Modeling Competence Framework Elements with an Ontology-based Approach

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***Abstract*—Organizations are required to pay constant attention to human resource development in order to prosper. Competence frameworks have received increased attention in this context, as the availability of qualified people with the right combination of competences establishes itself as a major issue for organizational performance. This paper investigates the modeling of competence frameworks in Enterprise Architecture: (i) we identify a key set of competence-related concepts found in competence frameworks; (ii) analyze them using the Unified Foundational Ontology to build a reference Competence Ontology, and, then; (iii) propose well-founded representation patterns for competence modeling in the ArchiMate EA language, discussing how these patterns can be embedded in enterprise competence-based practices.**

***Index Terms*—Competences, Ontologies, Competence Modeling, System Engineering, Enterprise Architecture**

I. Introduction

Considering the significance of human performance in business and in society at large, it is no surprise that the development of competences has received great attention. Advances in fields such as Vocational Education and Training (VET) and Human Resource Management (HRM) have resulted from the ongoing pursuit of human development. One of these advances has been the steady change from content-based to competence-based methods, which reflects a shift from a Supply-Oriented Model to a Demand-Oriented Model [9], [38].

Competence-based practices connect an organization's strategic imperatives with its major HRM initiatives in the businesses' context [14]. Competence-based practices are employed in a variety of aspects of human resource management, including individual selection, development, and performance management, as well as organizational strategic planning [37]. An organization can do self-assessment to enhance its HRM programs, such as talent acquisition procedures, performance management systems, training and development tools, employee retention policies, and organizational development plans, by reviewing staff competences [14]. Generally, these practices are realized in a context involving organizational capability development.

Commonly, in an organization, these practices are supported by well-known competence frameworks (e.g., [12], [23], [44]). Generally, they are applied to support some competence management tasks, such as competence assessment or identification. In this context, they provide a wide description of the desired competences expected by each required position in a specific business area or context. These descriptions frequently include elements such as observable characteristics that contribute to competent performance (i.e., skills, attitudes, and knowledge) and also some practical evidence of such competent performance (i.e., observable behaviors, performed tasks, products, and outcomes).

Despite their clear usefulness, these frameworks are defined as documents outside the scope of Enterprise Architecture (EA) frameworks or modeling approaches. Hence, there is a need to bridge the gap between the elements defined in competence frameworks and those in use in EA approaches.

In this work, we investigate how to support the modeling of the various elements of competence frameworks in an Enterprise Architecture (EA) context. By examining the importance of "individual capabilities" in an Enterprise Architecture, this research also complements previous work on capability-based strategic management [1] and ontology-based competence representation [7], [8]. To offer competence modeling representation strategies in Enterprise Architecture, we adopt a systematic approach. We defined the ontology's requirements and competency questions based on an analysis of some competence frameworks. Then, we first identify competence-based concepts aligned with the Competence Management literature. These concepts reflect a number of elements found in various competence frameworks, including: (i) human functional role (e.g. job position or occupation); (ii) human capabilities (competences and skills) and human aspects (knowledge, attitude, etc); (iii) human capability evolution (e.g. level of skill, proficiency level) and; (iv) human capability manifestation and results (e.g. tasks and artifacts). Following, we propose a Competence Ontology focused on these elements, the purpose of which is to clarify their semantics and their relations. This reference ontology is grounded on the Unified Foundational Ontology (UFO) [17] and builds up on the efforts reported in [7], [8]. Then, we validate this ontology based on the competency questions. This ontology is ultimately used as the basis to derive *well-founded competence representation patterns* in the ArchiMate EA language, enabling the use of competence framework elements in EA practice. We explore how these patterns can be incorporated into enterprise competence-based approaches, aligned with capability-based practices. Further, an implementation of the reference ontology is provided to support the structured representation of competences, allowing their machine processing.

The paper is structured as follows: Section II presents the theoretical background for this research, which includes a brief survey of the relevant literature on competences in the organizational context. Section III addresses the ontological analysis of competence and other fundamental competence-related concepts and describes the proposed UFO-based ontology; Section IV draws implications to a representation of competence framework elements in ArchiMate; Section V discusses related work and; Section VI presents our conclusions.

II. Competences in the Organizational Context

A. Competences

In a general sense, "competence"[1] is seen as a kind of human ability [30], [38], [46]. Some authors, such as [11], [43], state that competence consists of both an implicit and an observable component. From the implicit perspective, competence is formed by a latent cognitive structure that cannot be directly measured [43]. According to [46], competence is a result of the association of internal structures of declarative and procedural (task-related) knowledge that inhere an individual. From the observable perspective, competence is formed by the combination of perceptible characteristics, such as the "well-known" *knowledge*, *skills*, and *attitudes* (KSA) elements. These elements enable an individual to perform *tasks* efficiently [11], [30]. In this sense, competence generally has a performance-oriented aspect, more focused on "results" and task accomplishments [30], [38]. Wood and Power [46] reinforce this facet, defining competence as the ability to use knowledge or skills to act effectively to achieve some purpose through successful performance.

B. Competence Management

In this context, the CM discipline is one of the main approaches that help in competence development in an organization. CM is formed commonly by four macro-steps [11]: (i) mapping; (ii) diagnosis; (iii) development; and (iv) monitoring. The first step (mapping) is focused on the identification of desired competences of an organization, while the second step (diagnosis) is focused on discovering the competences the organization currently has or lacks. The third step (development) proposes concrete strategies to reach the desired competences from the current situation. Finally, the fourth step (monitoring) focuses on the continuous tracking of desired competence accomplishment [11]. Such macro-steps are supported by various tasks and processes such as competence identification, assessment, planning, modeling, and *gap analysis*. The latter is one of CM's most challenging tasks since it involves the comparison of current with desired (future) competences. Based on this, an organization can define strategies to reach a competence development stage [11].

C. Competence Models and Frameworks

In order to facilitate CM tasks, a number of reusable competence 'models' and frameworks have surfaced, defining organization-independent competences and skills. Some of these are "domain-specific", e.g., in the Software Engineering [12], [36], [40] and in the Systems Engineering [21], [23], [28], [44], [45] domains. Some are entirely domain-independent, such as Bloom's taxonomy [25], which classifies skills (or "generic" tasks) expected by an individual in distinct areas (affective, cognitive, and psycho-motor) and (complexity) levels.

D. Proficiency Level and Competence Development over Time

Most of the frameworks consider distinct levels of proficiency for competences [38]. Examples of such levels include: 'foundational', 'intermediate', and 'expert' [28]; or yet, 'awareness', 'supervised practitioner', 'practitioner', 'lead practitioner', and 'expert' [23]. Commonly, for each identified level of proficiency, there is some expected evidence or some indicator of the corresponding competence. Depending on the framework, this evidence includes observable characteristics (e.g. the KSA elements) and also observable results (e.g. products, outcomes) and behaviors (e.g. activities, tasks performed).

Proficiency represents the experience (i.e. expertise) that a person has in a competence (or skill) [46]. Generally, in a practical sense, it is referred to as a qualitative level or degree (i.e. low, medium, high) associated with a competence (or skill) [30] whose value varies over time. As a result, it can rank individuals' competences based on their individual learning, evolution, and range of experience [24]. Establishing a level (or grade) of proficiency helps in gap analysis and other CM tasks. Based on established proficiency levels, competence development strategies can be defined with a focus on increasing individuals' proficiency [24]. An individual's internal cognitive structure is dynamic. It can thus modify over time as a result of experiences stimulated by projects, systematic instructions, or other events. Practice and repetition help to develop competences. When individuals develop their competences, they enhance their ability to solve issues, predict

[1] We adopt in this work the term "competence" to refer to an individual's performative ability, and refrain from using the term "competency".

circumstances better, and increase flexibility and adaptability [27], [43], [46].

III. The Well-Founded Competence Ontology

A key step in our approach to addressing competence framework elements in EA is the development of a reference ontology covering the relevant notions. This ontology can then serve as a semantic foundation for well-founded competence representation in an EA language.

A. Foundational Baseline

We build up on the competence ontology concepts proposed in [7], [8], which in turn, build up on the UFO foundational ontology [18]. The relevant fragment for our efforts is shown in the UML class diagram in Figure 1. Elements in green are part of the UFO foundational layer, and elements in yellow in the shaded part correspond to a specialized layer focusing on competence-related notions.

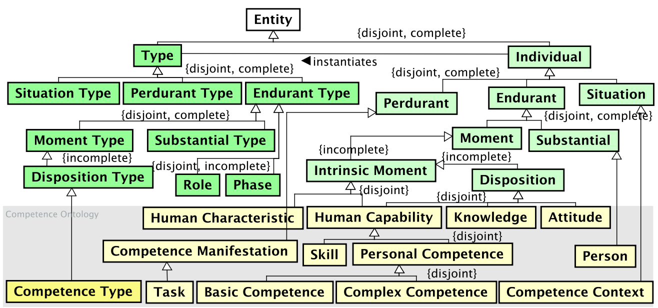

Figure 1. Unified Foundational Ontology (green concepts) and UFO-based Competence Ontology Fragments (yellow concepts)

The foundational layer includes domain-independent categories, starting with the distinction *types* (universals) and *individuals* (particulars). *Individuals* are further classified into *perdurants*, *endurants*, and *situations*. *Perdurants* (also termed events) are *individuals* that occur in time (i.e. activities, actions, tasks, processes). *Endurants* are individuals that persist in time while retaining their identity (i.e. people, organizations, projects, cars). *Endurants* include *moments* and *substantials*. *Moments* inhere in an *endurant* (termed its bearer), on which they are existentially dependent. All *endurants* can have essential and accidental properties and can change qualitatively while retaining their identity. *Moments* include *intrinsic moments*, which are existentially dependent on a single *individual* and can be either a *quality* (e.g. color, height, weight, and electrical charge) or a *mode* (e.g. John's headache). Following [1], [29], we assume that *modes* include what are known as *dispositions* ("powers" or "capacities") in the philosophical literature [31] (such as a magnet's disposition to attract ferrous materials or Anna's English speaking skill). *Dispositions* are modes that can be manifested through the occurrence of *perdurants* (possibly agents' intentional actions, such as Anna's speaking English). In *situations* where *dispositions may manifest*, they are said to be "activated" (e.g., when a magnet is close to some ferrous material; or when Anna is prompted to introduce the topic of a meeting).

In the competence layer, *human capabilities* are special types of *dispositions* that inhere in a *person* (a *substantial* subtype). *Human Capability* encompasses all human abilities, from those that are innate (inherited) to those that can be learned (formally or not), and is manifested through a *task* (an action with some goal or a work unit).Compared with personal competences, skills are simpler, less context-independent, and manifested in atomic tasks (e.g., java programming). Otherwise, *personal competences* (e.g., John's agile software development competence) are composed of human aspects like *skills* (e.g., John's Java programming skill), *knowledge* (John's design pattern knowledge), *attitudes* (e.g., John's collaboration attitude), and *human characteristics*. Like *human capabilities*, *knowledge* and *attitudes* are also subtypes of *dispositions*, since they can be manifested through some action (not necessarily a task). *Human characteristics* can be *dispositions* too, but not only. They can also be human qualities (such as age, height, etc) or also human traits (e.g., John's introversion and interests). As a result, they are a subtype of *intrinsic moments* in UFO terms.

B. Beyond Individuals

While the competence ontology presented in the previous subsection has been instrumental in the representation of individuals and their properties as demonstrated in [7], [8], competence frameworks demand further attention to the *universal* aspects of competences. These are key to account for "generic human capabilities" (*types* of skills and competences) and also "generic human aspects" (*types* of knowledge and attitudes) expected when someone fills a specific "position" in an organization (e.g. occupations or functions). Because of this, we add here concepts to the taxonomy of *types*. As can be observed in the left-hand side of Figure 1, in previous work, this taxonomy was under-explored in the competence layer, with only an unspecific notion of *Competence Type*.

By specializing the taxonomy of types in the competence layer, we mean to address: (i) the universal (i.e. not related to a specific individual) representation of "generic human capabilities" (such as skills and competences) and also "generic human aspects" (e.g. knowledge and attitudes) expected to a specific "position" (e.g. occupations or functions); (ii) the universal representation of the temporal (and intensity) aspect related to the human capability (and aspect) evolution through time, concerning the correspondent level of proficiency (or complexity); (iii) the universal representation of the competence manifestation (and performance) aspect concerning "generic" behaviors (e.g. tasks or attitudes) and artifacts (e.g. products) to allow better identification and assessment of human capabilities in an observable way.

We build up on the foundational layer which distinguishes *types* corresponding to the nature of the instantiated individuals, i.e., there are *endurant types*, *perdurant types*, *situation types*, *moment types*, *substantial types*, etc. *Endurant types* are also classified in an orthogonal way according to some metaproperties, e.g., rigidity. *Anti-Rigid Types* are those that apply contingently to their instances, classifying their instances dynamically and including *Phases* and *Roles*. They are the focus of our attention here, due to the dynamic nature of types that apply to persons in the context of organizations. *Phases* are the types whose contingent classification conditions are *intrinsic* (e.g., the various phases of persons according to age: Child, Adult, Senior Person). *Roles* are those types whose contingent classification conditions are *relational* (e.g., Student, Employee) [18].

C. The Proposed Competence Ontology

Figure 2 shows the hierarchy of proposed concepts, focusing on specialized types in the competence layer.

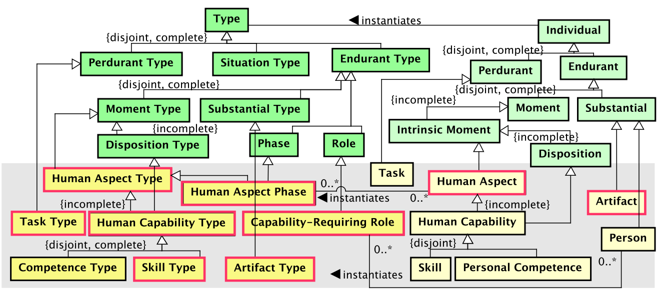

Figure 2. Proposed Concepts (in red), based on UFO Concepts (in green) - Hierarchical Perspective

As depicted, the main concepts considered are: (i) *capability-requiring role*, to allow the "generic" representation of positions, occupations, or functions performed by an "individual" *person*; (ii) *human aspect type*, to allow the "generic" representation of "individual" *human aspects* (proposed concept to generalize "individual" *knowledge*, *attitudes*, *human capability*, and other *human characteristics*; (iii) *human capability type*, to allow the "generic" representation and specification of *skills* and *competences* types related to a *capability-requiring role*; Regarding the "levels of proficiency" distinction, it is considered the *human aspect phase* concept, allowing the representation of the "individual" *human aspect* evolution (over time), i.e., correspondent to the level of *knowledge*, *attitude*, or *human capabilities*. Concerning the competence manifestation and results, the following concepts are considered: (i) *task type*, to allow the "generic" representation of the different kinds of behaviors, activities, and manifestations (and their characteristics) of human capabilities; (ii) *artifact type*, to allow the "generic" representation of the different kinds of products, outputs, and results of human capability manifestation.

1) Capability-Requiring Role: As seen, competence descriptions are related to the "*capability-requiring role*" concept. In this context, it represents any kind of formal or informal "position" or function, not related to a specific person, and that requires a capability. It has a temporary aspect since a person can perform a *capability-requiring role* for a while in one specific situation but not in another. This concept is considered relational since it is assigned through an external entity (e.g., a "contract"). In this sense, a *capability-requiring role* corresponds to a *role* performed by a person with certain capabilities. So, in UFO terms, we consider the *capability-requiring role* concept as a subtype of the *role* concept. This distinction is shown in Figure 2, where the *capability-requiring role* concept is a subtype of the *role* concept. Besides this, a *capability-requiring role* can "specialize" (e.g., the "front-end developer" role specializes the "software developer" one) and even be "dependent on" another (e.g. the "senior software developer" role depends on the "junior software developer" one). In this case, this means that to instantiate a (depender) capability-requiring role, a person must have the capabilities required by the dependee one. This distinction is depicted in Figure 3, which focuses on the relational aspect between the proposed concepts.

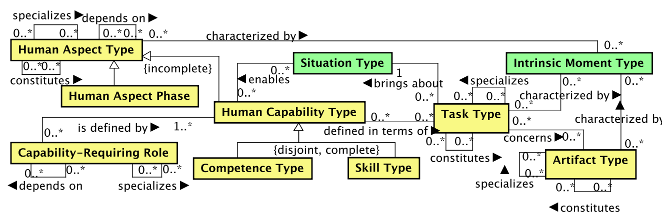

Figure 3. Proposed Competence Ontology model - Relational Perspective

Regarding the instantiation of this model, a *person* can instantiate a *capability-requiring role* for a while, as shown in Figure 2. As illustrated, a *person* can even instantiate more than one *capability-requiring role* at a time. Besides this, the instantiation can even change over time. For example, in one moment, John can perform the "junior developer" *capability-requiring role* and, in another, he can perform the "senior developer" *capability-requiring role*.

2) Human Aspect, Human Aspect Type, and Human Capability Type: In the context of this work, the proposed concept of the *human aspect* is a generalization of the concepts of *knowledge*, *attitudes*, *capabilities*, and *human characteristics* (as human *qualities* and *traits*), proposed in [7]. As these concepts are a subtype of the *intrinsic moment* [7] based on the UFO, the *human aspect type* is considered an *intrinsic moment* subtype, as illustrated in Figure 2[2].

Concerning the relations, a *human aspect type* can "depend on" other *human aspects*. In this case, this means that, if a *human aspect type* depends on the other, a person that instantiates a *human aspect* should instantiate the dependee first in order to instantiate the depender one (e.g., the "advanced programming skill" depends on the "basic programming skill"). This distinction is depicted in Figure 3. As shown, a *human aspect type* can also be constituted by others, on many levels, as a hierarchical structure. Besides this, a *human aspect type* (more generic) can be specialized by others (more specific).In

[2]As cited above, this concept includes *human capability type* (shown in the diagram), *knowledge type*, *attitude type*, and *human characteristic type* concepts (not shown in the figure)

addition, a *human aspect type* can be characterized by the corresponding *intrinsic moment types* that describe it, as shown in Figure 3 (e.g., sharpness, experience, accuracy, etc).

Human capability type, as the name implies, is a subtype of *human aspect type* that concerns types of *human capabilities*, such as *competence* and *skill* types. So, as a result, *human capability types* are used to establish descriptions and classify individual *human capabilities*. In this sense, it represents "generic" *human capabilities*, not those related specifically to a specific individual. A *human capability*, inhering a specific person, is a subtype of *disposition* as [7] states. In the same way, in this work, the *human capability type* as a *universal* kind is defined as a subtype of *disposition type* in UFO terms, as shown in the figure. As a consequence, *competence type* (considered in [8] as a subtype of *disposition type*) and *skill type* are considered in this work as a subtype of *human capability type*, as illustrated in Figure 2.

The *human capability type* concept, as a *human aspect type*, can also represent the dependence relation between *human capabilities*. This means that, in a general sense, a *human capability type depends on* other *human capability types* to exist (e.g. "back-end development" depends on "programming skill").Also as a *human aspect type*, a *human capability type* can be constituted by others (e.g. "full-stack development" *competence type* is constituted by the "front-end development" *competence type* and "back-end development" *competence type*). In this case, a *human capability type* can be represented constituted by others (on many levels, as a hierarchical structure). Likewise, as a subtype of *human aspect type*, *human capability types* can specialize others, also in many levels (e.g. "Java back-end development" specializes "back-end development").

In general, *human aspects* are applicable at distinct levels (e.g. basic, intermediate, advanced). These "*phases*" (levels, degrees, or stages) of a *human aspect* correspond to the qualitative development of its characteristics. So, in this work, the *human aspect type* can be branched into a distinct *human aspect phase*. As a result, the *human aspect phase* concept is seen as a subtype of the *human aspect type*, as depicted. But, differently from a *human aspect type*, a *human aspect phase* is also correlated with changes in the *intrinsic moments* of the *human aspect* that characterizes the development. So a *human aspect phase* is a subtype of the *phase* based on UFO. Likewise, *Human Capability Phase* (not shown in the figure) is a subtype of the *human aspect phase* that is also a sub-type of the *human capability type*.

As shown in Figure 2, besides instantiating a *human aspect type*, a *human aspect* instantiates a *human aspect phase*. This last instantiation, regarding the *human aspect phase*, it can change over time based on the qualitative evolution of the *human aspect*. For example, "John's front-end development" *competence* can instantiate the "medium level" in one moment and the "advanced level" in another moment, based on the evolution of the *competence*'s qualities (e.g. experience) and elements (*skills*, *knowledge*, and *attitude*).

3) Human Capability Manifestation (Task Type and Artifact Type): Generally, a *human capability type* can be defined by *task types* that represent the possible manifestations of people who instantiate that *human capability type*.*Task type* classifies tasks performed by a *person* as a manifestation of some *human capability*. As *tasks* are sub-types of *perdurant*, based on [7], in this work, *task types* are considered sub-types of *perdurant type* in UFO terms. Figure 2 illustrates this distinction. Regarding the relationships, a *task type* can also be constituted by others, as Figure 3 depicts.As *capability-requiring roles* and *human capability types*, (more generic) *task types* can also be specified by other (more specific) *task types*, as shown in the figure.As illustrated, *task types* can be characterized by *intrinsic moment types* that represent some aspects inherent to the *task*. These aspects can be related to *qualities* (e.g., duration of a task's execution, performance level) or *mode* types related to the way that the task is performed (collaboratively, quickly, etc.). As shown, *task types* can be detailed by *situations types* that represent types of outcomes generated by *task types* instances (e.g. customer satisfaction after receiving a deliverable).

Besides the *task types*, *human capability* descriptions generally also include artifact-type descriptions (even if implicitly). As a result, usually, *task type* descriptions concern with *artifact types*, as illustrated in Figure 3. In this context, the *artifact type* classifies the results of a *human capability* manifestation. It corresponds to the types of objects used, created, and terminated by a task (*perdurant*). Based on UFO, *perdurants* can use, create, and terminate *substantials*. So, in this work, *artifact types* are considered subtypes of *substantial types*. As illustrated, *artifact types* can also be classified and constituted by other *artifact types*.*Artifact types* can also be described based on some characteristics. So, as illustrated, *artifact types* are characterized by certain *moment types* (e.g., the usability of a web page).

A *task* instantiates the *task type* concept. As a subtype of *perdurants*, *tasks* can (i) have other *tasks* as part of them; (ii) bring about new *situations*; (iii) create, use, or terminate *substantials*; and (iv) have inherent *moments* characterizing them[3].Finally, the *artifact* (a *substantial* subtype) instantiates the *artifact type* concept[4]. As a subtype of *substantial*, *artifacts* can have other *artifacts* as part of them and can have inherent *moments* as characteristics.

IV. Well-Founded Competence Representation

This section will present an application established from the ontology presented earlier. Based on it, a well-founded language pattern is proposed in order to practically represent these ontological distinctions in an organizational context, especially in system and software engineering organizations. So, in this sense, this language pattern is proposed using ArchiMate notation, adopted in the enterprise architecture context.

[3]not shown in the model
[4]not explicitly shown in the model

a) The Incose UK Framework: In this case, the "Systems Engineering Competencies Framework" (Incose UK Framework) [23] will be used as an example, specifically to help the application of the proposed language pattern. This competence framework was proposed for organizations, academic institutions, and training providers to describe competences needed in distinct areas of system engineering, based on some system engineering standards. The Incose UK framework classifies the competences in areas and describes them at distinct levels of experience (i.e. proficiency). For example, the "Determining and Managing Stakeholder Requirements" competence, described in the Incose Framework, belongs to the "Holistic Lifecycle View" area and is detailed through some indicators, such as: "understands that there are different types of requirements, e.g., functional and non-functional" (at the "awareness" level); "(being) able to establish acceptance criteria for simple requirements" (at the "supervised practitioner" level); "has written good quality, consistent requirements" (at the "practitioner" level); "(being) able to establish acceptance criteria for requirements for the system of interest" (at the "practitioner" level); and "reviews and judges the suitability and completeness of the requirements set" (at the expert level).

A. The Proposed Representation

Based on the ontology, we proposed the language pattern, mapping each concept to an ArchiMate's construct and establishing distinct viewpoints. The strategy used to map the ontology to a language pattern was based on ontology-oriented guidelines stated by [4], [19]. According to these authors, to facilitate the understanding of some modeling languages, the visual aspects of the constructs should follow the ontological distinctions behind them. As a result, the authors proposed some guidelines to represent a construct based on UFO distinctions. For example, *kinds* and *subkinds* types from UFO are distinguished by the construct shape (e.g., the "human shape" representing the person, man, and woman *kinds* and *subkinds*); *role* types from UFO are distinguished by the relationships of the construct (e.g., the arrow between "human shape" constructs representing the parent and child *roles*); *phase* types from UFO are distinguished by changes in construct color (e.g. the color changing of "human shapes" construct representing living and deceased *phases* of a person); and *intrinsic moment* types from UFO are distinguished by the construct breakdown (or partition) related to the construct, labeling it (e.g., the floating label related to the "human shape" representing the name and age *intrinsic moments* of a person). Based on these ontology-oriented guidelines to define the visual aspects of constructs, the ArchiMate language pattern was proposed. As it will be detailed, basically, this language pattern is an extension based on the previous language patterns proposed by [1], [7], [8]. Among these works, [7], [8] also focused on competence modeling and was based on [1], which addressed the basis for capability modeling.The language pattern is formed by distinct viewpoints, as will be presented in the following.

a) Capability-Requiring Role Viewpoint: The *capability-requiring role* concept from the ontology was mapped to the *business role* construct in ArchiMate, specifically related to a *business actor*. As illustrated in Figure 4, the "requirement owner" is a *capability-requiring role* played by a "system engineer", a *business actor*; this *capability-requiring role* has three *capability-requiring role* specializations (represented with a yellow gradient): "junior requirement owner", "middle requirement owner" and "senior requirement owner". As illustrated, the *capability-requiring role*'s classification and dependence relationships from the ontology were mapped to the specialization and flow relationships of ArchiMate respectively. Furthermore, the *capability-requiring role*'s definition relationship (to a *human capability type*), from the ontology, was represented using the association relationship of ArchiMate (related to a capability construct). As shown, the "Middle Requirement Owner" is defined by "Requirement Determination Competence [P] (at the practitioner level)" competence. This *capability-requiring role* viewpoint is formed by the following possible alternative perspectives: (i) *Capability-requiring roles* taxonomy, representing how the roles can be classified using some occupation and job position taxonomy (e.g. [10] or [33]); (ii) *capability-requiring role* evolution, regarding the temporal aspect through dependence relationship between all the organization positions, establishing the "career paths" adopted into the organization.

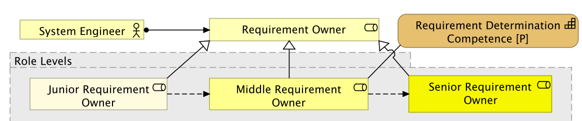

Figure 4. The proposed language pattern: Capability-Requiring Role viewpoint

b) Human Aspect Type Viewpoint: As a general concept, the *human aspect type* can be represented in distinct ways depending on the type. For example, the *human aspect types* that represent *knowledge type* or *attitude type* are represented using the *meaning* and *value* constructs from ArchiMate, as proposed in [7]. In any case, the focus of this work is to represent the *human capability type* specifically. The *human capability type* concept from the ontology is represented in the same way as the competence type in [7], [8]. As an *intrinsic moment* type, it is represented as the "breakdown" of a *capability-requiring role* (the bearer). So, it is mapped to the *capability* construct from ArchiMate related to a *business role* construct (bearer) using the association relationship, as in [7], [8]. In the case of this work specifically, this *business role* must represent a *capability-requiring role* concept. As shown in Figure 5, the *human capability*'s specialization and dependence relationships from ontology are mapped to specialization and flow relationships from ArchiMate, as previously described. The *human capability*'s constitution relationship from the ontology is represented by the aggregation (or composition) relationship of ArchiMate, the "defined in terms of" relationship is mapped to ArchiMate's realization relation with a behavioral element.

As illustrated in Figure 5, the “requirement determination” competence type (at the supervised practitioner level)” has a constitution formed by the “requirements writing skill” (in an advanced manner), the “acceptance criteria establishment skill” (in an appropriate manner), “careful attitude” type, and “good quality requirement characteristics understanding” knowledge type. In this case, the “requirements writing skill” type “is defined in terms of” the “write requirements properly”. This viewpoint is formed by the following alternative perspectives: (i) *Human aspects types* taxonomy representing how human aspects can be classified using competence classifications (operational, cognitive, social, meta-competence [9]; or the professional classifications of Esco and O*Net [10], [33]), skill classifications (e.g. hard and soft skill), knowledge classifications (e.g. implicit or explicit, procedural or declarative), or attitude classification (e.g., positive, negative, or neutral; affection, judgment, or appreciation); ii) the *human aspect types* constitution, representing some complex human aspect and the related parts as, for example, a complex *competence type* composed of (sub) competence and its correspondent *skill*, *knowledge*, and *attitude types*, as Figure 5 illustrated.

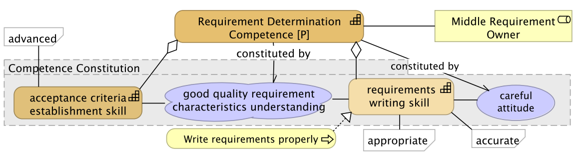

Figure 5. The proposed language pattern: Human Aspect Type viewpoint

c) Human Aspect Phase Viewpoint: The *human aspect phase* concept from ontology, as a subtype of *human aspect type*, is represented in the same construct (depending on the type of the correspondent *human aspect phase*). However, as a *phase* type, the *human aspect phases* are differentiated by the color’s gradient variation, as illustrated in Figure 6. As shown in the figure, the “Requirement Determination Competence” has four ordered levels (related by flow relationship), following the Incose UK framework. As depicted, each *human aspect phase* (*human capability phase* in this case) has a distinct color representing different phases of the “Requirement Determination Competence” *human capability type*. The darker it is, the more “developed” the *human capability type*. In this case, the “requirement determination” (at the supervised practitioner level)” is the lower phase, and the “requirement determination (at the expert level)” is the higher phase. As illustrated, the phases of a human capability type can be related by a flow relationship, representing the development order. An important aspect is, as a *human capability type* evolves, its constitution can change. For example, the “requirement determination” (at the supervised practitioner level)” has a distinct constitution, as shown in Figure 5.This viewpoint has as the main focus the *human aspect types* evolution regarding the temporal aspect, showing the dependence relation between distinct *phases* of *knowledge*, *attitude*, and *human capability types*. In the case of the *human aspect type* evolution, it is even possible to adopt a taxonomy like Bloom’s [25], which defines distinct levels of cognitive (related to knowledge), affective (related to attitude), and psycho-motor (related to skills) domains;

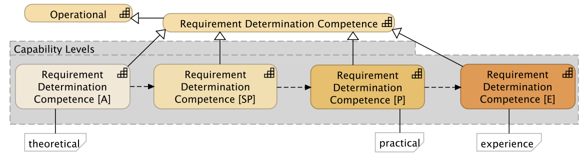

Figure 6. The proposed language pattern: Human Aspect Phase viewpoint

d) Manifestation Viewpoint: The *task type* concept from the ontology is mapped to ArchiMate’s *behavioral elements* (e.g., *business process* or *business event*), following the same strategy to represent *tasks* and *competence manifestation* in [7], [8]. The *artifact type* concept from the ontology is mapped to ArchiMate’s *structural elements* (e.g., *business object* or *data object*). The *task type* and *artifact type*’s specialization and constitution relationship are mapped to ArchiMate’s *specialization* and *aggregation* relationships. Besides this, the relationship of a *task type* “concerning” an *artifact type* is represented by the *access* relation in ArchiMate. An example is illustrated in Figure 7. In this case, the “Elicit requirement properly” *task type* is constituted by the “Write requirement properly” (in a proper manner) and “Validate requirement” task types. The former is a kind of “apply” *task type*, and the latter is a kind of “analyze” *task type*, as shown. In this context, “write requirements properly” concerns the “system requirement” *artifact type* (with “consistent”, “qualified”, and “suitable” characteristics), which constitutes the “system backlog” *artifact type*. This viewpoint is formed by the following specific perspectives: i) Task types classification using some task taxonomy (as Bloom’s taxonomy [25] or McGrath’s group task taxonomy [26]); ii) Artifact types classification using some generic classification (e.g. as physical, social, cognitive, symbolic, informational, technical, etc); iii) complex *task type* constitutions, from complex processes to atomic tasks; and iv) complex *artifact type* constitutions (representing its parts).

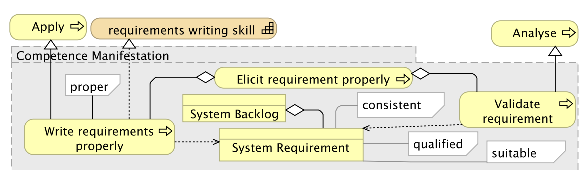

Figure 7. The proposed language pattern: Manifestation viewpoint

As illustrated in the examples above, the representation of characteristics (*intrinsic moments*) of the *human capability types*, *task types*, and *artifact types* (represented by the “characterized by” relationship) is made using the *note* construct of ArchiMate. In this case, as an *intrinsic moment* type representation, the *notes* “label” *human capability types*, *task types*, and *artifact types*, as a breakdown of them. Another way to represent the characteristics of the *human capability* *types* is by using the ArchiMate element's attributes, according to ArchiMate's customization mechanisms.

B. The Language Pattern's Individual Viewpoint

The examples shown above provide a general perspective on competence modeling at the type level, allowing the representation of competence frameworks in distinct situations. Otherwise, it is also possible to represent these concepts at individual levels, as it was focused on in [7], [8]. While the type viewpoint can be used as a reference for the organization, the individual viewpoint can be more practically used in the competence framework application. For example, it can be used to represent: i) real situations related to a specific professional (to support the *competence identification*); ii) desired situations (to support the *gap analysis*); and iii) hypothetical scenarios based on storytelling (to support the type level validation), as [3] propose, using storytelling to support the modeling at type view.

a) Competence Identification Illustration: Figure 8 illustrates an example of individual representation based on the competence framework model. As the figure depicts, to support the gap analysis activity of the professional John, the modeling includes the current moment (the result of the competence identification) and the desired moment. As shown, at the current moment, John is playing the "Middle Requirement Owner" role, and he has"requirement determination competence" (with "2 years of experience" and "partially supported"), at the practitioner level, and constituted by the "requirement writing skill".As shown, his competence is manifested by the "write Lifebox's requirement #22" task (performed "speedily" with a "duration of 10 minutes", and with "aid"). Likewise, this task generates as a result, the "requirement #22" artifact (with "good quality", "consistency", and "suitability"), a part of the "Lifebox's backlog" artifact, and as an outcome the "stakeholder understanding" situation.

b) Competence Mapping and Gap Analysis Illustration: As depicted, in the desired situation for John, he is able to perform the "Senior Requirement Owner" and evolved his "requirement determination Competence" from practitioner to expert level. As illustrated, qualitatively, in the desired stage, John has "three years of experience" in this competence and can perform it "autonomously". As shown, in the desired stage, John's competence acquired the "requirement judgment skill" and "best practices knowledge" as its part. As a result of his future competences, John will be able to perform new tasks such as, for example, "judge the Lifebox's requirement #27", "without aid" and for a "duration of twenty minutes". In this task, he judges "requirement #27" identifying it as "complete" and "suitable".

C. Ontology Implementation

Besides the language pattern with its distinct perspectives, the ontology was implemented in OWL using gUFO[5], a lightweight implementation of UFO. With this implementation, it is possible to represent competences not only using a human-readable visual notation (using ArchiMate) but also using a machine-readable format. As a consequence, it is possible to perform complex queries (e.g. using SPARQL), inferences, and reasoning (e.g. using Jena) based on competence stored data. Among the possibilities, this implementation can support the answers to such questions as (i) What is the evolution of John since last month (based on the human capability change)? (ii) What is the proper level of John's back-end development competence (based on the competence qualities)? (iii) Is John ready to perform in a higher position, as a senior front-end developer (based on the capabilities and performed tasks)?; (iv) What is the best professional to perform the system analyst role in the new project (based on individual competences)?; and (v) Is John properly manifesting his front-end development competence? (based on tasks and artifacts)?

[5]http://purl.org/coreo

V. Related Works

There has been a lot of work recently in the field of Ontology-based Competence. They are the natural evolution of XML-based standards aimed at data exchange between systems, such as HR-XML [22]. Most of the related works analyzed focus basically on the personal competences, related to a person. For example, [30] proposes a personal ontology that takes into account proficiency; [34] considers a performance indicator of personal competence; [42] also proposes an ontology that takes proficiency level into account.

Otherwise, other works that focus on the type level (or both), allows the representation of *competence types* (and *skill types*), and are related to some *human functional role*. Basically, they focus on the definition of *skill* or *competence type*, such as [5], [13], [15], [30], [35], [41], [42], [47]. As a result, just some consider the *capability-requiring role* concept, or correspondents, such as *role* [30], [42], [47] or *job situation* [41]. As they focus basically on *human capabilities*, only a small number of works consider the other *human aspects* distinctions considered here. The exceptions are [15], [30], [41], mainly concerning *knowledge type* and *attitude type*. Likewise, only a few consider the *human capability phase* distinction [5], [13], [42]. In this sense, most of the works focus on this distinction at the individual level, defining concepts such as *proficiency level*, *level of competence*, or *level of skill* [5], [6], [11], [30], [34], [35], [41]. The *task type* distinction is vaguely considered only by [13], [15], [39]. Besides being important to describe human capabilities, no distinction related to the *human capability type* results (as *artifact type* or outcomes) was considered by the related works. Besides this, none of the related works consider the relational distinctions regarded in this present ontology as specialization, characterization, dependence, and constitution relationships.

Regarding the works that address competences in EA, such as [20], most of them do not consider ontologies in this task. In this sense, the exceptions are [2], [32], which employ foundational ontologies in EA modeling. Both use UFO to perform ontological analysis of concepts closely related to competence: Capability and Service. [32], for example, defines

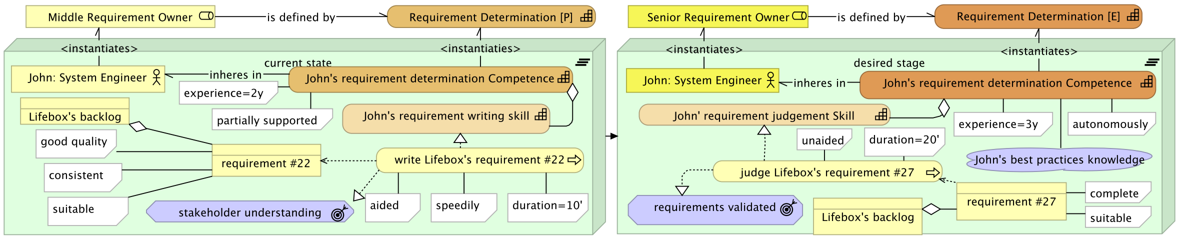

Figure 8. The proposed language pattern at the individual level

the Service concept as a competence manifestation, as this work did with the task concept. [2], on the other hand, performs an ontological analysis of Capability and is also related to Competence concept. The authors briefly discuss the definition of competence based on capability; we adopt and build up on that analysis in the present work. Competences, as we discuss here, can be placed in the so-called capability bundles of [1], thereby connecting individual-level capabilities (competences) with organizational capabilities.

VI. Final Remarks and Discussion

The research presented in this paper aimed to improve competence modeling and representation by utilizing a foundational ontology as a semantic foundation. The ontological analysis we conducted on concepts in the competence management literature and competence frameworks allowed us to first clarify a number of important issues. Furthermore, in ArchiMate, we were able to provide a well-founded set of patterns to support the application of competence frameworks in Enterprise Architecture modeling. The foundations provided us with the fundamental distinctions we needed to clarify concepts such as *capability-requiring role*, *human aspect type*, *human capability type*, *human aspect phase*, *task type*, and *artifact type*. Other foundational elements allowed us to relate competences to capability, allowing us to better integrate competence management with competence frameworks and models.

We investigated the relationship between competence frameworks and competence management in the Enterprise Architecture context. The proposed competence representation in ArchiMate makes it easier to adopt competence frameworks in EA from a practical standpoint. EA, in turn, contributes a wide range of its concepts to enrich the competence management practice and competence frameworks. This distinguishes the current work from the literature's existing ontology-based competence works.

The proposed representation can help with basic competence management (CM) activities like mapping, identification, and gap analysis. In this sense, pattern language aids CM activities by providing a visual representation of modeling competences from various perspectives, such as individual competence proficiency (current and desired), individual performance (current and desired), performed tasks and outcomes, and organizational capability related to individual competences. Through the lightweight version of the ontology, it is possible to perform a machine-based processing of competence data and information, allowing the migration from the document-based to the data-based CM.

a) Future work: Future work could delve deeper into a competence concept by defining new concepts such as known skills, knowledge, and attitudes, as well as exploring the competence relationship between them and with personal characteristics. Another important piece of research would be to delve deeper into the study of how organizational capabilities emerge from personal competencies. Capabilities do not emerge from simply combining competences. The high proficiency competence combination does not guarantee the formation of a high-performance team. Many factors influence this combination in this case. It is a very complex and difficult topic that deserves further exploration. In this sense, we also see an opportunity to incorporate General System Theory (GST) concepts into the ontological foundation and, as a result, in our analysis of competence. Incorporating these concepts into the ontological analysis, we believe, will throw new light on the representation of competence and capability composition, emergence, and evolution, particularly in the context of Enterprise Architecture. Finally, the proposed competence representation patterns should be validated in case studies. Although ontological analysis provides the foundation for a well-founded representation (as the foundation used here incorporates advances in Formal Ontology, Philosophical Logics, Philosophy of Language, Linguistics, and Cognitive Psychology [17]), the pragmatics of a representation in its usage context should be thoroughly assessed. Similar efforts have already been made in this vein for other UFO-based representation schemes, such as [16], [32].

Acknowledgment

This study was supported in part by CNPq (313687/2020-0), FAPES (281/2021, 1022/2022), and the DSYNE INTPART network (Research Council of Norway project number 309404).

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