreover, while it is a member of the organization, an agent can play different *internal business roles* (both at the same time, as well as switching between different roles). The *internal business role* construct also limits the range of business roles that a member of the organization that plays a certain *Business Role* can claim (through the "cover" relationship). This situation is common in matrix organizations where an employee can play a *business role* in a department and a different *business role* in a project. A *business role* is defined in the context of a *formal organization*.

Collaboration roles represent roles played in recurrent interactions outside and inside the organization. It is defined in the context of the *business collaboration* construct, being part of the definition of a collaboration. The *collaboration role* is more flexible than *internal business role*, admitting that an external actor (physical or social) may play the *collaboration role*, while only members of the organization can play *internal business roles*. In the revised metamodel, the *business collaboration* construct is also not a specialization of *business role*. We made this change in response to the semantic problems that arise from relationships that were inherited from business role in the original metamodel but that cannot be applied meaningfully to collaborations.

5 Related Work

The organizational structure domain has been the focus of a number of ontologies since the end of the 90s. The Enterprise Ontology EO, e.g., includes a fragment that addresses the organization structure domain [21]. It is described in natural language and is based on formalized meta-ontology, with good coverage of concepts related to organization structure. Differently from O3, it makes no distinction between staff, line and missionary units. EO also includes a direct relationship between a "person" and an "organisation unit" ("working for"), without the intermediary of roles or positions they play in the scope of an "organizational unit". In case a person plays multiple roles its not possible to define which role is played in the context of each "organisation unit". The organization ontology for the TOVE enterprise model [22] chooses for a fixed structure with three levels: organization, division and sub-division. It has a notion of team that is independent of these levels of decomposition. It does not distinguish staff and line units as well as the different categories of roles individuals may play. Roles are also not related to organization units (only indirectly through authority). The Organizational Structure Ontology of the SUPER project (OSO) [23] is aimed at providing organizational context for the execution of business processes. Differently from O3, OSO is not specified using a well-defined language and is not based on a foundational ontology. Further, it does not include some important distinctions in O3 (line vs. staff units, different sorts of roles). The W3C Org Ontology [24] concerns the description of organizational structure for Semantic Web applications. It is defined in OWL and, given its focus on Semantic Web data, it is less suitable for meaning negotiation, which is required in our intended application (semantic analysis and language revision). It does not make fine distinctions in the sorts of roles that can be played in an organization as well as the different kinds of organizational units (staff, line, missionary). The W3C Org Ontology is further not grounded in a foundational ontology. Finally, E-OPL [25] aims to provide a basis for an enterprise pattern language whose fragments can be selected flexibly. It is grounded in UFO and is defined using OntoUML, however it does not cover missionary and staff units, which is important to the representation of organograms in EA descriptions. We intend to add patterns to E-OPL that reflects the distinctions in O3 as part of our future work.

In a broader scope, some approaches aim to provide languages for representation of EA aspects in general, including the organizational structure aspects. UPDM [26], e.g., is a profile for DoDAF and MODAF frameworks focused on representation of EA aspects in UML, including active structure elements. It is grounded on the IDEAS foundational ontology. UPDM lacks expressivity, since it does not differentiate types of organizational units and types of business roles. It could also have been the subject of our analysis (along with other EA modelling techniques beyond ArchiMate).

The use of reference ontologies for evaluating and revising enterprise modeling languages have been shown to be promising, as observed in [4][5][3][19]. The efforts most closely related to this work include: a semantic analysis of another fragment of ArchiMate (more specifically the motivational layer [4]); a semantic analysis of the notion of role in ArchiMate and other EA description techniques [5]; and an analysis and revision of the ARIS capabilities for organizational structure modeling [3]. Here we address a different language (or language portion) and we use more specialized domain concepts (with domain distinctions that complement general UFO notions).

6 Final Considerations

This work demonstrates the application of an organizational ontology in the semantic analysis and improvement of a modeling language and is part of a research for defining a well-founded ontology for the organizational domain. The organizational domain ontology presented covers the basic aspects discussed in the organizational literature, such as division of labor, social relations and classification of structuring units. We have intentionally left out in the current version aspects related to skills, resource allocation, business interaction and communication relations.

The use of the well-founded OntoUML profile for modeling O3 leverages the conceptual distinctions in UFO as well as the tool support already developed for OntoUML. Future work in the development of O3 include employing the OntoUML tools for formal verification of the model (guaranteeing that the models are compliant with UFO axioms), validation of the model via visual simulation (relying on an OntoUML infrastructure developed on top of the Alloy Analyzer) as well as the systematic implementation of O3 in computational level languages such as OWL.

The analysis using O3 has revealed predominant themes of the literature on organizational structure – those that have influenced the design of the O3 – have been left out of the range of expressions of ArchiMate. We have proposed a revised metamodel that address the identified shortcomings, enabling a more sophisticated representation of organizational structures in the language. We have strived to maintain the alignment of the introduced revisions with the original metamodel in order to favor the acceptance by prospective users. Thus many of the additions are in fact specializations of the existing constructs of the language. Further investigation is required in order to propose graphical conventions to represent the abstract syntax elements identified here.

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