Artefacts and Roles: Modelling Strategies in a Multiplicative Ontology

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Abstract. The purpose of this paper is to examine different modelling strategies available in a multiplicative formal ontology, and the principles that drive their choice. This study is based on the results of recent work aiming at extending the foundational ontology DOLCE to grasp two quite different notions, that of artefact and that of role. These results, summarized in the paper, show that two multiplicative modelling strategies, entity stacking and property reification, are essential in both cases.

Keywords. representation methodology, ontology of social reality, multiplicativism, kinds of entities, reification

Introduction

Some topics pose very general modelling puzzles in formal ontology. For instance, how should we handle artefacts? As properties or as separate categories of individuals? If *the paperweight on my desk* refers to the same individual as *this pebble*, then "being a paperweight" could simply be a property instantiated by the pebble individual. But if the paperweight has some properties that arguably the pebble doesn't have, like being meant to hold papers, then, *the paperweight* could denote a distinct individual. Similarly, are roles properties or individuals? Does *the Chancellor of Germany* refer to a specific person, Angela Merkel, enjoying a certain property, or to a more abstract entity, an 'institutional role', that can be 'played' by several people across time? And is there any difference between Angela Merkel and "Angela Merkel as Chancellor"?

The purpose of this paper is to show that the answers to such questions do not simply rely on personal taste, and that a careful examination of data is needed before deciding on the property vs. individual issue. The overall picture is even more complex for two reasons: there exist several theories of properties [23] and concepts [14] and several ways to formalize them. If simple predication, which semantically corresponds to class membership in classical first-order logic, is a standard means to express properties [3], some authors advocate the use of tropes or individual properties [5], while others use universals and a non-extensional instantiation relation [1].

In this paper we will present two recently proposed theories of artefacts and roles which make use of two modelling strategies involving the introduction in the domain of new entities in addition to less controversially existing ones. Such strategies are sometimes indicated as *entity multiplication* [6].

This work can be seen as a first attempt to clarify what, beyond predication, are the modelling strategies useful in formal ontology. This means recognizing when predication is not adequate and identifying the adequate alternative strategy. For each of these alternative strategies, if they are multiplicative, it is also essential to clarify the identity criteria of the new entities and analyse the different relations they enjoy with the other ones. Of course, such a discussion, which we consider important for the field, won't be exhausted by the present paper.

This paper is structured as follows. In the next section, we will briefly review some multiplicative approaches used in philosophy. We focus on two strategies, respectively called *entity stacking* and *property reification*. They both result in the extension of the domain with new individuals, but these are of different sorts and enjoy different relations with respect to the other individuals. Sections 2 and 3 will then present two different works on the modeling of, respectively, artefacts and roles, which make use of the two strategies. The theory of artefacts is a first attempt to encode in a formal system recent philosophical analyses of this notion. The theory of roles builds on a larger literature, in both computer science and philosophy, which has raised a number of subtle modeling issues and is thus a more elaborated one. Finally, in Section 4 we discuss why and how the two strategies have been used in these works. To clarify the differences between the two, we also try to contrast these uses when the choices do not appear obvious.

1. Brief review of multiplicative approaches in philosophy

Parsimony is a principle that no-one, philosopher or computer scientist, renounces to. But this principle is more often than not faced with puzzles of different kinds, and philosophers have come up with various answers requiring and motivating the multiplication of entities and/or entity sorts in various ways and degrees. As a result, one finds a wide range of philosophical stands, from the extreme unifier (reductionist) that will accept only one sort of entities —and the least quantity of them— e.g., bunches of molecules, to the extreme multiplier for whom each non-synonymous linguistic description denotes a different entity. In this paper, we place ourselves in a framework which is neither extremes, i.e., a moderate multiplicativist one. We put forward motivations for multiplication that we find compelling, although we are well aware that these arguments are motivated more from a representational point of view than a philosophical one.

Here, we briefly examine two different multiplicative approaches that correspond to two ways a first-order theory can be enriched by introducing new entities in the domain of quantification: *entity stacking* and *property reification*.

Entity Stacking. Entity stacking is grounded on the notion of identity, or rather, non-identity between entities. Two identity criteria for entities are widely used: entities are identical if and only if they have the same proper parts (mereological extensionality), or if and only if they display the same properties (Leibniz's law). Many philosophers interpret mereological extensionality (in the case of concrete entities) as a rendering of the motto "no two things at the same place at the same time", assuming parthood amounts to spatial inclusion [25,31]. The identification of *having the same proper parts* with *being co-located* and the adoption of mereological extensionality yields that spatial co-location implies identity.

This position raises famous puzzles when the two identity criteria clash: the *statue and the clay* and *the ship of Theseus* [25, Introduction]. In the first puzzle, the statue is co-located at all times with the clay but their modal properties are different: the clay but not the statue can be reshaped and the statue but not the clay can loose tiny parts. The second puzzle is more complex as it involves identity across time. Assuming that the ship of Theseus undergoes a successive change of all of its planks, and supposing that the old planks are kept apart and eventually re-assembled into a ship, which one is the ship of Theseus? Considering Leibniz's law, one would tend to chose the first, since preserving ownership and some form of spatio-temporal continuity, while considering mereological extensionality, one would chose the second.

Some authors are compelled by such puzzles to conclude that co-location doesn't imply identity, and that the relation between the statue and the clay or between the ship and the aggregate of planks is instead one of *constitution*. Constitution is a form of existential dependence between co-located entities, i.e. an asymmetric relation that gives rise to *levels* or *substrates* of different kinds of entities with specific identity criteria, e.g. matter, physical object, intentional agent, collective... Assuming this *entity stack*, the puzzles disappear because having the same proper parts is no longer equivalent to (but only implies) co-location (see [31] for a detailed discussion).

A similar but slightly different problem regards the identity criteria for players of *roles*. In particular, the *counting problem* [15] makes evident that in order to *count* the passengers of an airline in a year we cannot count the persons that flew that airline. The properties of passengers are different from those of persons, so here too entity-stacking can solve the issue (although alternative solutions exist). In Section 3, this strategy is applied introducing new individuals, called *qua-entities*: *John qua Alitalia passenger of flight 123 on day D* is co-located with and *inheres in* John. As we will see, there are differences between *constitution* and *inherence*.

Property reification. In FOL, properties are usually represented by *predicates*, which have *sets* as semantic counterpart. Predicates necessarily model extensional, static, and a-contextual properties and are closed under logical connectives. Many philosophical and/or cognitive theories of properties drop some of these assumptions: for example *universalists* (see [1] for a review) refuse extensionality and Boolean closure, while *conceptualists* (see [18] for a review) tend to think that concepts are properties created and possibly destroyed at specific times, dependent on human minds or societies, etc.

To relax the previous assumptions and to talk of temporal extensions and dependences of properties, i.e., to predicate over properties, staying in a FOL framework, a *reification* process that introduces properties as individuals in the domain of quantification and in the language is necessary. And just as done in the general models for reducing a fragment of second-order logic to first-order [30], in addition to reifying properties, new primitive relations of *instantiation* (one for each arity) are required to replace predication in the language.[1] Finally, in this approach, we are obliged to characterize the additional sort of individual, say, *Universal* or *Concept*.

The reification process has been adopted in philosophy of language or computer science for reifying more complex logical constructs, like propositions, facts or states

[1] In the general models, the domain of interpretation of properties is (a subset of) the standard one, i.e. properties denote sets or sets of tuples of (other) individuals. Dropping the assumption that properties are extensional, as Universalists do, requires a different interpretation, thus different models.

of affairs, as in the cases of *events* in Davidsonian semantics [8] or of *situations* in the *situation calculus* [26]. We will nevertheless consider in this paper only the reification of properties.

2. A Multiplicative Approach to Artefacts

Let's first examine the proposal for a theory of physical artefacts put forward in [4] as an extension of the foundational ontology DOLCE [20,3]. This proposal is based on the recognition of the creator's intentions as an essential property of artefacts and thus the distinction of physical artefacts into a separate category from the physical objects that constitute them.

2.1. Physical Artefacts as a Separate Category

The notion of *physical artefact* is a slippery one even when limiting ourselves to non-agentive artefacts: we all think we know what we mean when talking about these objects and we can provide good examples of them. When asked to name artefacts, most of our examples point to manufactured items. Indeed, the recognition of physical manipulation on an item gives us a strong indication that that entity is an artefact. Nonetheless, physical manipulation is not a key element for artefacts: tons of manipulated entities are definitely not counted as artefacts (e.g., sawdust, cut-off hair, mowed grass) while a moment of thought suffices to find physically unaltered objects that actually make up artefacts (e.g., the pebble used as paperweight of the introduction, the unworked shells used as money in the past).

The fundamental element to single out artefacts is intentionality [9,2]: we intentionally select objects in order to use them for a purpose perhaps physically modifing them to suit our tasks. Intentionality then is part and parcel of the process of attributing functionalities (capacities) to objects, i.e., of the process in which artefacts are created. The intentionality involved in this process is not a property *of* artefacts and even less so of the selected entities, it's a property of the agents who created them. Artefacts are the results of agents' intentionality so their existence depends on an action of entities external to them. These observations lead to consider artefacts as ontologically separated from other physical entities like water and trees, and therefore to entity-stacking: the paperweight is not the pebble, it is co-located with it and constituted by it. Indeed, it can be argued that the pebble does not depend on any creation event, nor on any agent, that it is not meant to hold papers, and that it is older than the paperweight.

This approach constitutes an alternative to the more obvious option considering artefactuality as a property that physical objects may or may not have or acquire. This would mean though, rejecting the widely recognized sortal nature of artefacts [10], as well as failing to acknowledge that being the object of intentions is an *essential* property of artefacts, and being unable to account for the just-mentioned dependence relations and the other commonsensical differences between the pebble and the paperweight. As we will see shortly, the multiplicative approach has another advantage which the predicative approach has difficulties to cope with. Artefacts can maintain their identity trough repair, i.e., through the change of the entity that constitute them.

The class of artefacts addressed in [4], which is also the most studied in the philosophical literature [2,17,10,29], collects entities constituted by entities in two subcategories of Endurant in the DOLCE taxonomy [20]: amounts of matter (olive oil, pieces of glass) and non-agentive physical objects (statues, boats, microchips).[2] The result is the extension of DOLCE with the category Physical Artefact, proposed as a new subcategory of Physical Endurant, along with the given Amount of Matter, Physical Object, and Feature.

2.2. Intentional Selection and Attributed Capacities

We have motivated the view that artefacts have an ontological status and are essentially the result of an intentional act of an agent (or group of agents) called creator. In [4] this intentional act, the creation, is considered as an act of *intentional selection* of the entity to constitute the artefact. This intentional selection is not enough, though. In the example of the paper-weight made of a pebble, the artefact is the result of some agent intentionally selecting the pebble and *attributing* to it some *capacities* (holding paper without ruining it, being easily grasped by hand, being firm etc). Of course, the artefact might turn out not to have the capacities the agent attributed to it, as it could be flawed or malfunctioning, but that does not affect the existence of the artefact itself.

The notion of capacity is taken from Cummins [7] and characterizes the dispositions [24] or behaviors a physical endurant is able to express, independently of any agent, even in the specific case of artefacts. Capacities are a type of DOLCE individual *qualities* possessed by elements in (at least) categories Amount of Matter, Non-agentive Physical Object, and Physical Artefact. Individual qualities in DOLCE are each mapped to a value in the quality space (e.g., the space of colors, the space of times, etc.) that characterizes how they are structured [3]. Although the notion of *capacity space* is quite complex and not yet well understood, we can say that the value corresponding to the capacity quality of an entity at a given time is a region of the capacity space collecting all the various dispositions the entity is able to express at that time. For instance, the capacity of this pen has now the value of writing finely in black when swept on paper, fitting in one's hand when grasped, making a certain noise when struck on the table…

The *attributed capacity* is a distinct individual quality of entities in Physical Artefact only that maps to the *same* space as the capacity quality, and characterizes the purpose or function of the artefact as determined by its creator. The pen above certainly has the attributed capacity to write finely in black when swept on paper and to fit in one's hand when grasped, but most probably not to make a certain noise when struck on the table. The fact that (actual) capacities and attributed capacities are elements of a same space has a number of advantages since it allows to define malfunctioning (see [4]) and reconcile the physical and mental nature of artefacts [17]. Note that, although capacities and attributed capacities map into the same space, the first are physical qualities whereas the latter are intentional. Also, they differ in their dependence on time: the attributed capacity is fixed by the creation event and does not change over time.

Although we do not discuss the formalization here (see [4] on this), we point out that some elements new to DOLCE are needed to characterize the category of artefacts. In addition to the qualities *capacity* and *attributed capacity*, we assume the ontological formalization of a primitive relation of *intentional selection* which characterizes the

[2]The notion of artefact, though, arguably covers individuals constituted by entities of yet other categories: agentive physical objects (robots), features (speed bumps, folds in a skirt), perdurants (judgements, performances, wars) and more abstract ones like pieces of music, laws or social institutions.

events that we called *creations*. *IntentionalSel*(e, p, x, y, q) stands for "e is the event of the agent p intentionally selecting the amount of matter or non-agentive physical object y and attributing to it the attributed capacity q, obtaining the artefact x". Then the category Physical Artefact is characterized by an axiom positing that artefacts are the result of such events (among other axioms).

2.3. *Entity stacking*

A central element in this formalization of artefacts is the assumption that the artefact (the paper-weight) *is not* the endurant of which it is made (the pebble). As said above, the paper-weight starts existing when it is created, generally well after the pebble does; the two objects, although co-located when both present, have different properties, in particular different lifetimes, and are therefore different. In addition, the paper-weight depends on — here, is constituted by — the pebble but not vice versa. We thus adopt the entity-stacking strategy described in Section 1.

DOLCE already adopts such a multiplicative approach, in particular to distinguish the statue (as a physical object) from the clay, the amount of matter that constitutes it. However, for artefacts it is important to note that what constitutes the paper-weight is the physical object pebble, and not simply the amount of (rock) matter that in turn constitutes the pebble.[3] The pebble is not an amount of rock since it is shape-dependent: the amount of rock persists after crushing, but the pebble doesn't. Artefacts therefore add still another layer, an intentional one, to the DOLCE constitution hierarchy. As a result, in the traditional example of the statue which actually is an artefact, we need to distinguish three co-located entities, and not simply two as argued in DOLCE and more generally in the literature on material constitution (see Section 1): the intentionally created statue, the specifically shaped and structured physical object,[4] and the mereologically determined amount of matter.[5]

Since artefacts are distinct from physical objects and amounts of matter, they obey different identity criteria as suggested by the fact that artefacts can be repaired and undergo parts substitution without losing their identity. In the ship of Theseus example, substituting a plank doesn't destroy the artefact, although it does destroy the original physical object that constituted it, i.e., the plank assembly.[6] So, part substitution implies the disappearing of the original constituting entity and the coming into existence of a new one, with some degree of spatio-temporal continuity between the two. This explains that an artefact cannot "jump" from one material entity to a separate one at will, as your home does when you move, the two separate houses both preexisting to and surviving the move. This observation brings some light on the important distinction between artefacts (e.g., a house) and roles (e.g., a home) which we will address in Section 4. To further illustrate the approach on the ship of Theseus story, when the original planks are assembled again, depending on the identity criteria given to physical objects, one could

[3] The amount of matter also constitutes the artefact, as constitution is transitive in DOLCE.

[4] DOLCE doesn't provide generic identity criteria for physical objects. Here we assume that shape and internal structure are involved, although this requires further studies.

[5] There are also cases in which the artefact is directly selected out of an amount of matter as in the cases of a cup of water selected as a cake ingredient, or of the plastic produced in a factory.

[6] The amount of wood doesn't disappear since the old plank is not annihilated but kept apart. It is simply no longer a self-connected amount of matter.

argue that the original physical object comes back into existence. The artefact that is created then, though, is a different one, with perhaps another creator and other attributed capacities.

The identity criteria of artefacts are based on their intentional aspect, i.e., their attributed capacity, and their constituting entities. Two artefacts are the same if they have the same attributed capacity, were originally selected out of the same physical object or amount of matter, and are constituted of the same entities at all times. Identity criteria should also state under which conditions an entity persists or disappears all together. Ordinary malfunctioning does not make an artefact disappear, so the identity criteria cannot impose a simple match between attributed capacity and capacity. The artefact's disappearing is not simply due to its constituting entity's disappearing either, since the latter can be substituted as we have just seen. A combination of the two aspects, modulated by appropriate notions of granularity and vagueness, is required. The persistence of artefacts thus combines a *significant* degree of spatio-temporal continuity of the successive constituting entities, the existence of all specific essential parts if any (e.g., for a car, its frame), and the actuality of a *significant* part of the attributed capacity. The latter is modeled by a significant overlap between (the value of) the attributed capacity and (that of) the capacity. Note that since the attributed capacity is not restricted to the overall or main function of the artefact and covers structural specifications like size, shape, weight, composition etc., a malfunctioning artefact does possess most of its attributed capacity. Even an ill-designed artefact, e.g., a medieval flying machine, may possess most of its attributed capacity.

3. Roles, concepts and qua-entities

The second case examined in this paper is that of *relational roles* (henceforth called roles) of objects as analyzed in [22,21]. Typical examples of roles are socially relevant notions such as *student*, *president* or *customer*, but *catalyzer* is an example in another domain. Following the main literature on this topic (see [28]), roles are considered in this work as dynamic, anti-rigid, and relationally dependent properties.

The first two aspects (dynamism and anti-rigidity) regard, respectively, the temporal and modal nature of the relation between roles and their *players*. Entities could play a role only during a specific time interval (in a possible world or set of possible worlds). For instance, a person could be a student for only two years, and even in the case she is a student for her whole life, it is not necessary for her, i.e. persons are not necessarily students. In order to represent these aspects, standard modelling approaches consider a modal (possibly temporal) logic and assume roles as unary predicates, or introduce a parameter (possible world or time) and assume roles as binary predicates.

As far as the third aspect is concerned, intuitively, a property is relationally dependent when it depends — via a *pattern of relationships* [27] — on additional "external" properties.[7] [22] adopts a generalization of the notion of *definitional dependence* introduced by Kit Fine [12]: a property ϕ is definitionally dependent on a property ψ if, nec-

[7] A property ϕ (generically) depends on an external property ψ if, necessarily, for every instance x of ϕ there exists an instance y of ψ which is an *entity external* to x. The notion of "external entity" is not straightforward. Note though that notions like part, constituent, and quality typically identify entities that are "internal" to other entities.

essarily, any *definition* of ϕ ineliminably involves ψ. In particular, roles can be defined on the basis of a relation whose arguments are characterized by specific properties. This aspect is standardly represented by defining the predicates that correspond to a role. Let us consider, for example, the role of 'being a customer' defined as: "a customer is a person that (repeatedly) buys (something) from a company". In this case, the (unary) predicate 'being a customer' is defined on the basis of 'buy', 'being a person', and 'being a company".[8] On the basis of the same predicates we can define the role 'being a seller' as "a seller is a company from which a person (repeatedly) buys (something)". Formally we have:

(Dc) $\mathit{Customer}(x) \triangleq \mathit{Person}(x) \wedge \exists y(\mathit{Buy}(x, y) \wedge \mathit{Company}(y))$,
(Ds) $\mathit{Seller}(x) \triangleq \mathit{Company}(x) \wedge \exists y(\mathit{Buy}(y, x) \wedge \mathit{Person}(y))$.

3.1. Concept Reification

The novelty of the approach introduced in [22] consisted in taking seriously into consideration two additional aspects of roles, their *intensional* and *conventional* nature. The intensional nature relies on the fact that the previous definition (Dc) not only specifies the extension of the role 'customer' but *defines* what a customer is. While in classical logic two co-extensional predicates are necessarily indistinguishable, one would like to consider that two co-extensional roles are different if they are defined in different ways. The conventional nature implies an existential dependence on some society that produced the conventions, sometimes described as context-dependence. For instance, the role of president (of a country) depends on the existence of that country, but also on the existence of some sort of constitutive text defining what 'being a president' means in that country: constraints on who can be player, ways in which players are appointed, norms constraining what the player may or may not do, etc. In addition, this role can be dated: it has been created at some point, and so exists in time.

As discussed in Section 1, in a FOL framework, these latter aspects can be captured by reifying the roles, and the social conventions or contexts that define them, so that the definition and dependence relationships can be expressed. Making roles, and, more generally, socially defined concepts, part of the domain of discourse also enables making justice to their temporal dimension.

The approach followed in [22] is based on a clear distinction between (i) the properties in the *ground ontology*, represented as predicates and therefore assumed as static, rigid, extensional, and not explicitly defined or linked to a social context (e.g., the primitive predicates of the theory); and (ii) the properties (called "concepts") reified at the object level, that are not necessarily static, rigid, and extensional and for which it is possible to explicitly describe some aspects of the social contexts that define them (called "descriptions").

Concepts (CN) are *defined* (DF) by *descriptions* (DS) and they *classify* (CF) other individuals: $\mathsf{DF}(x, y)$ stands for "the *concept* x is defined by the *description* y"; $\mathsf{CF}(x, y, t)$ stands for "at the *time* t, the *individual* x is classified by the *concept* y", i.e., "at the *time* t, the *individual* x satisfies all the constraints stated in the description of the

[8] This definition obviously is very rough, and just for expository purposes. In particular, we do not consider the aspects linked to time and modality.

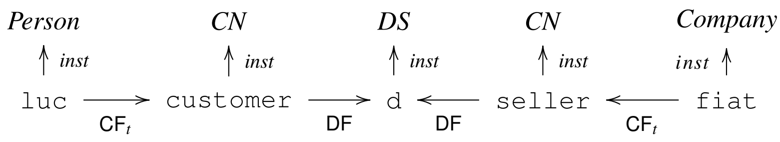

Figure 1. The customer/seller example with the reification of roles.

concept y".[9] Because we want to talk about the creation or destruction of concepts, we consider them as a special kind of endurants that are present (i.e., exist) in time. In addition, concepts must be defined (DF) by an unique description that cannot change during the life of the concept, i.e. new descriptions define new concepts and new concepts are defined by new descriptions.[10] Assuming that *Person* and *Company* are predicates in the ground ontology, the previous customer/seller example can be represented as in Figure 1 (where an arrow labelled with *inst* stands for standard predication, an arrow labelled with CF_t between a and cn stands for $\mathsf{CF}(\mathtt{a}, \mathtt{cn}, t)$, and an arrow labelled with DF between cn and d stands for $\mathsf{DF}(\mathtt{cn}, \mathtt{d})$).

3.2. Qua-entities

An important characteristic of roles consists in the possibility of introducing 'new' attributes or of hiding attributes of the players: students but not persons have a registration number, passengers but not persons have a flight number, customers but not persons have a code or a purchase number, persons but not customers have weights...

Let us consider, for example, the 'customer code' attribute. luc can be (simultaneously) the customer of different companies, and therefore he can have different codes, one for each company he is customer of. But if *code* is an attribute of customer then luc can have only one code value.[11] In the case of customer codes, it is possible to solve the problem modelling *code* by means of a function with two arguments — the customer and the company — but the problem can be more serious as in the case of two classical puzzles: the *counting problem* [15] and the *conflicting properties paradox* [11]. In these cases we could be forced to add parameters. For example "Luc as customer of Fiat spent 15K euros last year, while as customer of Sony just 2K euros". The 'having spent 15K euros' and 'having spent 2K euros' cannot apply to the person luc on pain of inconsistency. Therefore we need to introduce the customer code as additional parameter on 'having spent 15K euros'. For counting passengers, as the same person can fly several times the same company, we need to consider a temporal parameter.

In [28], an alternative multiplicative solution is assumed. This solution presupposes the existence of *adjunct entities*, instances of *Customer*, that existentially depend but are disjoint from instances of *Person*. Each instance of *Customer* has a customer code. Instead of the notion of *adjunct entity*, some philosophers (see [13] for example) have introduced that of *qua-entity*. [13] considers qua-entities (called qua-objects) to solve the

[9] This is for unary concepts, but the approach can be extended to concepts of any arity.

[10] This is a strong assumption that makes impossible to account directly for the intuition that some concepts evolve in time. In this approach, this intuition can be handled by a series of related concepts.

[11] Note that it is not possible to introduce one code attribute for each company, because the general theory of customer cannot be based on which companies exist.

statue-and-clay puzzle (see Section 1): "the statue may be identified with that matter under the description of having Goliath shape", or with that matter qua-Goliath shaped. Indeed the same idea can be applied to entities that are playing some roles. So, in addition to `luc` there are two new individuals: `luc` *qua* Fiat customer (`luc`$_{\text{qua}}$`fiat_cust`) and `luc` *qua* Sony customer (`luc`$_{\text{qua}}$`sony_cust`) that *inhere in* `luc` (see Figure 2). The inherence relation i is typically addressed in *trope* theory. It is an asymmetrical relation that specializes the *existential specific dependence* (eSD) by the non-*transferability* principle introduced in [19]: $i(x, y) \wedge i(x, z) \rightarrow y = z$. Note that both relations of inherence and constitution are asymmetric dependences, but while inherence holds at all times, so `luc`$_{\text{qua}}$`sony_cust` always depends on `luc`, the ship of Theseus can change the physical object and amount of matter constituting it during its life. In addition, while constitution necessarily implies spatial co-location, in the case of inherence this constraint is not made explicit, even though in the example of customer/seller co-location holds.

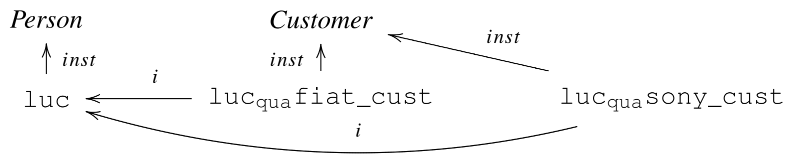

Figure 2. Customers are different from persons.

Putting together the reification of roles and the introduction of qua-entities, we obtain the solution illustrated in Figure 3. Note that qua-entities existentially depend not only on the entities they inhere in but also on the roles (`customer` in the example) and on the respective *selling* companies (`fiat` and `sony`), i.e. as expressed in (Dc) and (Ds), the qua-entities depend on the fact that a 'buy' relation holds between one specific person and one specific company.

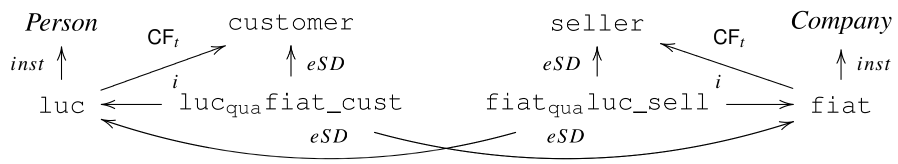

Figure 3. Putting together the reification of roles and the introduction of qua-entities.

Using qua-entities may appear excessively multiplicative, and one may wonder whether alternative solutions could be found. For instance, to solve the *counting problem* we could think to count *events* instead of qua-entities. In the passenger example, the problem indeed disappears counting "carrying events" because they have a one-to-one correspondence with qua-entities. And similarly with counting (singular) "buying events" for the role customer. In these cases, roles can be seen as specific ways of participating in events (like thematic roles). However, firstly note that the conflicting properties paradox as described above is not solved because the properties considered don't apply to events but to persons, and the same person can buy different things at different prices. The commitment to a four-dimensional account of persons and to their *temporal* *slices* does not help either because a person who participates (as customer) in simultaneous buying events has just one temporal slice during these events so the two inconsistent properties apply to this slice. Secondly, counting events is not enough when the same person participates in the same single event (or more generically in the same kind of events) with several roles. For instance, let us suppose that Berlusconi participated to some industrial meeting both as Italian Prime Minister and as the President of Mediaset. If we want to count the *representatives* present at the meeting we cannot count persons (just Berlusconi), we cannot count temporal slices (just Berlusconi during the meeting), and we cannot count events (just the meeting). That qua-entities do participate as such in events appears compelling in this example. It also shows that is not so obvious that one can do without qua-entities.

4. Discussion

Let's summarize the sorts of evidence that motivated the adoption of entity-stacking and property reification in the above studies, and the issues at stake.

Entity-stacking. Applying Leibniz's law, entities are to be distinguished when different properties apply to them. Of course, not all apparent differences in properties are to be taken at face value. In particular, one must be cautious with distinguishing *de re* assertions from *de dicto* ones before claiming that we are facing differences [31]. So in this task, one may want to focus on *essential properties* of the entities to be modelled, and rely on philosophical analyses to uncover them.

As already said, the main drawback of the entity stacking strategy is the expansion of the domain of quantification. Because philosophers tend to accept the Quinean principle "to be is to be the value of a variable", the consequence is a stronger *ontological commitment*, which is not accepted by all. However, in a modelling perspective, constraints on the expressive power of the adopted representation language and the analysis of (possibly different) ontological positions assumed in different existing models need to be taken into account. In such cases it is often necessary to enrich the domain with entities that are *useful* from a conceptual and practical point of view, even though one may claim their ontological ground is shaky. In addition, as noted by Heil [16], unification (reductionism) can be quite impractical because a too complex reduction can make some high-level patterns and relations, e.g. political decisions or social interactions, "invisible at the level of physics". On the other hand, if modelling is done for a particular application in mind, and with no reuse or interoperability perspectives, one should of course limit the range of properties under consideration to relevant ones. So, for instance, if function and purpose are not relevant in a given application dealing with artefacts (however surprising this might be) one is better off without entity stacking at all.

If entity stacking is adopted, in addition to the respective identity criteria, one must pay special attention to the nature of the existential dependence relations linking the entities of different layers. We have seen above that physical artefacts require constitution and qua-entities inherence. Indeed, a physical artefact needs a physical object (or amount of matter) in order to exist, but at different times the same artefact can be constituted by different entities, as it might be repaired. On the other hand, qua-entities inhere in the same *host* during their whole life (the host can undergo changes, e.g. Luc can become fatter, but he remains Luc), i.e. the dependence is specific. Simple existential dependence is not enough for entity-stacking: in both cases, at a given time, the artefact is (directly) constituted by and the qua-entity inheres in a unique entity.[12] Further studies are needed to examine the range of dependence relations possibly involved in entity-stacking. For example, if extending the work on artefacts to non-physical ones, constitution, which entails spatial co-location, is no longer appropriate.[13]

Let's note that our use of entity-stacking is peculiar: the motto "no two objects of the same kind at the same place at the same time" adopted by philosophers accepting co-location, such as Wiggins [32], doesn't apply to artefacts and qua-entities considered as kinds. Indeed, an entity usually simultaneously plays several roles and therefore gives rise to several qua-entities inhering in it at the same time. For artefacts, this is less obvious, but still happens when the same physical object is repeatedly selected for different purposes. The pebble which was selected for making a paperweight might at some point be selected again for making a pestle or a hammer, without making the paperweight disappear.

Property reification. The motivation for property reification appears to be less ontological, i.e., of a more practical nature. The need to predicate over properties forces reification in a first-order framework but not in a second-order one. And applied ontology does not use second-order languages for obvious tractability reasons. However, all philosophers studying properties propose analyses characterizing the properties of properties. So, following the Quinean principle, they all ontologically commit to the existence of (first-order) properties, although probably for them there is no different ontological commitment in introducing a property in the basic domain of quantification (as an individual) or at the meta-level (as a predicate in a second-order language).

One should be aware of the major drawback of property reification. If specifying the logical structure of complex properties on the basis of simple ones is required, one has to face the technical problem of introducing in the theory the whole 'logical' language necessary to do so. Not only we have to characterize the instantiation relation between reified properties and other individuals in the domain, but we might need new relations that stand for logical connectives and quantifiers. This can both be very expensive and lead to serious formal troubles.

We have seen that property reification is required to account for the social (intensional and conventional) aspects of roles. This is actually needed for artefacts too. Above we considered only the notion of individual artefact, but *artefact types* are no less important. Bell invented the telephone, but didn't create the telephone that sits on your desk. Most engineers actually create designs (artefact types), although they also often create some prototypes (individual artefacts) in order to test these designs. In [4] a proposal is made to characterize artefact types, i.e., those concepts — the reified properties introduced in [22] and described above — that classify (individual) artefacts.

We have argued above that individual artefacts require entity-stacking, i.e., cannot be dealt with simple predicates describing a property of their constituting entities. For

[12] Qua-entities depend also on other entities like the role and the other instantiations of the arguments of the relation on the basis of which the role is defined, but inhere only in the player of the role.

[13] Entity-stacking is needed in the abstract domain too. Theories have to be distinguished from their semantic contents: Turing machines and recursive functions are proved to be equivalent, but still are different theoretical objects.

the same reasons, a simple reified property cannot do. It might be less obvious that roles and qua-entities are not adequate (see, e.g., Fine's proposal for considering the statue as a qua-entity in Section 3.2). But artefacts cannot be the qua-entities generated by a role of physical objects: as explained above, constitution and inherence behave differently, so we would be unable to account for artefact repairing. There are of course reified properties *of artefacts*, for instance the artefact types just evoked. Other such properties are roles; for instance, *home* is a role of houses, and *product*, in the sense of item in the selling list of a merchant, is a role that most often has artefacts as players.

In this paper we described, illustrated, and compared two multiplicative modelling strategies, entity-stacking and property reification. We believe such a study is useful in applied ontology, when computer scientists are faced with practical modelling choices. But this study is by no means complete. In particular, we have not examined a third, important, multiplicative strategy, the one calling for individual properties or tropes. While waiting for a full methodological 'manual' we hope will be made available in a near future, the reader may refer to [3] for a detailed discussion of the motivations for the use of *qualities* as individual properties in DOLCE.

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