Towards Ontology-based Competence Modeling in Enterprise Architecture

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***Abstract*—Organizations today can hardly thrive without continuous attention to human resources development. In this context, competence-based approaches have been receiving increasing attention, as the availability of qualified people with the right combination of competences establishes itself as a major success factor. This paper investigates the integration of competence-based approaches into Enterprise Architecture modeling. We follow a principled approach to propose competence modeling representation strategies in Enterprise Architecture. We first identify a key set of competence-related concepts, analyze them based on the Unified Foundational Ontology, and then propose well-founded representation patterns for competence modeling in the ArchiMate language. We discuss how these patterns can be embedded in competence-based practices for the enterprise.**

***Index Terms*—Competences, Competence Modeling, Enterprise Architecture**

1. Introduction

Given the central role of human performance in the success of organizations and in the advancement of society at large, it is no surprise that much attention is devoted to human resource management in organizations and to education and training in general. The constant search for human development results in advances in areas such as Vocational Education and Training (VET) and Human Resource Management (HRM). One of such advances has been the gradual shift from content-based to competence-based approaches, in part reflecting a shift from a Supply-Oriented Model to a Demand-Oriented Model in Vocational Education and Training (VET) [7]. Methods and models like Competence-based Assessment, Learning, and Curriculum have been increasingly used in many contexts, from innovative learning environments to traditional courses and in-company training. According to [7], there are many reasons for the increasing adoption of competence-based approaches, including the establishment of lifelong learning policies in some countries and the prioritization of non-formal and informal learning in companies, universities, and schools. The focus on competences stimulates a better integration between formal education, vocational training and professional development. Finally, an important justification for the increasing adoption of competence-based approaches is the need to massively improve the workforce skills and qualifications to promote better work mobility through new competences [7].

In the context of enterprises, "competency-based practices [...] align the strategic imperatives of an organization with its key HR programs." [11] They are "used in many facets of human resource management, ranging from individual selection, development, and performance management to organizational strategic planning" [31]. By evaluating employee competences, an organization can perform self-assessment "to improve its HR programs, including talent acquisition practices, performance management system, training and development tools, employee retention practices, and organization development strategies." [11]

In this paper, we investigate how to integrate competence-based approaches into Enterprise Architecture (EA) modeling. This complements earlier work on capability-based strategic management [4], [5] by looking at the role of "individual capabilities" in an Enterprise Architecture. We follow a principled approach to propose competence modeling representation strategies in Enterprise Architecture. We first identify a key set of competence-related concepts by reviewing the literature on the topic. Then, we analyze the identified concepts and their relations in the light of the Unified Foundational Ontology [14]. This enables us to propose well-founded representation patterns for competence modeling in the ArchiMate language. We discuss how these patterns can be embedded in competence-based practices for the enterprise.

Despite the importance of competence-based approaches in practice as discussed above, certain conceptual aspects of competence remain elusive, including the definition of the concept of "competence" itself. All practices related to Competence Management (CM) in the HRM area such as identification, representation, assessment, and measurement of competences are based on (implicit) conceptual assumptions. These assumptions naturally have implications in the understanding, communication and agreement between stakeholders of all CM tasks. Competence is often defined loosely as a mix of attitudes, abilities and knowledge. Without a clear conceptual account, there are persistent difficulties in the identification, representation and measurement of human competences. This challenge justifies our adoption of a foundational ontology as a semantic background for

our analysis, following a number of successful ontological analysis of EA models in various domains of EA including organizational structure [33], motivation and requirements [3], resources and capabilities [4], and risk [32].

This paper is further structured as follows: Section 2 presents the theoretical background employed in this paper, including a brief review of the relevant competence literature and of the ontological foundations employed here; Section 3 presents the ontological analysis of competence and other central competence-related concepts; Section 4 presents the proposed pattern language in ArchiMate; Section 5 discusses related work; and, finally, Section 6 concludes the paper.

2. Background

2.1. Competences and Competence Management

Competences[1] are generally known to consist of behaviors, skills, knowledge, and attitudes. According to [37], competence has two main perspectives: the theoretical and the operational (practical). According to the former, competence is composed of an implicit cognitive structure that supports a specific behavior or skill. According to the latter, competences are explicit and observable characteristics that "cover a broad range of higher-order skills and behaviours that represent the ability to cope with complex, unpredictable situations". This definition includes not only knowledge, skills, and attitudes but also other human characteristics such as metacognition, strategic thinking, and decision-making [37].

Commonly in a professional context, competence is defined as a performative characteristic. The UK National Vocational Council for Vocational Qualification, for instance, describes competence as: "the ability to perform in work roles or jobs to the standard required for employment". Following a similar sense, the HR-XML Consortium [17] defines a competence as: "A specific, identifiable, definable, and measurable knowledge, skill, ability and/or other deployment-related characteristic (e.g. attitude, behavior, physical ability) which a human resource may possess and which is necessary for, or material to, performing an activity within a specific business context."

Competence Management (CM) is composed generally by a Competence Life Cycle that proposes four macrophases: (i) Competence Mapping; (ii) Competence Diagnosis; (iii) Competence Development; and (iv) Competence Monitoring. While Competence Mapping is focused on the future, Competence Diagnosis is focused on understanding the current situation of an organization. Competence Development focuses on proposing strategies and activities to enhance competences of individuals and organizational capabilities, from a current to a desired situation. Finally, Competence Monitoring focuses on the continuous examination of achievement of desired situations [10]. These phases are supported by processes and systems that help mainly in activities as: competence identification, competence assessment, competence modeling, competence planning and profile description. These activities occur in the context of workforce planning, recruitment management, learning management, career development, success planning [10].

One of the key tasks in Competence Management is Competence Modeling. A Competence Model often describes the required competences to perform satisfactorily a specific role or occupation. A Competence Model can focus both on representing the current situation and the desired one. This modeling is useful in Skill Gap Analysis, a comparison between available and needed competences. A Competence Model may also include behavioral descriptors, detailing proficiency levels at which a professional must perform. The development of a Competence Model typically follows these distinct steps: definition of competences and behavioral indicators, development of initial models, refinement of models, validation and finalization of models [10].

Competence models can also be used to describe competence patterns and standards, to represent individual characteristics or to specify educational or training models. They can also focus on outcomes of individual (skills, knowledge, attitudes), professional tasks (activities by occupation) or personal characteristics of an individual [7]. As with any kind of model, competence models can be constructed from different points of view, levels of abstraction, addressing different perspectives and aspects. For example, concerning the level of abstraction, a particular competence can be detailed into many sub-competences that can be subsequently detailed into skills and knowledge [37].

2.2. Semantic Foundation for Competences

In order to account for competence-related phenomena more precisely, we employ here a fragment of the UFO foundational ontology [14], which defines a system of domain-independent categories and their ties, which can be used to articulate conceptualizations of phenomena of interest. UFO has been developed based on theories from Formal Ontology, Philosophical Logics, Philosophy of Language, Linguistics and Cognitive Psychology [16] and has been employed successfully in a number of conceptual modeling tasks including language revision [33] and redesign [4], [32].

The employed fragment captures first two basic ontological categories: that of the *universals* (concepts, types) and that of the *individuals* (particular things). It then distinguishes between "substantial" independent entities (roughly, objects) and the non-substantial existentially dependent entities (features, objectified properties, termed here "moments"). Combining the two distinctions generates four basic ontological categories of interest here: "substantial universals" (such as Person, Airplane), "moment universals" (such as Weight, Fuel Capacity), "substantials" (John, Mary, Air Force One) and "moments" (John's Weight, Mary's Weight, Air Force One's Fuel Capacity). We have shown in [21] how this "four-category ontology" is beneficial in conceptualizing organizational "capabilities" as it grants

1. We provisionally use the term "competence" in this section. Later in the paper, the term "competency" [38] will also be introduced and related to "competence".

them first-class citizenship through reification. Here, we show how this same conceptual strategy can support the interpretation of the notion of competence in HRM.

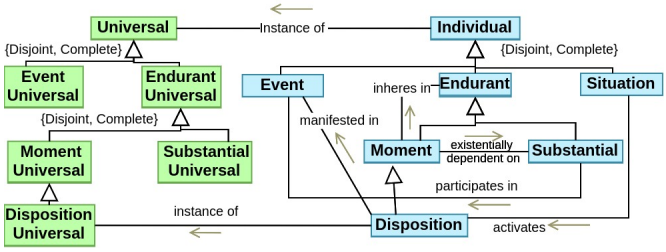

Figure 1. UFO fragment covering the key distinctions used in this paper

Figure 1 presents a class diagram containing the UFO fragment relevant for this paper. According to the presented model, UFO divides individuals into: endurants, situations and events. Events are those individuals that happen in time (i.e. activities, actions, tasks, processes). Endurants are those individuals that persist in time, maintaining their identity (i.e. people, organizations, projects, cars). Of particular interest to us here is the partition of endurants into moments and substantials as discussed earlier. Moments inhere in a substantial (termed its bearer), on which they existentially dependent. We assume, following [4], [21] that moments encompass what are termed dispositions ("powers" or "capacities") in the philosophical literature [23], e.g., the disposition of a magnet to attract metallic material, Anna's English speaking skill. Dispositions are moments that may be manifested through the occurrence of events (possibly actions of intentional agents, such as Anna's speaking English). Dispositions are said to be "activated" in the situations in which they may be manifested (e.g., when a magnet is close to some ferrous material, when Anna is prompted to introduce the topic of a meeting). A detailed account of UFO can be found in [15], [16].

3. Ontological Analysis

In this section, we use the UFO fragment discussed above, to perform an ontological analysis and discuss the semantics of competence-related concepts. The ontological analysis was carried out with the following steps. First, (i) by means of literature review, we identified the main issues and challenges related to competence definition and competence modeling (sub-section 3.1). Further, (ii) we identified a set of central concepts in competence phenomena (sub-section 3.2). Then, (iii) we analyzed these concepts using the ontological distinctions of UFO (sub-section 3.3). This analysis forms the basis for well-founded competence representation, which we will discuss later in Section 4, considering the activities of competence mapping, diagnosis and gap analysis.

3.1. Important Issues in Competence Modeling

There are several issues regarding the semantic interpretation and modeling of competences that relate to both conceptual and practical aspects. Among the conceptual aspects, we can highlight the subjectivity of the competence concept itself, the difficulty in distinguishing competence from related concepts, the variety of classifications for competences and the various levels of abstraction in which competences can be considered.

3.1.1. Issue 1: Concept Definition and Modeling. Competence is considered in the literature a complex and fuzzy concept, as discussed in [37]. The author argues that it has an internal structure that is not directly and completely observable. Hence, he concludes that competence is more an abstract entity than a concrete one. These aspects show that conceptually modeling competence is a challenge [37]. [38] identifies three main competence meanings: "competency" (a concept related to a person), "competence" (a concept related to an area, field, or function) and "competencies" (a mixture of the two). [24] builds up on [38] and proposes a similar definition, but complements that "competencies" represent a set of (identifiable) attributes related to a "competency". Competence Ontologies (e.g., [22], [28]), provide similar definitions. These ontologies are usually concerned with practical implementations in XML/OWL and ordinarily associate competence with a person, group, or organization. Some ontologies also associate competence with a professional role. In other models, competences are also associated with an occupation or profession, with no relation to a specific individual. Some works consider these two meanings for competence, such as [22]. Other works, such as [28], fail to differentiate these two meanings, semantically overloading a single same concept of the ontology.

3.1.2. Issue 2: Relations to Other Phenomena. In addition to the difficulties in defining competence, there is also some confusion regarding the boundaries between competence and competence-related concepts. For example, [37] discusses the close relations between competence and performance. According to [36], they are semantically very related but their conceptual relation is not made clear in the literature. This negatively impacts the comprehension and usage of the concepts. Representing the performance of a competence is important for competence modeling. Depending on the context, one needs to know what kind of actions a professional can perform based on their competences. Despite that, most of the Competence Ontologies in the literature do not represent related actions or performances. Some of them, such as [35], [40], represent prerequisites relating the required competences to a potential task or activity. Other works, as [40], associate an occupation (not competences) to activities. Some works, such as [22] and [30], include a related concept of Evidence. Evidence is usually based on competence manifestations, but is in fact a different concept, as it refers to perceptions of these manifestations.

3.1.3. Issue 3: Variety in Competence Classification. As pointed out in Section 2, competences are commonly classified into skills, knowledge and attitudes (KSA). In addition, there are several classifications depending on the system,

theory, or approach adopted [7]. This motivated some effort in the past to integrate these different classifications. [7], for example, attempted to generalize the most well-known competence classifications, representing them on two axis. In the first, competences could be conceptual (describing knowledge) or operational (describing action, activities). The second axis classifies competences in individual (describing personal characteristics) or occupational (describing social and attitudinal aspects). As a result of combining these axis, the author proposes a classification of competences into: Operational, Social, Cognitive and Metacognitive (the latter also termed Metacompetence). Regarding competence ontologies, most of them do not consider any classification. Some works, such as [22], consider a KSA classification, but partially. The authors consider this classification only for competences related to a person, not considering competences generically related to an area or function. Most works that do incorporate some competence classification make limited use of the distinctions that underlie the classification, failing to explore them in their models. These distinctions could be employed to clarify the relation between competences and other competence-related concepts. For example, in the case of an operational competence, there are often manifesting actions. Differently, in the case of a social competence, there are often manifestations of interactions (such as communication).

3.1.4. Issue 4: Difficulties in Competence Context Definition. Another issue in the definition of the concept of competence relates to its context. The competences of a person (or other agents) are constantly changing in time, as discussed in [37]. The author also strongly relates the concept of competence to the environment: workplace characteristics, resources (software, hardware, human), artifacts, interaction with others. According to the author, competences must always be related to the context, to account for their environmental and temporal dimensions. Depending on the environment, for example, it may be impossible for a competence to be manifested. Moreover, the competences related to an occupation and their characteristics can change in time. Most ontologies do not represent these contextual aspects. An exception is [22] that represents the "Context" concept in his ontology, but does not consider temporal and environmental dimensions. The work of [40] does not address context in general, but includes resources, artifacts and/or temporal concepts related to competence.

3.2. Central Concepts

Based on the discussions above, we identify the following competence-related concepts for our analysis: (a) *Personal Competence*: Competence as a personal entity, related to an individual agent (based on Issue 1); (b) *Competence Type*: Competence as impersonal entity, related to an area, field, or occupation (based on Issue 1); (c) *Competence Manifestation*: Manifestation of personal competence by performance of a Task, Work, including the Artifacts or other Results (based on Issue 2); (d) *Competence Subtypes*: Classification of competences, for example, as skills, knowledge, and attitudes (or Operational, Cognitive, Social, and Meta Competences, according to [7]) (based on Issue 3) and; (e) *Competence Context*: Context related to a Competence Type or a Personal Competence and that enables the manifestation of it, including related Environment, Resources, Artifacts, and Time Interval (based on Issue 4). Next, each of these concepts are analyzed.

3.3. Ontological Analysis Using UFO

3.3.1. Analysis 1: Personal Competence. The difficulties in the definition of "competence" can be addressed by using the four ontological categories discussed before. As illustrated in Figure 2[2], Personal competences can be understood as dispositional particularized features (dispositions) inhering in an individual person.[3] Personal Competence, as an inherent property of a person, is an internal characteristic that is not directly observable, not unlike the definition of competence described by [37]. For example, Karl's competence for front-end development, cannot be perceived directly, except through its manifestation when Karl develops a web form or other piece of front-end software. As such, Personal Competence is present in a person in the form of a potentiality. Personal Competence is a potential characteristic that may or may not manifest, depending on a situation. Personal Competence is often created and developed as a result of learning events. This observation emphasizes the importance of reifying Competences as endurants (object-like entities) in their own right. As such, a person's competence (such as Anna's Java programming competence) can be subject to change in time, while keeping its identity.

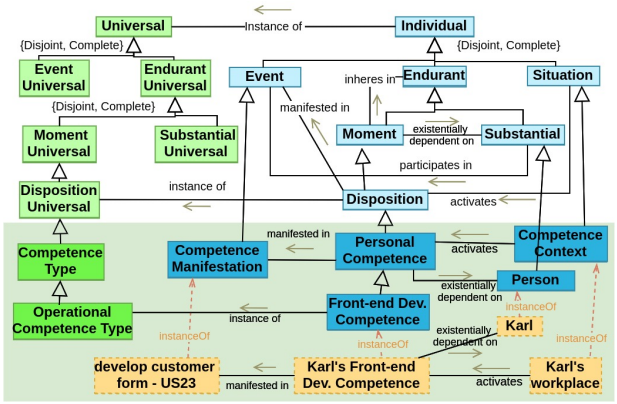

Figure 2. Defining Competence Concepts based on UFO

3.3.2. Analysis 2: Competence Type. The "abstract" or impersonal aspect of competences can be addressed further with the notion of Competence Type as a specialization of

2. For an operational version of this fragment as a specialization of the OWL implementation of UFO, see http://purl.org/nemo/repo/competence

3. Here, we focus on human agents; we use the term "capabilities" instead when related to groups, teams or organizations [4], [21].

Disposition Universal, as shown in Figure 2. Competence Types become relevant when a general (person-independent) perspective is required; in this case, we are not referring to specific individuals. Disposition Universals can be related to Substantial Universals to establish those types of persons (such as roles and occupations) whose instances bear dispositions of that type. For example, it may be the case that each instance of "Software Developer" (such as Karl) bears a competence of a certain type ("Karl's Front-end Development Competence" instantiates the type "Front-end Development Competence"). Competence Type is usually defined to facilitate the identification of a profile or to define the desired competences for an individual or organization. In this way, it is used to guide the tasks of selecting professionals, developing, or/and training them in more future-oriented activities, such as the planning activities.

3.3.3. Analysis 3: Competence Manifestation. Competence Manifestations are Events through which the Personal Competence (Disposition) is manifested, including the involved Substantials (which may have been created, changed, and terminated). Figure 2 illustrates this. When manifested, competence can be partially observed through the results it generates. Competence manifestation occurs through observable behaviors performed by a person in certain contexts (such as work environment, a project, or a partnership). Such behaviors can be recognized by others, allowing competence recognition, identification, and/or assessment. This permit semantics clarification for tests (as well as certifications). In addition, Competence Manifestation not only includes the direct product of the tasks performed from a Personal Competence, but also indirect and intermediate results. For example, a cook when cooking, besides food, produces dirty pots, interactions, mental moments, and knowledge. These indirect results can even be associated as evidences of a Competence Manifestation, also helping with the competence identification and assessment. Further, when considered at a general level, it is also possible for us to consider the relations between Competence Types and the Event Universals which characterize the manifestations of those Competence Types. For example, in general, a "Front-End Development Competence", such as "Karl's Front-end Development Competence", is manifested in instances of the Event Universal "Develop customer form", such as "develop customer form - (User Story 23)". Personal Competence is commonly recognized based on a Competence Type, adopted as a reference to facilitate the planning, identification, evaluation, and monitoring of competences.

3.3.4. Analysis 4: Competence Subtype. Using subtypes of the general notion of "Competence" (and hence of "Disposition"), it is possible to accommodate the various classifications of competences, including the ones identified in Issue 3. As seen, a competence can have various classifications, based on different criteria and classification systems. The most common is the classification based on the KSA. Other classifications can be accommodated as orthogonal specializations of the general notion of "Competence". For example, "Hard Skill" and "Soft Skill" can be considered subtypes of "Competence" adhering to different criteria. Other classifications can be introduced with other orthogonal specializations, e.g., partitioning "Competence" into "Operational Competence", "Cognitive Competence", "Social Competence", and "Metacognitive Competence" as discussed in [7]. Figure 2 represents this. As illustrated, the Competence Type "Front-end Development Competence" is an instance of the Competence Subtype "Operational Competence". This subtype pattern should be used when needed.

3.3.5. Analysis 5: Competence Context. A context is composed of several elements and,as such, is a Competence Context. Competence Context can be divided into environmental and temporal dimensions, according to [37]. We consider that a Competence Context is a type of Situation in UFO; situations are entities composed of entities (situation constituents or contextual elements) that stand in certain relations. This addresses the environmental dimension. For example, as illustrated in Figure 2, Karl is a person who knows how to develop front-end. However, he can only perform this development task (Event) if he is in the appropriate context of development, with appropriate hardware, software and infrastructure (Situation), which enables the manifestation of his disposition. In addition, as a Situation has another event as its post state, a new Competence Context can result from the manifestation of a Personal Competence. In the cook running example, the dirty kitchen may represent the new Competence Context, possibly activating other Personal Competences, as the one for washing dishes. Finally, a Situation in UFO is related to a framing Time Interval and hence this notion can be used to address the temporal dimension of the competence context.

4. Well-Founded Competence Representation

4.1. A Pattern Language for ArchiMate

We adopt here the ArchiMate "capability" construct following the dispositional account discussed in [4] and consistent with our interpretation for "competences" as dispositions. In order to illustrate the patterns, we use an example in the context of a Software Development organization. As illustrated in Figure 3, a Competence (such as "John's Bootstrap Front-end Development Competence") is represented as a Capability associated with an ArchiMate Business Actor representing the competence's bearer (in this case "John"). A Competence Type (such as "Web Front-end Development Competence") is then represented as a Capability (at type level) associated with an ArchiMate Business Role that can be assigned to an ArchiMate Business Actor representing a person (in this case the "Software Developer" role). A type of Competence Manifestation is represented by Behavioral Elements of ArchiMate, Competence Subtypes are represented by specializing capabilities (using plain ArchiMate specialization). Aspects of Competence Context can be represented by the Location and Plateau Elements.

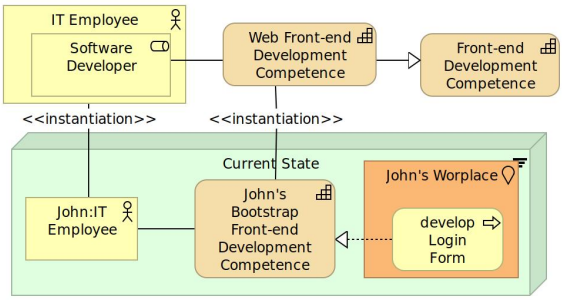

Figure 3. Basic representations of the Pattern Language

In the sequel, we present the various representation patterns using this same scenario for the following Competence Management activities: Competence Mapping, Diagnosis and Gap Analysis.

4.1.1. Competence Mapping. In Competence Mapping, the desired competences of the organization are identified. As they are related to a future (or hypothetical) scenario of the organization, competences may be represented at the type level. Figure 4 shows an ArchiMate model for the mapping of Competence Types in the Software Development Scenario.

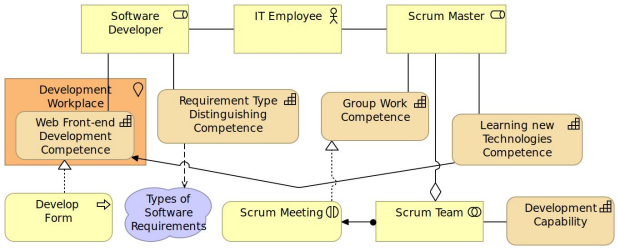

Figure 4. Competence Types Representation in ArchiMate

"Web Front-end Development Competence", "Requirement Type Distinguishing Competence", "Group Work Competence", and "Learning new Technologies Competences" are examples of Competence Types as they are related to the "Scrum Master" and "Software Developer" roles of an "IT Employee". "Development Capability" is represented as a Capability as it is a characteristic related to the social agent "Scrum Team".

Each subtype of competence adopted from [7] (Operational, Social, Cognitive and Metacompetence) gives rise to a different pattern. An Operational Competence Type is identified through the relationship with an ArchiMate behavioral element, such as a Business Process. For example, "Web Front-end Development Competence" is an Operational Competence Type due to its relation to the "Develop Web Form" process. The Cognitive Competence Type, in turn, is identified through the relationship with a Meaning (or another element that represents knowledge, such as a document). For example, the Competence Type "Requirement Type Distinguishing Competence" is a Cognitive Competence as it requires knowledge about the types of requirements adopted in the organization in addition to knowing how to distinguish each of them. A Social Competence Type is identified through the relationship with ArchiMate's collaboration and interaction elements. For example, the Competence Type "Group Work Competence" is a social Competence due to its relation to "Scrum Team" and "Scrum Meeting". Finally, a Competence Type that is Metacompetence is identified by a triggering relation with another Competence Type. For example, the Competence Type "Learning new Technologies Competence" is a Metacompetence as it changes the "Web Front-end Development Competence", represented by a triggering relation. As discussed in Section 3, a Personal Competence (Disposition) requires a context (Situation) to activate it. Thus, this language pattern enables the relation of a Personal Competence or Competence Type to its related Context type. In this case, ArchiMate's Location element was used to represent the Competence Context, in the environment dimension. In Figure 4 , "Web Front-end Development Competence" is a type of competence whose context which enables its manifestation is the "Development Workplace".

4.1.2. Competence Diagnosis. According to the CM activities, after mapping the desired competences, the competences currently present in the organization must be identified. Here, the representation of Personal Competences is paramount; Competence Types instantiated can also be explicitly identified. Below, we show examples of the proposed language pattern with regard to these concerns.

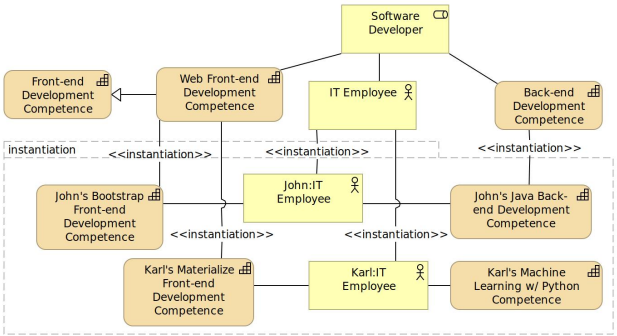

Figure 5. Personal Competence Representation

Figure 5 illustrates how the proposed language pattern represents the instance level in tandem with the type level. Similarly to the case of Competence Types, the concept of Personal Competence is represented using the ArchiMate Capability construct, albeit associated with Business Actors representing persons as discussed earlier (here "John" and "Karl"). Instances can be related to their respective types through associations stereotyped «instantiation». Grouping can also be used to facilitate the identification of instances in the model. For example, "John" and "Karl" are instances of the Business Actor "IT Employee". Likewise, "John's Bootstrap Front-end Development Competence" and "Karl's Materialize Front-end Development Competence" are instances of the "Web Front-end Development Competence"

Competence Type. Also, "John's Java Back-end Development Competence" is an instance of the Competence Type "Back-end Development Competence". Note that the "Karl's Machine Learning w/ Python Competence" is not associated with a Competence Type. In this case specifically, the organization in the example does not have any Competence Type related to "Machine Learning" or similar. Such competence is probably not yet identified as strategic for the company and therefore there is no Capability related to this area. But this should not exclude the representation of Karl's competence as it can be useful in other situations.

As discussed earlier, a Personal Competence (as a Disposition) can be manifested through events (Event) depending on the context (Situation). The language pattern allows us to capture these relations, as shown in Figure 6. The figure illustrates a manifestation of "Karl's Materialize Front-end Competence".

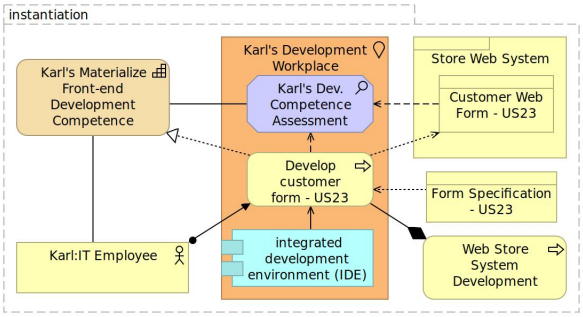

Figure 6. Personal Competence Manifestation

This manifestation occurs through the "Develop customer form - US23" Business Process (Related to the User Story 23). Further, in order to perform this Business Process, Karl uses "Form Specification - US23" as an input and generates "Customer Web Form - US23" as a result. In addition, Karl uses "integrated development environment (IDE)" as a necessary resource to manifest his competence. Therefore, representing a Personal Competence Manifestation can involve several aspects in addition to the representation of the event itself: Resources, Inputs, Output, Context and other competences (e.g. as the "Web Front-end Development" Competence Type depends on the "Development Workplace" Context to be manifested, "Karl's Materialize Front-end Development" Competence requires the "Karl's Development Workplace" Context to be manifested).

Another important point to CM is the evaluation of Competences, which can be assessed when manifested in specific contexts. In our proposal, we represent the assessment of a competence using ArchiMate's Assessment element, as illustrated in Figure 6. Figure 6 represents the assessment of Karl's competence through one of its manifestations. As illustrated, the assessment is related to the Competence's Manifestation Context, in order to analyze Karl's behavior during the process execution. Furthermore, as represented, the assessment is also based on the Competence generated artifact, i.e., the Business Process's results, in the example case, the "Customer Web Form - US 23". Regarding Competence Modeling, other ArchiMate motivational elements could also be used to represent Outcomes, Goals and Requirements related to competences.

4.1.3. Gap Analysis. Considering Competence Management, one of the most challenging tasks for managers is to perform Gap analysis. In this task, the organization's current and desired future competences are compared. Based on this comparison, strategies are defined on how to develop such competences. In this section, we show our proposal for modeling Gap analysis, illustrating it using two examples. One possibility is to realize Gap Analysis using ArchiMate's Implementation and Migration Elements, as illustrated in Figure 7. In this alternative, both the current and the future states are represented using ArchiMate's Plateau Element with the current and desired elements nested in the Plateaus. In this case, the current state of the organization is modeled based on diagnosis activity and the future state based on mapping activity. For example, in Figure 7, the organization in which John and Karl work have a "Traditional Software Development Competence". In addition, John has "B2 English Proficiency", whose type is defined in accordance with the Common European Framework of Reference for Languages (CEFR). However, based on the activity of "Software Dev. Competence Assessment", it was identified the absence of agile competences in the team. Thus, the "Agile Competences Development Program" was carried out. As a result, John and Karl acquire the competence of "Agile Software Development Competence".

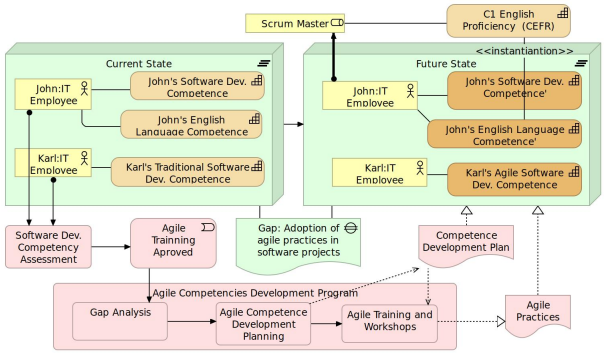

Figure 7. Integrating Competence with Enterprise Architecture Migration

Competence evolution representation through ArchiMate Migrations can be associated with the company's Career Plan. Company functions, e.g., may be related to specific competences as its prerequisites. For example, suppose that in this company the developer needs two prerequisites to assume the Scrum Master role: (i) taking part in the Agile training, and (ii) reaching C1 in English proficiency (based on CEFR). In this case, as illustrated, John, in addition to having participated in the training, should also provide evidence to the company that he reached the required proficiency degree in English (e.g., through certification). Here, he assumed the position of Scrum Master, as shown in the figure. Note that in this last example, Plateau represents the Competence Context, in the temporal dimension.

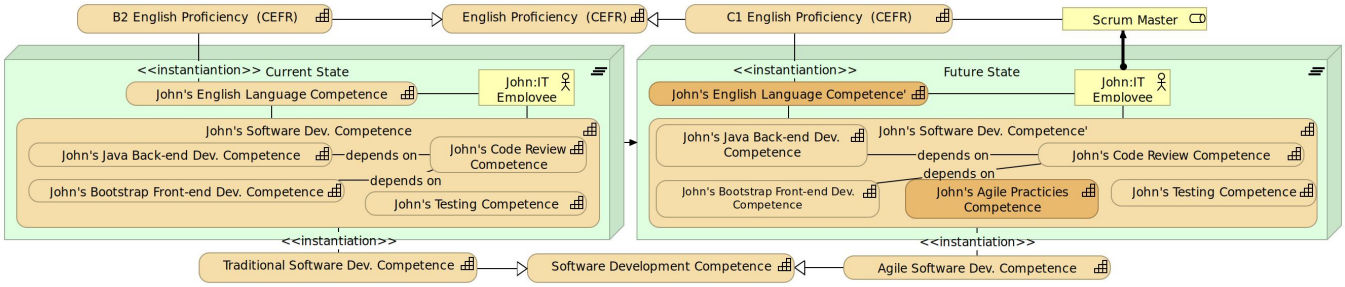

Figure 8. John's Competence Evolution

Understanding how competences develop is an important aspect of Competence Management. Figure 8, details how John's Competences developed. Two states of the organization are represented, both capturing John's Competences. The example shows another important aspect related with Competence Representation: the composition of competences, using the notion of Capability Bundles proposed originally in [5]. As shown, through training and workshops, John learned new competences. In fact, what happened was an evolution of his competences. For example, "John's Software Development competence" just changed its composition as John acquired a new (sub) competence: "John's Agile Practices Competence". The same happened with the competence to speak English, which evolved. It is the same competence in both states, but it has changed qualitatively, which is reflected in a different classification. For example, as illustrated, John's software development competence was an instance of "Traditional Software Dev. Competence" before the training. After the training, it became an instance of "Agile Software Dev. Competence". However, at both times, it is an instance of "Software Development Competence". This is also illustrated for "John's English Language Competence", which changed its classification from "B2 English Proficiency (CEFR)" to "C1 English Proficiency (CEFR)".

5. Related Work

There are several frameworks that define some basic competence-related concepts as knowledge, skill, attitude, learning outcome [36]. In this context, well-known initiatives include the Occupation Information Network (O*NET) [27], from the US Department of Labor Employment and Training Administration (USDOL/ETA), and the European Skills, Competences, Qualifications and Occupations (ESCO) classification [8], from European Commission (EC). Both initiatives built their own competence models through taxonomies about competences and occupations. Further, these initiatives share an open database with millions of items in in different languages [20]. Some other competence standards focus on competence processing and data-exchange. The most well-known are: (i) the Human Resource XML (HR-XML) specification, to enable the automation of human resources-related data exchange [17]; (ii) the IEEE Reusable Competency Definition (IEEE RCD) [18]; (iii) IMS Reusable Definition of Competency or Educational Objective (IMS RDCEO) [19], that provides a specification of competences, career plan and learning outcomes [29]. Differently of typologies and taxonomies cited early, these standards offer more detailed schemas for competence representation, further supporting system interoperability and other kinds of automated processing. In general, works in the area focus on competence modeling without offering a visual representation for Competence Management. None of the cited initiatives are integrated with an Enterprise Architecture language. All of them focus on competence taxonomies and standards to allow data-exchange at the syntactic level.

Recently, many works have been using ontologies to solve issues at the semantic level. Among these works we can cite [9], [10], [12], [22], [28], [29], [39]. All of these use ontology-based competence to propose CM Systems and Software to support the Competence Management Process in organizational context. [29], for example, propose an ontology-based framework for lifelong competence management that uses different kinds of integrated ontologies as Competence, Learning objectives, Portifolio, Learning, and Domain Ontologies. [29], in turn, use ontologies to provide a CM System to integrate Organizations with Non-formal Education Providers. Alternatively, some works in Ontology-based Competence area focus mainly on proposing new Competence Ontologies, without proposing any application, as the works of [2], [12], [34]. They all proposed competence ontologies using OWL as an implementation language. Other works propose solutions integrated with other organizational areas and processes, such as [1], which proposed a Competence Ontology at a more conceptual level, integrating Competence and Knowledge Management areas, providing a reference model to another solution in this context.

Regarding the ontology-based works we found, the one presented by [22] is the closest to our work. The authors report in-depth work to understand other competence models, identifying important concepts related to the field. This work, for example, is one of the few that distinguishes between "Competence Type", "Competence" and "Competency". Although offering more fine grained distinctions, it still leaves open a number of conceptual issues open that could have been settled by adopting a foundational ontology.

Other related works that employ Foundational Ontologies in EA modeling include [5], [26]. Both use UFO to perform ontological analysis of concepts closely related to competence: Capability and Service. [5], for example, performs an ontological analysis of Capability, a topic closely related to Competence. 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 [4], thereby connecting individual-level capabilities (competences) with organizational capabilities.

6. Final Remarks

The work presented in this paper aimed to improve competence modeling and representation using a foundational ontology as semantic background. The ontological analysis we performed on concepts in the literature of Competence Management allowed us first to clarify a number of important issues in the literature. Further, we have been able to provide a well-founded set of patterns in ArchiMate to support Competence Management in Enterprise Architecture modeling. The foundations provided us with the basic distinctions underlying the so-called four-category ontology, allowing us to clarify the notion of competence (and its relation to competence types). Other elements in the foundations allowed us to relate competences to other central competence-related phenomena (competence manifestation, competence subtypes, context).

We have explored the synergy between Competence Management and Enterprise Architecture. The proposed competence representation strategies facilitate the adoption of Competence Management concepts in EA. In turn, EA contributes with the breadth of its concepts to enrich the Competence Management practice and embed it into an overall organizational setting. This distinguishes the present work from existing standards, taxonomies for competence in the literature, including ontology-based ones.

With the proposed pattern language, it is possible to support Competence Management (CM) activities such as mapping, development and gap analysis. In this sense, the pattern language helps with CM activities by providing a visual representation to modeling competences in different perspectives, as: individual competences (instance perspective), competences of an occupation or position (type perspective), current competences (present perspective), and desired ones (future perspective).

Future work includes proposing a more detailed Competence Ontology based on UFO to further benefit from this well-founded approach. Other work is the incorporation of concepts related to evaluation (outcomes, evidence, rating) based on the well-founded Measurement Ontology proposed by [6]. The representation of such concepts can also help the organization in automating assessment tasks. Regarding ArchiMate, a possible future work is to explore further the connection of competences with other perspectives, including Motivation Elements. The ontological analysis in this case can involve other UFO concepts, related to intentions as Goal and Proposition [3]. In this sense, an interesting possibility is to allow ArchiMate to model competence requirements explicitly, in an integrated manner with the organization's strategic objectives.

We also see an opportunity to incorporate General System Theory (GST) concepts in the ontological foundation and consequently in our analysis of competence. GST area has many system-related concepts similar to the concepts approached here, as input, output, levels, environment, feedback, composition, configuration, and (specially) emergence. We believe that incorporating these concepts in the ontological analysis will shed further light into the representation of competence composition, configuration, creation and evolution, especially in the Enterprise Architecture context.

Finally, the competence representation patterns proposed here should be subject to validation in case studies. Although ontological analysis provides the basis for a well-founded representation (as the foundation employed here incorporates advances in Formal Ontology, Philosophical Logics, Philosophy of Language, Linguistics and Cognitive Psychology [16]), the pragmatics of a representation in its context of usage should be thoroughly assessed. Similar efforts in this vein were already conducted for other UFO-based representation schemes, e.g., in [13], [25].

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