Agent Roles, Qua Individuals and *The Counting Problem*

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Abstract. Despite the relevance of the concept of *role* for conceptual modeling and agent-orientation, there is still in the literature a lack of consensus on the meaning of this notion and how it should be incorporated in existing conceptual modeling languages and frameworks. In this paper, we offer a contribution to this problem by employing a well-founded reference ontology (UFO) to analyze and reconcile two competing notions of role existing in the conceptual modeling literature. Moreover, a modeling solution based on this ontology is proposed, which incorporates the benefit of the two approaches analyzed.

1 Introduction

Roles represent a fundamental notion for our conceptualization of reality. This notion has received much attention both in philosophical investigation [20,32] and in the conceptual modeling literature [2,31,34]. In particular, in the sub-area of conceptual modeling concerned with *agent-oriented conceptual modeling*, the concept of role is considered of fundamental relevance [5,25,26].

In a comprehensive study on this topic, Friedrich Steimman [31] defends that the role concept naturally complements those of *object* and *relationship*, standing on the same level of importance. However, Steimann also recognizes that *"the role concept, although equally fundamental, has long not received the widespread attention it deserved"*, and that *"although there appears to be a general awareness that roles are an important modelling concept, until now no consensus has been reached as to how roles should be represented or integrated into the established modeling frameworks"* [ibid., p.84]. The last statement can be verified by inspecting the diversity and incompatibility of the several conceptualizations of roles currently co-existing in the literature [2,18,31,34].

Recently, not only has the interest in roles grown continuously, but also has the interest in finding a common ground on which the different notions of role can be judged and reconciled [20,22]. In this paper, we employ the *foundational ontology* developed in [11,12] to provide real-world semantics, and to harmonize two competing notions of role present in the conceptual modeling literature.

In section 2 we present the theoretical background of the work presented here, i.e., the foundational ontology which is employed in the rest of the paper. A discussion on the categories of this ontology is continued in section 3, in which we formally define the notion of *role* that is adopted in our ontological framework. In section 4, we dis-

cuss a second notion of role that deviates from most of the proposals in the literature. This second notion of role has been initially proposed in [34] to address a philosophical problem known as *The Counting Problem* but it has been later adopted by other modeling approaches. In section 5, by using the foundational ontology presented in section 2, we manage to provide an ontological interpretation for both notions of role discussed. Moreover, we propose a conceptual modeling solution based on this ontology that is able to harmonize these two competing notions of role while maintaining the benefits of the two approaches. Section 6 concludes the article by presenting some final considerations.

2 Background: The Unified Foundational Ontology (UFO-A)

In this section, we present a fragment of a philosophically and cognitively well-founded reference ontology (foundational ontology) that has been developed in [11,12]. In particular, in [12], this ontology is named UFO (Unified Foundational Ontology) and is presented in three compliance sets. Here, we focus on the first of these sets (UFO-A), which is an *ontology of endurants*. As demonstrated in [12], this ontology comprise a number of core ontological categories that can be extended to provide a foundation for *Agent Modeling Concepts* (UFO-C). In the sequel, we restrict ourselves to a fragment of UFO-A, depicted in Figure 1 (see aforementioned references for details).

In what follows, we offer a formal characterization of some of the notions discussed by using a language of quantified modal logics with identity. The domain of quantification adopted is that of *possibilia*, which includes all possible entities independent of their actual existence. Therefore we shall quantify over a constant domain in all possible worlds. Moreover, all worlds are equally accessible. As a result we have the simplest language of quantified modal logics (QS5) with identity [9]. Finally, all formulas described are assumed to hold necessarily.

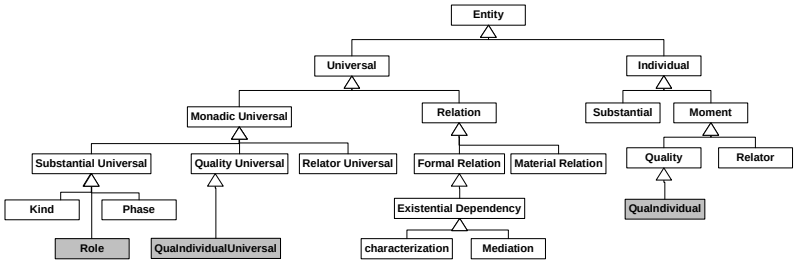

Figure 1. Excerpt of the Foundational ontology UFO-A.

A fundamental distinction in this ontology is between the categories of ***Individual*** and ***Universal***. Individuals are entities that exist in reality possessing a unique identity. Universals, conversely, are space-time independent pattern of features, which can be realized in a number of different individuals. The core of this ontology exemplifies the so-called *Aristotelian ontological square* comprising the category pairs ***Substantial-Substantial Universal***, ***Moment-Moment Universal***. From a metaphysical point

of view, this choice allows for the construction of a parsimonious ontology, based on the primitive and formally defined notion of *existential dependence* [11]:

Definition 1 (existential dependence): Let the predicate ε denote existence. We have that an individual *x* is *existentially dependent* on another individual *y* (symbolized as *ed(x,y)*) iff, as a matter of necessity, *y* must exist whenever *x* exists, or formally **(1). ed(x,y) $=_{def}$ $\Box(\varepsilon(x) \rightarrow \varepsilon(y))$.** ■

2.1 Moments

The word *Moment* is derived from the german *Momente* in the writings of E. Husserl and it denotes, in general terms, what is sometimes named *trope*, *abstract particular*, *individual accident*, or *property instance* [21]. In the scope of this work, the term bears no relation to the notion of time instant in ordinary parlance. The origin of the notion of moment lies in the theory of individual accidents developed by Aristotle. According to him, an accident is an individualized property, event or process that is not a part of the essence of a thing. We here use the term "moment" in a more general sense and do not distinguish *a priori* between essential and inessential moments.

As pointed out by [28], there is solid evidence for moments in the literature. On one hand, in the analysis of the content of perception, moments are the immediate objects of everyday perception. On the other hand, the idea of moments as *truthmakers* underlies a standard event-based approach to natural language semantics.

The notion of moment employed here comprises: (a) *Intrinsic Moments* or ***Qualities***: an individualized (objectified) color, temperature, or weight, a symptom, a skill, a belief, an intention, an electric charge; (b) *Relational Moments* or ***Relators***: a kiss, a handshake, a covalent bond, a medical treatment, but also *social objects* such as a flight connection, a purchase order and a commitment or claim [12].

An important feature that characterizes all *moments* is that they can only exist in other individuals (in the way in which, for example, electrical charge can exist only in some conductor). To put it more technically, we say that moments are *existentially dependent* on other individuals. Existential dependence can also be used to differentiate intrinsic and relational moments: qualities are dependent of one single individual; relators depend on a plurality of individuals.

A special type of existential dependence relation that holds between a moment *x* and the individual *y* of which *x* depends is the relation of ***inherence*** (*i*). Thus, for an individual *x* to be a moment of another individual *y*, the relation *i(x,y)* must hold between the two. For example, inherence glues your smile to your face, or the charge in a specific conductor to the conductor itself. We formally characterize a moment as an individual that inheres in (and, hence, is existentially dependent upon) another individual:

Definition 2 (Moment): (2). Moment(x) $=_{def}$ Individual(x) $\wedge \exists y$ *i*(x,y) ■

In our framework, we adopt the so-called *non-migration* (or *non-transferability*) *principle*. This means that it is not possible for a moment *m* to inhere in two different individuals *a* and *b*: **(3). $\forall x,y,z$ (Moment(x) $\wedge$ *i*(x,y) $\wedge$ *i*(x,z) $\rightarrow$ y = z)**

This characteristic of moments seems at first counterintuitive. For example, if we have two particulars *a* (a red apple) and *b* (a red car), and two moments r_1 (particular redness of *a*) and r_2 (particular redness of *b)*, we consider r_1 and r_2 to be different individuals, although perhaps qualitatively indistinguishable. What does it mean then to say that *a* and *b* have the *same* color? Due to (3), sameness here cannot refer to strict (numerical) identity, but only to a qualitative one (i.e., equivalence in a certain respect). In conformance with DOLCE [21], we distinguish between the color of a particular apple (its quality) and its 'value' (e.g., a particular shade of red). The latter is named *quale*, and describes a projection of an individual quality into a certain *conceptual space* [11].

The unique individual *y* that a moment *x* inheres in is termed the *bearer* of *x* and is defined as follows:

Definition 3 (Bearer of a Moment)[1]**: (4).** $\beta(x) =_{def} \iota y\, i(x,y)$ ■

Finally, the bearer of a moment can itself be another moment. An example of moment inhering in another moment is the individualized time extension, or the graveness of a particular symptom. The infinite regress in the inherence chain is prevented by the fact that there are individuals that cannot inhere in other individuals, namely, ***substantials***.

2.2. Substantial

Substantials are individuals that posses (direct) spatial-temporal qualities and that are founded on matter. Examples of Substances include ordinary objects of everyday experience such as an individual person, a dog, a house, a hammer, a car, Alan Turing and The Rolling Stones but also the so-called *Fiat Objects* such as the North-Sea and its proper-parts, postal districts and a non-smoking area of a restaurant. In contrast with moments, substantials do not inhere in anything and, as a consequence, they enjoy a higher degree of independence. We define the category of substantials as follows:

Definition 4 (Substantial): A substantial is an individual that does not *inhere in* another individual, i.e., which is not a moment. Formally, **(5). Substantial(x)** $=_{def}$ **Individual(x)** $\wedge \neg$**Moment(x)** ■

As we have previously stated, substantials enjoy a higher degree of independence when compared to moments. Can we make a stronger statement? Can we say that substantials are existentially independent from all other individuals? If we take the notion of existential dependence that we have given in definition 1, the answer is no. Since, there are certainly pairs *(x,y)* where *x* is a substantial that satisfy *ed(x,y)*. For example, if *y* is any of the essential moments of *x* (the particular DNA of a person). Moreover, even if both *x* and *y* are substantials, *ed(x,y)* can be satisfied. Take for example a substantial and any of its *essential parts* (e.g., a car and its chassis as an essential part). Or, alternatively, a substantial *x* and another object *y* of which *x* is an *in-*

[1] The iota operator (ι) used in a formula such as ιxφ was defined by B. Russel and implies both the existence and the uniqueness of an individual *x* satisfying predicate φ.

separable part (e.g., a brain and person of which this brain is an inseparable part). The notions of essential and inseparable parts are discussed in depth in [11].

However, suppose that *x* and *y* are two substantials that are *disjoint* from each other, i.e., they are neither part of each other nor they share a common part. The symbols ∫ and < below represent disjointness and *proper parthood*[2], respectively:

(6). $(x \int y) =_{def} \neg(x < y) \wedge \neg(y < x) \wedge \neg(\exists z\ (z < x) \wedge (z < y))$.

Then, in this case, we can say that x and y are necessarily *independent* from each other (symbolized as *indep*):

(7). $indep(x,y) =_{def} \neg ed(x,y) \wedge \neg ed(y,x)$

(8). $\forall x,y\ Substantial(x) \wedge Substantial(y) \wedge (x \int y) \rightarrow indep(x,y)$

For example, a person depends on her brain, and a car depends on its chassis. However, a person (car) does not dependent on any other substantial that is disjoint from her (it). Notice that formula (8) also excludes the case of mutual existential dependence between substantials that share a common essential part (e.g., two rooms that share a wall as a mutual essential part).

2.3. Relations, Relators and Qua Individuals

Relations are entities that glue together other entities. In the philosophical literature, two broad categories of relations are typically considered, namely, *material* and *formal* relations [14,29]. Formal relations hold between two or more entities directly, without any further intervening individual. Examples of formal relations include existential dependence (*ed*), inherence (*i*), *part-of* (<), *subset-of*, *instantiation*, among many others not discussed here [11,21].

Material relations, conversely, have material structure on their own and include examples such as *working at*, *being enrolled at*, and *being connected to*. Whilst a formal relation such as the one between Paul and his knowledge *x* of Greek holds directly and as soon as Paul and *x* exist, for a material relation of *being treated in* between Paul and the medical unit MU_1 to exist, another entity must exist which *mediates* Paul and MU_1. We name these entities *relators*. Relators are individuals with the power of connecting entities. For example, a medical treatment connects a patient with a medical unit; an enrollment connects a student with an educational institution; a covalent bond connects two atoms. The notion of relator (relational moment) is supported by several works in the philosophical literature [14,28,29] and, the position advocated here is that they play an important role in answering questions of the sort: what does it mean to say that John is married to Mary? Why is it true to say that Bill works for Company X but not for Company Y?

An important notion for the characterization of relators (and, hence, for the characterization of material relations) is the notion of *foundation*. Foundation can be seen as a type of *historical dependence* [8], in the way that, for instance, an instance of *being kissed* is founded on an individual *kiss*, or an instance of *being punched by* is founded

[2] Formally, an individual *x* is a proper part of an individual *y* iff *x* is part of *y* and *x* is not identical to *y*, i.e., $(x < y) =_{def} (x \leq y) \wedge \neg(x = y)$.

on an individual *punch*, an instance of *being connected to* between airports is founded on a particular flight connection.

Suppose that John *is married to* Mary. In this case, we can assume that there is an individual relator (relational moment) m_1 of type *marriage* that mediates John and Mary. The foundation of this relator can be, for instance, a wedding event or the signing of a social contract between the involved parties. In other words, for instance, a certain event e_1 in which John and Mary participate can create an individual marriage m_1 which existentially depends on John and Mary and which mediates them. The event e_1 in this case is the foundation of relator m_1 and, m_1 is the so-called truthmaker of the propositions "John is married to Mary".

Now, let us elaborate on the nature of the relator m_1. There are many qualities that John acquires by virtue of being married to Mary. For example, imagine all the legal responsibilities that John has in the context of this relation. These newly acquired properties are intrinsic moments of John which, therefore, inhere and are existentially dependent on him. However, these moments also depend on the existence of Mary. We name this type of qualities *externally dependent qualities*, i.e., externally dependent qualities are intrinsic moments that inhere in a single individual but that are existentially dependent on (possibly a multitude of) other individuals.

Definition 5 (Externally Dependent Quality): A quality *x* is externally dependent iff it is existentially dependent of an individual which is independent of its bearer. Fornally, **(9). ExtDepQuality(x) $=_{def}$ Quality(x) $\wedge \exists$y indep(y,β(x)) $\wedge$ ed(x,y).** ■

In the case of a material externally dependent moment *x* there is always an individual *external* to its bearer (i.e., which is not one of its parts or intrinsic moments), which is the foundation of *x*. Again, in the given example, we can think of a certain event e_1 (wedding event or signing of social contract) in which both John and Mary participate and which founds the existence of these externally dependent moments inhering in John. Now, we can define an individual that bears all externally dependent qualities of John that share the same external dependencies and the same foundation. We term this particular a *qua individual* [22]. Qua individuals are, thus, treated here as a special type of *complex externally dependent qualities*. In this case, the complex quality inhering in John that bears all responsibilities that John acquires by virtue of a given wedding event can be named *John-qua-husband*.

To continue with the same example, we can think about another qua individual *Mary-qua-wife* which is a complex moment bearing all responsibilities that Mary acquires by virtue of the same foundation and that albeit inhering in Mary are also existentially dependent on John. The qua individuals *John-qua-husband* and *Mary-qua-wife* are existentially dependent on each other. Now, we can define an aggregate m_1 composed of these two qua individuals that share the same foundation, i.e., (*John-qua-husband* < m_1) and (*Mary-qua-wife* < m_1). In this example, m_1 is exactly the instance of the relational property *marriage* that mediates John and Mary and that makes true propositions such as "John is married to Mary", "Mary is married to John", "John is the husband of Mary", and "Mary is the wife of John".

In this example, a particular instance of the relational property marriage (i.e., a particular marriage relator) is the sum of all instantiated responsibilities that the involved parties acquire by virtue of a common foundation. In general, a relator can be defined

as the aggregation of a number of qua individuals that share the same foundation. A relator is said to mediate (or connect) the relata of a material relation. Formally we have that: let *x*, *y* and *z* be three distinct individuals such that (a) *x* is a relator; (b) *z* is a qua individual and *z* is part of *x*; (c) *z* inheres in *y*. In this case, we say that *x mediates y*, symbolized by *m(x,y)*, and the following holds:

(10). $\forall x,y\ m(x,y) \rightarrow relator(x) \wedge Individual(y)$

(11). $\forall x\ Relator(x) \rightarrow \forall y\ (m(x,y) \leftrightarrow (\exists z\ quaIndividual(z) \wedge (z < x) \wedge i(z,y)))$

Additionally, we require that a relator mediates at least two distinct individuals, i.e.,

(12). $\forall x\ Relator(x) \rightarrow \exists y,w\ (y \neq w \wedge m(x,y) \wedge m(x,w))$.

Again, using the example above, we say that the particular relator marriage m_1 mediates the substantials John and Mary and, for this reason, we can say that John and Mary are married to each other.

Finally, in the theory present here, qua individuals are always *inessential* moments. In other words, if a qua individual *q* inheres in a substantial *x* then it does so *contingently*, i.e., only in certain situations. To see that this must be the case, suppose the contrary. By definition 5, a qua individual *q* that inheres in *x* is also existentially dependent on a individual *y* which is independent from *x*, i.e., *ed(q,y)* and $\neg ed(x,y)$. However, if *q* is a essential to *x* then we have that *ed(x,q)*. Now, since existential dependency is a transitive relation, with *ed(x,q)* and *ed(q,y)* we have that *ed(x,y)*, which is a contradiction. Hence, we have that qua individuals cannot inhere in its bearer necessarily.

2.4. Universals

A ***Substantial Universal*** is a universal whose instances are substances (e.g., the universal Person or the universal Apple). A ***Quality Universal*** is a universal whose instances are individual qualities (e.g., the objectified color of this apple is an instance of the universal color, a particular headache is an instance of the universal Symptom), and a ***Relator Universal*** is one whose instances are individual relational moments (e.g., the particular enrollment connecting John and a certain University is an instance of the universal Enrollment). Both quality and relator universals are moment universals.

In general, conceptual specifications (such as UML class diagrams and ER specifications) represent conceptualizations only at the type level, i.e., only universals and relations among universals are typically represented. Thus, we define the formal relations of ***Characterization*** and ***Mediation*** as the counterparts at the type level of the relations *inheres in* and *mediates*, respectively. In these definitions, the symbol :: represents the formal relation of instantiation.

Definition 6 (Characterization): A universal U is characterized by a moment universal M iff every instance of U bears an instance of M. Formally, **(13).** $charac(U,M) =_{def} Universal(U) \wedge MomentUniversal(M) \wedge \forall x\ (x::U \rightarrow \exists y\ y::M \wedge i(y,x))$ ■

Definition 7 (Mediation): The mediation relation holds between a universal U and a relator universal U_R iff every instance of U is *mediated by* (*m*) an instance of U_R. Formally, **(14). mediation(U,U_R) =$_{def}$ Universal(U) ∧ RelatorUniversal(U_R) ∧ ∀x (x::U → ∃r r::U_R ∧ *m*(r,x))** ■

Figure 2 below exemplifies the ontological categories discussed in this section. It depicts the *substantial universals* Person, Patient and Medical Unit, the *quality universal* Symptom, the *relator universal* Treatment. Moreover, it represents the *quality universal* Duration which characterizes the quality universal Symptom, and the corresponding *formal relations* connecting these entities. As argued in [11], a complex quality universal such as Symptom in figure 2 is the ontological counterpart of the concept of *Weak entity types* in EER diagrams.

In this figure and in the remainder of this article we use a UML class *stereotype* «quality» and «relator» to represent quality and relator universals. Additionally, we use the UML association stereotypes «characterization» and «mediation» to represent the respective formal relations. The classes stereotyped as «kind» and «role» represent substantial universals and will be discussed in the next section. These stereotyped constructs belong to an ontologically well-founded UML profile defined in [11] for the purpose of conceptual modeling and ontology representation. For UML extension mechanisms and, in particular, stereotypes, we refer to [24].

In the conceptual models represented in this article, we only represent as UML associations the stereotyped existential dependence formal relations discussed above, i.e., *characterization* and *mediation*. Material relations are represented by explicitly representing their founding relators. As discussed in depth in [11], this approach introduces many benefits to conceptual modeling when compared to the traditional modeling of relational properties as *associations*.

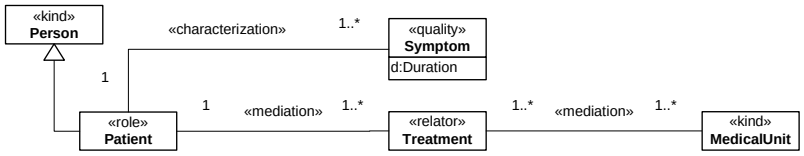

Figure 2. Conceptual model exemplifying some of the ontological categories discussed.

3 Roles as Substantial Universals

In [23], cognitive psychologist John Macnamara investigates the role of *substantial universals* in cognition and provides a comprehensive theory for explaining the process that a child undergoes when learning proper names and common nouns. He proposes the following example: suppose a little boy (Tom), who is about to learn the meaning of a proper name for his puppy. When presented to the word "Spot", Tom has to decide what it refers to. A demonstrative such as "that" will not suffice to determinate the bearer of the proper name. How to decide that "that", which changes all its perceptual properties is still *Spot*? In other words, which changes can Spot suffer and still be *the same*? As Macnamara (among others) shows, answers to these ques-

tions are only possible if *Spot* is taken to be a *proper name* for an individual that instantiates a special type of substantial universal, namely, one that supplies a principle through which we can judge whether two individuals are *the same*, i.e., a *principle of identity*. The principles of identity supplied by these universals are essential to judge the validity of all identity statements. For example, if for an instance of the universal *Statue* loosing a piece will not alter the identity of the object, the same does not hold for an instance of *Lump of Clay*.

Let us take another example. Consider a statement such as *"Exactly five X were in the kitchen last night"*. This statement is only determinate (i.e., has a determinate truth value) if X stands for a universal that supplies a principle through which we can individuate and, thus, count individuals, i.e., a *principle of individuation*. To verify this, we can substitute X in the sentence above by the universals *Thing*, *Object* or *Red*. A request to "count the red in this room" cannot receive a definite answer: Should a red shirt be counted as one or should the shirt, the two sleeves, and two pockets be counted separately so that we have five reds? The problem in this case is not that one would not know how to finish the counting but that one would not know how to start, since arbitrarily many *subparts of a red thing are still red*.

In summary, a sentence such as *"The X which is the same as Y"* is only be determinate if X and Y can supply a principle of identity for its instances, and a sentence such as *"Exactly five X"* is only determinate if X can supply a principle of individuation and counting. Substantial Universals such as Person, Car, Dog, Student that carry a principle of identity, individuation and counting for its instances are named *Sortal Universals*. In contrast, universals such as Thing, Red, Tall, Heavy are named *Characterizing Universals*, since they only attribute properties to (characterize) individuals which have already being individuated by sortal-supplied principles. The distinction between sortal and characterizing universals is reflected in natural language in the distinction between common nouns and other general terms (e.g., adjectives, verbs), respectively. Notice that only the substitution of X and Y in the sentences above by common nouns will render sentences which are grammatical. For a fuller formal theory of substantial universals that propose further distinction among both sortal and characterizing universals one should refer to [10,11].

The statement that the identity of an individual can only be traced in connection with a Sortal Universal, which provides a *principle of individuation* and *identity* to the particulars it collects amounts to one of the best-supported theories in the philosophy of language [13,19,23,32]. The position advocated in this article affirms an equivalent stance for a theory of conceptual modeling. We defend that every substantial individual in a conceptual model of the domain must be an instance of a conceptual modeling type representing a sortal universal.

As argued by Kripke [16], a proper name such as Spot or Mick Jagger are rigid designators, i.e. they refer to the same individual in all possible situations, factual or counterfactual. For instance, the proper name Mick Jagger refers to the same individual both now (when he is the lead singer of Rolling Stones and a sexagenarian) and in the past (when he was the boy Mike Philip living in Kent, England). Moreover, it refers to the same individual in counterfactual situations such as the one in which he decided to continue in the London School of Economics and has never pursued a musical career. For this reason, a proper name must be typed by a sortal that applies to its instances *necessarily*, i.e., in all possible situations. In this case, the sortal Person is

the sortal that defines the validity of the claim that Mick Jagger is *the same* as Mike Philip or, in other words, that Mike Philip persists through changes in height, weight, age, appearance, etc., as the same individual.

Once more, person can only be the sortal that supports the proper name Mick Jagger in all possible situations because it applies *necessarily* to the individual referred by the proper name, i.e., instances of Person cannot cease to be so without ceasing to exist. This meta-property of universals is named *Modal Constancy* [13] or *rigidity* [10] and can be formally characterized as in the *formula schema* below:

Definition 9 (Rigidity): A universal U is rigid if for every instance *x* of U, *x* is necessarily (in the modal sense) an instance of U. In other words, if *x* instantiates U in a given world *w*, then *x* must instantiate U in every possible world *w'*: **(15).** $\mathbf{\Box(\forall x\ x::U \rightarrow \Box(x::U))}$. ■

In summary, since principles of identity apply to individuals in all possible situations, we have that only *rigid sortals* can supply principles of identities for their instances. A rigid sortal universal that supplies a principle of identity for its instances is named here a ***Kind***. Examples of sortal universals that apply to their instances only *contingently* (i.e., possibly only in certain situations) include universals such as *Boy* and *Adult Man*, but also *Student*, *Employee*, *Caterpillar* and *Butterfly*, *Philosopher*, *Writer*, *Alive* and *Deceased*. Sortals that possibly apply to an individual only during a certain phase of its existence are named *phased-sortals*. Contrary to kinds, phased-sortals are *anti-rigid* universals:

Definition 10 (Anti-rigidity): A universal U is anti-rigid if for every instance *x* of U, *x* is *possibly* (in the modal sense) not an instance of U. In other words, if *x* instantiates U in a given world *w*, then there is a possible world *w'* in which *x* does not instantiate U: **(16).** $\mathbf{\Box(\forall x\ x::U \rightarrow \Diamond(\neg x::U))}$. ■

Being anti-rigid, phased-sortals cannot *supply* a principle of identity for their instances. However, since they are sortals, they must *carry* a principle of identity, which they inherit from a Kind. Therefore, we have that every phase-sortal PS must be a *subtype* of Kind such that PS inherits the principle of identity supplied by K. In other words, every instance of PS is necessarily a K and, thus, obeys the principle of identity supplied by K. For example, for an individual John instance of Student, we can easily imagine John moving in and out of the Student type, while being the same individual, i.e. without loosing his identity. This is because the principle of identity that applies to instances of Student and, in particular, that can be applied to John, is the one which is supplied by kind Person of which the phase-sortal Student is a subtype.

If PS is a phased-sortal and K is the substance sortal specialized by PS, there is a *specialization condition* φ such that *x* is an instance of PS iff *x* is an instance of K that satisfies φ [32]. A further clarification on the different types of specialization conditions allows us to distinguish between two different types of phased-sortals which are of great importance to the practice of conceptual modeling, namely, *phases* and *roles*.

Phases (also named *states* in [2]) constitute possible stages in the history of a substance sortal. Examples include: (a) Alive and Deceased: as possible stages of a Person; (b) Catterpillar and Butterfly of a Lepidopteran; (c) Town and Metropolis of a City; (d) Boy, Male Teenager and Adult Male of a Male Person. *Universals representing phases constitute a partition of the kind they specialize*. For example, if

‹Alive, Deceased› is a *phase-partition* of the kind Person then for every world *w*, every Person *x* is either an instance of Alive or of Deceased but not of both. Moreover, if x is an instance of Alive in world *w* then there is a world *w*' such that x is not an instance of Alive in *w*', which then implies that x is an instance of Deceased in *w'*.

Contrary to phases, ***Roles*** do not necessarily form a partition of kinds. Moreover, they differ from phases with respect to the specialization condition φ. For a phase Ph, φ represents a condition that depends solely on intrinsic properties of Ph. For instance, one might say that if Mick Jagger is a Living Person then he is a Person who has the property of being alive or, if Spot is a Puppy then it is a Dog who has the property of being less than one year old. For a role Rl, conversely, φ depends on extrinsic (relational) properties of Rl. For example, one might say that if John is a Student then John is a Person who is enrolled in some educational institution, if Peter is a Customer then Peter is a Person who buys a Product *x* from a Supplier *y*, or if Mary is a Patient than she is a Person who is treated in a certain medical unit. In other words, an entity plays a role in a certain context, demarcated by its relation with other entities. This meta-property of Roles is named *Relational Dependence* and can be formally characterized as follows [10,11]:

Definition 11 (Relational Dependence): A universal U is relationally dependent on another universal W via relation R iff for every instance *x* of U there is an instance *y* of W such that *x* and *y* are related via R: **(17).** $\Box(\forall x\, x::U \rightarrow \exists y\, y::W \wedge R(x,y))$. ■

In figure 1 we show the refinements in the category of substantial universals proposed in this section. Thus, the material ***Roles*** employed both in conceptual modeling and natural language (e.g., Student, Customer, Supplier, Husband, Patient) are defined here as *anti-rigid* and *relationally dependent substantial sortals*.

4 Roles as Qua Individual Universals

In [34], Wieringa and colleagues discuss the need for elaborating on the distinctions among the types of universals used in conceptual modeling and propose three type categories: *static classes*, *dynamic classes* and *roles*. The first two of these correspond to our categories of *kinds* and *phases*, respectively. However, differently from our proposal, in their approach a role universal is not a phased-sortal. Conversely, their roles are *rigid* universals whose instances are said to be *played by* instances of ordinary (static and dynamic) types. The *played by* relation (also termed *inheritance by delegation* by the authors) between a role *r* and an object *o* implies that *r* is *existentially dependent* on *o*. This means that *r* can only be played by *o*, and that r can only exist when played by *o*. However, in contrast, *o* can possibly be associated via the *play by* relation to many instances of the role class (and to many different role classes). Moreover, role universals are responsible for supplying a principle of identity for its instances, which is different from the one supplied by the universals instantiated by their players. Figure 3 depicts an example of an ordinary and a role universal according to Wieringa et al.

Figure 3. Example of Role and Role Player Universals.

An inspection of the role literature shows, however, that most authors conceive role universals in a way which is akin to the notion proposed in section 3, i.e., as substantial universals. This includes authors both in philosophy [32] and in conceptual modeling in computer science [2,7,15,31]. Moreover, several authors share the view sponsored in section 3 that the identity of a role instance is supplied by a (kind) universal subsuming the role type that it instantiates [1,17,27]. Finally, there are authors that explicitly share both views [10,31]. In fact, in an extensive study about the topic of roles in the conceptual modeling literature, Steimann [31] deems the approach of Wieringa and colleagues to be a singular case in which the identity of role instances is not supplied by a universal subsuming the role type they instantiate.

The motivation for such a view proposed by Wieringa and colleagues lies in a philosophical problem known as *The Counting Problem* [13]. Consider the following argument:

> KLM served four thousand passengers in 2004
> Every passenger is a person
> Ergo, KLM served four thousand persons in 2004

Thus, as Wieringa et al. write [34]: *"if we count persons, we may count 1000, but if we count passengers, we may count 4000. The reason for this difference is that if we count things we must identify those things, so that we can say which things are the same and which are different. But in order to identify them, we must classify them."* In other words, the counting problem is that, by following the premises in the argument above, one can derive a mistaken conclusion.

Although, we appreciate and share the view of connecting *counting with identity* and *identity with classification*, we do not agree with the conclusion the authors draw from this example, namely, that since person and passenger do not share a principle of counting then they must not share a principle of identity either. Since, a principle of identity can only be supplied by a rigid universal, this must be the foundation of the authors' conclusion that a role universal therefore must be a rigid universal.

Why do we think the conclusions made by the authors are not warranted? To start with, in line with [32], we defend that the counting problem is actually a fallacy. Take the argument posed by its defenders: "The person that boarded flight KL124 on April 22nd, 2004 is a different passenger from the person who boarded flight KL256 on November 19th, 2004, but the two passengers are the same person". We do not agree that it can be correctly said that *the two passengers are the same person*, or, alternatively, that a single *person is distinct passengers* (at different times), if we are truthful to our commonsense use of the *common noun* passenger. However, let us suppose that this is the case, i.e., that person and passenger obey different principles of identity. In this situation, the second premise of the argument is no longer valid, i.e., one cannot say anymore that *every passenger is a person* in a reading in which the copula "is" is interpreted as a relation of identity. This is because, due to the so-called *Leibniz Rule of Identity* [32], the identity relation holds necessarily if it holds at all. Moreover, since identity is an equivalence relation, we would have that

> "passenger *x* on flight KL124" is (necessarily) identical to person *y*
> "passenger *z* on flight KL256" is (necessarily) identical to person *y*
> Ergo, "passenger *x* on flight KL124" is (necessarily) identical to "passenger *z* on flight KL256"

This conclusion contradicts the initial premise that the two passengers were different. Therefore, if we have the second premise interpreted in the strong reading, one must conclude that passenger carries the same principle of identity as person and, hence, that "passenger *x* on flight KL124" and "passenger *z* on flight KL256" are indeed numerically the same. In this case, though, the first premise ceases to be true, i.e., one can no longer say that "KLM served four thousand passengers in 2004". We must conclude then that the second premise should have a weaker reading in which the copula does no represent a relation of identity but one of *coincidence* [21]. But, if this interpretation is taken the whole argument is clearly invalid, since the conclusion cannot be expected to follow from the premises.

In summary, the conclusion that different principles of identity must be supplied by role types and the types instantiated by their players cannot follow from this argument. However, despite disagreeing with the conclusions, we think there is an important truth highlighted by the argument of Wieringa and colleagues. If not instances of passengers, what does one count when stating that "KLM served four thousand passengers in 2004"? Let us analyze the concept of role proposed by Wieringa et al [34]:

1. a role universal is a rigid classifier;
2. role instances are (one-sidely) existentially dependent of a unique object, which is said to *play* the role;
3. objects *play* these roles only contingently, i.e., the *play* relation is only a contingent relation for the player. As a consequence, ceasing to play the role does not alter the identity of the player object.

A recent work that has a concept of role similar to the one of Wieringa et al [34] is the one of Frank Loebe [18]. However, Loebe's roles are not only *existentially dependent* on their players, but they also depend on the existence of another entity (distinct from their players), in the way, for instance, that *being a student* depends on the existence of an education institution, or *being a husband* depends on the existence of a wife, *being an employee* depends on the existence of an employer, etc. This feature of roles is recognized in our analysis in section 3. In fact, it is generally accepted in the literature that roles only exist in a certain context, or in the scope of a certain relation [2,4,6,10,20,30,31]. Thus, Loebe's notion of role agrees with that of Wieringa et al. in the points (1), (2) and (3) above, but it also characterizes role instances as existentially dependent on each other.

It should be clear by now that the concept of role in Wieringa et al [34] and Loebe is equivalent to our notion of *qua individual* discussed in section 3. We can interpret their *play by* relation as a sort of inherence. Both relations represent a one-side monadic existential dependence relation. Thus we can say that, like their notion of role, our qua individuals are: instances of a rigid classifier (1); one-side existentially dependent on objects, which are related to their "players" via a contingent sort of existential dependence relation (2)(3). Furthermore, a qua individual is a complex of externally dependent qualities (e.g., in figure 3, *student id*, *average grade*[3]), which, by definition, depends also on the existence of another object extrinsic to its bearer

[3] To see that, for example, having a particular *student id* is an externally dependent moment, the reader should imagine a person that is registered in different departments of a university, having a different student id for each department.

(player). Thus, as in Loebe's concept of role, asides from the inherence (play) relationship with its bearer (player), our *qua individuals* stand in parthood relationship with a unique relator in the scope of a material relation. Since relators consist of at least two distinct qua individuals (formula 12), we conclude that the qua individuals composing a relator are existentially dependent on each other.

5 Harmonizing the Two Notions

Now, how can we relate the notion of role as a qua individual discussed in section 4 with the one proposed in section 3? Let us revisit the example depicted in figure 3 above. To start with, a point that can be argued against this model is the representation of optional cardinality constraints. In fact, since no restriction is defined for the kind subsuming a role classifier, optional cardinalities must be represented in both Wieringa's and Loebe's approaches. As argued, for instance, in [33], from an ontological standpoint, there is no such a thing as an optional property and, hence, the representation of optional cardinality leads to unsound models, with undesirable consequences in terms of clarity. Moreover, as empirically demonstrated in [3], conceptual models without optional properties lead to better performance in problem-solving tasks that require a deeper-level understanding of the represented domain. To put it simply, not all persons bear a student moment, but only those persons that, for example, are enrolled in an educational institution. We can then define a restriction of the universal Person, whose instances are exactly those individuals that bear a student *moment*, i.e., that are enrolled in an educational institution (see figure 4).

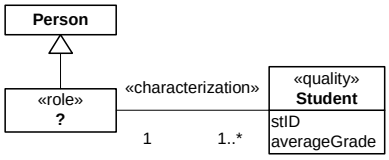

Figure 4. A Role universal, its subsuming kind and an exemplification relation to a qua individual universal.

Now, the universal stereotyped as «role» in figure 4 is exactly what we mean by a role in section 3 and it is the one idea of role that accurately corresponds to the commonsense use of roles in ordinary language. For this reason, we propose to use the role name for the role universal and to create a new name for the *qua individual* universal (see figure 5). Notice that the general term Student (Passenger, Employee, etc.) in natural language belongs to the grammatical category of *count nouns* as it is usually the case of substantial sortals, not to the category of *adjectives*[4] as it is usually the

[4] Etymologically the English word *noun* comes from the latin word *substantivus*, meaning expressing *substance*. The original form is still preserved in latin languages such as Portuguese (substantivo) and Italian (sostantivo), as well as in the English word *substantive*, which is a less familiar synonym for noun. Conversely, one of the meanings of *adjective* in English is "not standing by itself, dependent" (see, for example, www.m-w.com).

case with substantial characterizing universals corresponding to *determinate* moment universals (Red, Tall, Heavy).

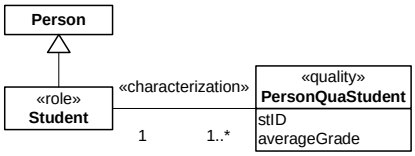

Figure 5. A Role universal, its subsuming kind and an exemplification relation to a qua individual universal (revised version).

Although an improvement of figure 4, figure 5 is still incomplete in the sense that it does not express the additional dependence relation that a *qua individual* has with other objects external to its bearer. This problem is solved in figure 6, in which relators (as aggregates of qua individuals) are represented explicitly and in which the externally dependent moments of a qua individual are represented as *resultant moments*[5] of the relator. In this figure, the associations between Student and Enrolment and between Education Institution and Enrolment stand for formal relations of mediation.

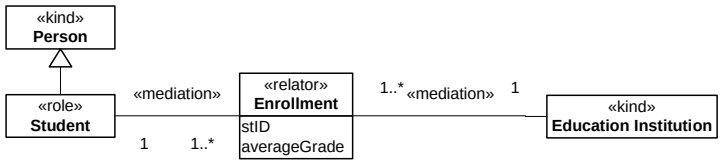

Figure 6. A Role universal, its subsuming kind and an associated Relator universal.

Now, let us return to the "counting problem" previously discussed:

500 students graduated from the University of Twente in 2004
Every student is a person
Ergo, 500 persons graduated from the University of Twente in 2004

In this argument, if the first premise is true than the word *student* refers to the mode *Person qua student*. The counting of these entities in a given situation is equal to the cardinality of the extension of the PersonQuaStudent universal in figure 5 (i.e., #*ext*(PersonQuaStudent)) or the cardinality of the extension of the Enrollment universal in figure 6 (i.e., #*ext*(Enrollment)), since there is always a 1-1 correspondence between relators and their composing qua individuals. However, if this interpretation for student is assumed, the second premise is simply false, since the relation between a student and a person would be one of inherence, not one of identity. Alternatively, if the word student is interpreted (in the more natural way) as in figure 5, then the counting of students is equal to the cardinality of the extension of the Student universal in

[5] Resultant properties of an object are properties that a whole inherits from one of its parts.

this figure (i.e., *#ext*(Student)). Though, in this case, premise one is not necessarily true.

In both cases, the alleged "counting problem" disappears. Nonetheless, with the model of figure 6 we are still able to represent for both kinds of entities (roles and qua individuals) and their respective counting in an unambiguous manner. Additionally, this solution is able to make explicit and harmonize the two diverse senses of Role which have been used in the conceptual modeling literature.

Finally, we can refine the characteristic or *relational dependence* defined for roles in section 3 by explicitly relating the two notions of role discussed in this article. Roles, as substance sortals, are always defined in the context of material relations [11]. Thus, the relation R in definition 11 can be further analyzed as being derived from a certain relator universal U_R [11]. Consequently, we can state that a role universal as a substantial sortal (in the first sense of section 3) is always characterized by a qua individual universal (role in the second sense of section 4):

(18). $\forall x$ Role(x) $\rightarrow \exists y$ QuaIndividualUniversal(y) $\wedge$ charac(x,y)

Or alternatively, we can state that a role universal (as a substantial sortal) bears always a mediation relation to a relator universal.

(19). $\forall x$ Role(x) $\rightarrow \exists y$ RelatorUniversal(y) $\wedge$ mediation(x,y)

As a consequence of formula (19), we have that, in the UML profile employed in figures 2 and 6, a UML class stereotyped as «role» must always be connected to an association end of a «mediation» relation [11].

5 Final Considerations

The development of a philosophically well-founded upper level ontology is an important step towards the definition of real-world semantics for conceptual modeling and agent-oriented concepts. In this article, we focus on the concept of *Role*. Despite its fundamental relevance to conceptual modeling and, in particular, to agent-orientation, there is still a lack of consensus on the meaning of this category and on how it should be incorporated in the metamodels of existing conceptual modeling languages.

In this paper, we use a fragment of the Unified Foundation Ontology (UFO) proposed in [11,12] to analyze two competing notions of role existing in the conceptual modeling literature. In particular, we consider the notion of role offered by Wieringa et al. in [34], which proposes the complete separation of roles and kind taxonomies, therefore, deviating from most of the approaches in the literature.

The proposal of Wieringa et al. is motivated by a philosophical problem known as *The Counting Problem*. As we demonstrate in this article, this problem is actually fallacious and, thus, the separation of role and kind taxonomies cannot be argued for on this basis. Nonetheless, there is an important truth highlighted by their argument which is generally neglected in most conceptual modeling approaches, namely, that in different situations one might want to count "role instances" in different senses.

By relying of the ontological category of *qua individual* discussed in this article, we manage to provide an ontological interpretation for the notion of roles proposed by

Wieringa and colleagues. Moreover, we manage to harmonize it with the more common view of roles taken in the literature, and the one which more naturally represents the commonsense use of roles in ordinary language, namely, the conception of roles as *relationally dependent and anti-rigid substantial universals.*

Finally, by explicitly representing roles as both substantial universals and *qua individual* universals, we can account in an unambiguous way for the alternative senses of counting "role instances" previously mentioned.

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