

Relationships and Events: Towards a General Theory of Reification and Truthmaking

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Abstract. We propose a novel ontological analysis of relations and relationships based on a re-visitation of a classic problem in the practice of knowledge representation and conceptual modeling, namely *relationship reification*. Our idea is that a relation holds *in virtue of* a relationship's existence. Relationships are therefore *truthmakers* of relations. In this paper we present a general theory of reification and truthmaking, and discuss the interplay between events and relationships, suggesting that relationships are the *focus* of events, which emerge from the context (the *scene*) they occur in.

Keywords: relationships, truthmaking, events, reification, ontology.

1. Introduction

In a recent paper [1], building on previous work by Guizzardi [2] on the notion of 'relator', we proposed an ontological analysis of relations and relationships based on the re-visitation of a classic problem in the practice of conceptual modeling, namely relationships reification. First, we argued that a relationship is not a tuple (i.e., an ordered set of objects), but rather an object in itself, that needs to exist in the world in order for a relation to hold: relations *hold* (that is, relational propositions are true) in virtue of the *existence* of a relationship; relationships are therefore *truthmakers*¹ of relations (more exactly, they are truthmakers of relational propositions). Then, considering the ontological nature of such truthmakers, we dismissed the idea (suggested by an early Chen's paper [3]) that they are events², proposing instead to consider relationships similarly to objects that can genuinely change in time. Yet, we acknowledged that reifying relationships as events may make a lot of sense in several practical cases, especially when there is no need to take change aspects into account.

In this paper we maintain our position that relationships are similar to objects, but we discuss the interplay between events and relationships in more detail. In short, the

¹The notion of truthmaking will be further discussed and refined.

² For the time being, we are using here the term 'event' in its most general sense, as a synonym of what in the DOLCE ontology are called *perdurants* (note that also states and processes are considered as perdurants). In the rest of the paper, we propose a more restricted notion of event.

need to have events (in addition to relationships) in the domain of discourse is motivated by the fact that, when we describe the dynamics of a single relationship, we may want to add details concerning its spatiotemporal context, i.e., the *scene* that hosts the relationship (which may involve many *other* relationships); conversely, when we describe a complex scene, we may want to focus on a single relationship that is present in the scene. Indeed, as we shall see, we propose a view according to which events *emerge* from scenes as a result of a cognitive process that focuses on relationships: relationships are therefore the *focus* of events, which in turn can be seen as *manifestations* of relationships. So, referring to the relationship (which maintains its identity during the event) is unavoidable when we need to describe what changes in time, while referring to the event is unavoidable when we need to describe contextual aspects that go beyond the relationship itself. For instance, consider the classic example of a *works-for* relation holding between an employee and a company: we may refer to a particular employment relationship while describing how duties and claims (say, concerning the salary) vary in time, while we refer to one or more events while talking, say, of the location where the work occurs, or the weekly schedule or the activities performed in the framework of the work agreement.

The paper is structured as follows. In Section 2 we introduce the key notions of reification and truthmaking. First we characterize the class of relations that deserve being reified by revisiting Guizzardi's earlier distinction between *formal* and *material relations* and isolating the class of *descriptive relations*, which hold in virtue of some qualities of their relata. Then we introduce the notion of *weak truthmaker*, and, generalizing our analysis to the case of descriptive properties (monadic descriptive relations) we show how *individual qualities* such as those adopted in the DOLCE and UFO ontologies can be understood as their reifications. In Section 3 we discuss the crucial case of the reification of comparative relations, treated in an unsatisfactory manner in the earlier Guizzardi's work. In section 4, we shift our attention to events, discussing the interplay between events and relationships, and arguing that relationships are the *focus* of events. Finally, in Section 5 we present our conclusions.

2. Reification and Truthmaking

Before illustrating our theory, let us briefly clarify some terminological issues concerning reification and relationships. In general, reification is the process of including a certain entity in the domain of discourse. For example, Davidson's move of putting events in the domain of discourse [6] is a reification move. Also, when we ascribe metaproperties like symmetry to a binary relation such as *married with*, we are reifying the whole relation (intended as a set of tuples). This is different from reifying a single *instance* of a relation, say the single tuple $\langle \text{John}, \text{Mary} \rangle$, and is also different from reifying the result of a *nominalization* process of the relation's predicate holding for that tuple, namely the *marriage* between John and Mary. The latter, *and not the tuple*, is what we call a *relationship*.

Note that such understanding of a relationship deviates from the mainstream, since Chen defines a *relationship type* as a mathematical relation (i.e. a set of tuples), and a relationship as one of such tuples. So, under the mainstream approach relations (relationship types) and relationships are *extensional* notions. Yet, Chen admits that dif-

ferent relationship types (say, *friend of* and *colleague of*) may involve the same tuples, so each relationship type seems to have a unique "meaning" (its *intension*) conveyed by its *name*³. We claim that it is this intensional aspect of a relationship that people have in mind, when they talk of relationship reification. This is why, for the sake of clarity, we prefer to use the term 'relationship' only in its intensional meaning, adopting 'tuple' to refer to the extension. The rest of the paper is devoted to understanding when it is useful and legitimate to consider such 'intensional meaning' as an element of our domain of discourse, and, if so, what its ontological nature is.

2.1 Which relations deserve reification?

In the past, a problem we encountered while developing our approach to relationships reification concerned the kinds of relation that deserve reification⁴. In the early Guizzardi's work, a crisp distinction was assumed between *formal relations*, which "*hold between two or more entities directly without any further intervening individual*", and *material relations*, which require the existence of an intervening individual. The modeling proposal was to systematically introduce –for all material relations– a specific construct, called the *relator*, standing for such intervening individual. Note that *comparative relations* such as *taller than* were considered by Guizzardi as formal, because they hold just in virtue of the intrinsic properties of the relata.

In the philosophical literature, however, the formal/material distinction varies significantly among different authors, and overlaps with other distinctions. The definition of *formal* (vs. *material*) relations adopted by Guizzardi is indeed equivalent to one of the various definitions proposed in the literature to account for *internal* (vs. *external*) relations. We report here the one by Peter Simons, based in turn on Moore [10]: "*If it is possible that a and b both exist and it not be the case that aRb, then if aRb we say the relational predication is true externally. If it is not possible that a and b both exist and it not be the case that aRb, then where aRb we say the relational predication is true internally*" ([8], p. 203).

According to this definition, as Simons observes, comparative relational predications go across the internal/external distinction: some of them turn out to be internal (and therefore formal, in Guizzardi's terminology), but others turn out to be external, and therefore material. For instance, the mere existence of an electron *e* and a proton *p* is enough to conclude that *heavier(p, e)* holds (since both of them have that particular mass *essentially*), but the mere existence of John and Mary is not enough to conclude that *taller(John, Mary)* holds, since they don't have that particular height essentially, so something else is required. Moreover, notice that, within the same relation, some predications –like *heavier(p, e)*– may be true internally, while others –like *heav-*

³ Another way to capture this meaning is to add attributes to the original tuple, which somehow express the properties the relationship has. This is the approach followed by Thalheim [7], who defines a relationship type as a sequence of entity types followed by a set of attributes.

⁴ By 'a relation that deserves reification' we mean a relation that deserves reification of its relationships. Informally, we talk of reification of a relation to mean reification of its relationships.

*ier(John, Mary)*⁵– may be true externally. So, the picture is rather complicated, and this is the reason why, in our previous paper, we decided to abandon the formal/material distinction and just focus on a relevant class of relations that certainly deserve reification, those we called *extrinsic* relations, without taking a position on the reification of *intrinsic* relations, to which comparative relations belong.

In short, an intrinsic relation is a relation that can be derived from the intrinsic properties of its relata⁶. This clearly applies to all comparative relations (whether or not they depend on the mere existence of their relata), as well as to all relations that just depend on the mere existence of their relata. Extrinsic relations are just the relations that are not intrinsic: for example, you can't decide whether *married(John, Mary)* holds just on the basis of the intrinsic properties of John and Mary.

Interestingly enough, in philosophy there is another way of defining the *internal/external* distinction, owed to Armstrong [9], according to which 'internal' and 'external' become synonymous, respectively, of 'intrinsic' and 'extrinsic'⁷. So, in retrospective, we can conclude that, although Guizzardi's definition was following Simons, what he actually had in mind –especially while insisting on considering comparative relations as formal– was Armstrong's distinction.

That said, still we have to answer our original question: which relations deserve reification? Elsewhere [1, 2, 12] we have discussed extensively the practical advantages of the *relator* construct in the practice of conceptual modeling, so no doubt that most *extrinsic* relations (i.e., those Guizzardi labeled *material* relations) deserve reification. But are we sure that comparative relations don't deserve reification? For instance, one may want to keep track of the difference in height between him and his son, or may measure the extent of a temperature difference between two bodies. In general, we may be interested in talking of *qualitative relationships* among things: we can have temperature relationships, size relationships, mass relationships, so that we can say that the mass relationship between the Earth and the Moon is responsible of the way they move around.

In the light of these examples, our position is that, besides extrinsic relations, also comparative relations may deserve reification. But what do they have in common? Our answer is that they both belong to the broad class of what we call *descriptive relations*, which hold in virtue of *some particular aspect* (some *individual qualities*) of their relata. Under this view, both *taller than* and *being in love with* count as descriptive.

⁵ Of course, one could consider *heavier(John@t, Mary@t)* to be a relation between the states (snapshots) of John and Mary at *t*. In this case, the relation would hold internally if at all.

⁶ We shall take the notion of intrinsic property as primitive. Intuitively, an intrinsic property is a property that holds for an entity independently of the existence of any other entity.

⁷ See the recent overview by MacBride [11] of the various philosophical positions on relations. According to him, there are three ways of understanding the internal/external distinction: "internal relations are determined by the mere existence of the things they relate, or internal relations are determined by the intrinsic characters of the things they relate, or internal relations supervene upon the intrinsic characters of the things they relate". The first position (adopted by Simons) is due to Moore. The second one is due to Armstrong, while the third one to Lewis.

Note that *descriptive/non-descriptive* and *intrinsic/extrinsic* are orthogonal distinctions. The general picture is reported in Fig. 1, where we have shown how internal relations (in Moore's sense) go across the descriptive/non-descriptive distinction, while being included in the class of intrinsic relations. Let us briefly discuss the four quadrants shown in this figure. *Intrinsic descriptive relations* include all comparative relations holding among objects and events, plus for example all relations of mutual spatial location (at least as long we consider spatial location as an intrinsic property). *Intrinsic non-descriptive relations* include internal relations such as *existential dependence* and *resemblance*, which hold in virtue of the mere existence of their relata, as well as all comparative relations holding among tropes and qualities. Altogether, exactly because they do not depend on particular aspects of their relata, they may be called *formal* relations (abandoning therefore the notion of 'formal' as synonyms of 'internal'), in the sense that their domain and range are not limited to specific domains. The figure shows that not all formal relations are internal: for instance, *necessary part of* would be internal, while *contingent part of* would be external. *Extrinsic descriptive relations* include relations such as *works for* and *married to* that hold in virtue of some *actual* qualities of their relata, but also historical *relations* such as *author of*, which hold in virtue of some *past* quality (of the author). Finally, *extrinsic non-descriptive relations* include merely historical relations such as *born in*, that holds in virtue of an event occurred in the past, and the so-called *Cambridge relations* such as *being both observed by somebody*, which hold in virtue of something external that doesn't affect the relata.

| | Descriptive | Non-descriptive |
|-----------|---|--|
| Intrinsic | <ul style="list-style-type: none"> • Comparative relations among objects and events • Mutual spatial location | <div style="border: 1px solid black; padding: 2px; display: inline-block;">Internal</div> <ul style="list-style-type: none"> • Formal relations (<i>part, resemblance, dependence, comparative relations among tropes and qualities...</i>) |
| Extrinsic | <ul style="list-style-type: none"> • <i>Works for, married to...</i> • Historical descriptive relations (<i>author of...</i>) | <ul style="list-style-type: none"> • Merely historical relations (<i>born in...</i>) • Cambridge relations (<i>being both observed by John...</i>) |

Figure 1. Kinds of relations.

In conclusion, to decide whether a relation deserves or not reification we need to check whether it is a descriptive relation or not, i.e., whether it holds in virtue of some individual qualities of its relata. Individual qualities, originally introduced in the DOLCE ontology [13], are now a common feature (with minor differences) of other top-level ontologies such as UFO [2] and BFO [14]. In the following, we shall see how individual qualities capture the notion of truthmaking, accounting not only for the truth of a relational predication, but also for the way a relationship behaves in time. In short, we shall see how *individual qualities constitute relationships*.

2.3 Weak truthmaking

In our earlier paper [1], we based our re-visitation of Guizzardi's original idea of *relators* on the philosophical notion of *truthmaking*. In that paper, we did not take a position concerning the specific nature of such notion, just assuming that truthmaking is a primitive, fundamental relation linking what is true to what exists. In general, a shared intuition is that a truthmaker for a property or a relation is an entity *in virtue of* which that property or relation holds. Several attempts have been made by philosophers to formally capture such intuition [15], i.e., to account for what '*in virtue of*' means. According to the mainstream doctrine, the truthmaker of a proposition is something *whose very existence* entails that the proposition is true. This means that the truthmaking relation holds *necessarily*. There is, however, a weaker notion of truthmaking, introduced by Josh Parsons [16], according to which the truthmaker of a proposition is something that makes the proposition true not just because of its existence (i.e., because of its *essential* nature), but because *of the way it contingently is* (i.e., because of its *actual* nature). The truthmaking relation does therefore hold *contingently*. This notion of *weak truthmaking* is the one we shall adopt here, since –as we shall see– it seems to be the most apt to support our view of (descriptive) relationships as entities that can change in time, accounting not only for the *fact* that a relation holds, but also for the *way* it holds and develops in time.

In the following, we shall illustrate such a view by considering three main cases of descriptive relations: descriptive properties (i.e., descriptive monadic relations), intrinsic descriptive relations, and extrinsic descriptive relations. While in our previous paper we only focused on the third case, we believe that considering the former two cases is illuminating in developing a general theory of truthmaking and reification.

2.4 Descriptive properties and weak truthmaking

Consider a simple proposition involving a descriptive property, such as *this rose is red*. What is its truthmaker? According to the mainstream theory, an answer⁸ is that it is a *trope*, i.e., particularized redness property. We consider it as an object-like entity, a kind of *disposition* to interact with the world that is existentially dependent on the rose (it *inheres* in the rose). Under this view, a redness *event* is not a trope, but rather a *manifestation* of a redness trope. Both the trope and the redness event, because of their very existence, are such that the proposition is true. They are therefore both truthmakers of that proposition. Since the trope *participates* to the redness event we consider it as the *minimal* truthmaker, although we are aware that a precise account of the notion of minimal truthmaking is still under discussion⁹.

⁸Another answer could be that the truthmaker is a *fact* of redness. In light of the discussion in [1] against facts as a viable interpretation for relationships, we do not consider this option here.

⁹For our purposes, we define a minimal truthmaker of a proposition as a truthmaker such that no entity *inhering* in it, *being part* of it or *participating* to it is itself a truthmaker of the same proposition.

Suppose now that the rose is red at time $t1$, and becomes brown after several days, at time $t2$. According to the mainstream theory, the truthmaker at $t2$ will be a different one, namely a specific brownness. According to Parsons' theory, instead, the *weak truthmaker* at both times is the rose itself: it is the very same rose, because of the way it is at $t1$ and at $t2$, that is a truthmaker of '*this rose is red*' at $t1$ and a truthmaker of '*this rose is brown*' at $t2$. In other words, a weak truthmaker is something such that, because of the way it is, makes a proposition true.

We should observe, however, that the rose is not the *minimal* weak truthmaker of these propositions. There is something smaller –so to speak– than the whole rose: the rose's *color*. Indeed, it is exactly because of the rose's color that the rose is red at $t1$ and brown at $t2$. As we mentioned above, this color is modeled as an *individual quality* in the DOLCE and UFO ontologies¹⁰. A peculiar characteristic of individual qualities is that they are *endurants*, i.e., they can qualitatively change in time (e.g., change their “value” from red to brown) while maintaining their identity.¹¹

In conclusion, individual qualities are the minimal weak truthmakers of simple propositions involving a descriptive property. So to speak, they are *responsible* for the truth of such propositions, in the precise sense –as explained by Parsons– that the proposition can't become false without an intrinsic change of its weak truthmaker, i.e., since the weak truthmaker is an individual quality, without a movement in the space of possible values such quality can assume [13]. So, as we have seen, the same quality can be responsible for the truth of different propositions holding at different times.

Let us see now how the weak truthmaking mechanism described above can be used to establish an ontological foundation for *reification* choices in the practice of conceptual modeling. The practical rule we suggest is: "*Whenever a model includes a descriptive property, typically represented by an instance attribute of a class, one should reflect on the possibility of reifying it as an individual quality*".

Suppose for example that, in an employment scenario, we have the attribute *mood* for the *Employee* class, with possible values *happy* or *sad*; reifying the *mood* quality as a separate class (whose instances inhere to the instances of *Employee*) would allow you the possibility to express, for instance: (1) *Further details on the reified entity*: “Mary has a pleasant mood”; (2) *Information on its temporal behavior*: “Mary’s mood got much worse in the last days”; (3) *Information on its causal interactions with the world*: “Because of Mary’s mood, she wasn’t very productive at work”. As we shall see, these are indeed the main reasons for the reification of descriptive relations of arbitrary arity, not just descriptive properties.

Note that, strictly speaking, we cannot say that in this way we are reifying the *happy* and the *sad* properties, since the same *mood* quality may “reify” both of them at different times. A strict reification would result in the explicit introduction of a specific happiness and a specific sadness, intended as *completely determined* particularized

¹⁰ We shall not discuss the differences among these ontologies concerning the notion of quality. In particular, we shall ignore the fact that DOLCE does not consider qualities as endurants, and we shall collapse, for the sake of simplicity, UFO’s distinction between *qualities* and *modes*.

¹¹ This notion of individual qualities as endurants is similar to Moltmann’s *variable* tropes.

properties, which would be tropes and not qualities. In this case, however, as discussed by Moltmann [17] and in our earlier paper, we would lose the flexibility of expressing the additional information described above. So, we may consider the strategy outlined above as a *weak reification* strategy, which turns out, however, to be more effective in practice than a strict reification strategy.

3. Descriptive relations and weak truthmaking

3.1 Intrinsic descriptive relations

Having described the truthmaking mechanism for descriptive properties, let us now generalize it to descriptive relations, considering first the intrinsic ones, and in particular *comparative relations*. Take for example *taller(John, Mary)*. In the light of the previous discussion, it is easy to see that its minimal weak truthmaker is the *mereological sum*¹² of two individual qualities, namely John's height and Mary's height. Similarly to what is noted above, should the *height relationship* between John and Mary change in a certain way, this would be also the weak truthmaker of *as-tall-as(John, Mary)* and *taller(Mary, John)*. In our view, this means that there is a single entity in our ontology, namely a *height relationship*, consisting of a *quality complex* having the two individual heights as proper parts. Such a relationship is an *endurant*, whose internal configuration may be such that one of the three possible propositions above is true at a given time.

In conclusion, we can say that comparative relationships (as mereological sums of intrinsic qualities) are the weak truthmakers of comparative relations. Reifying them has the same advantages we have seen above in terms of the possibility to add further details: for instance, we can express the actual *height-distance* between the two relata as a property of the relationship (which in principle may itself be reified, originating a height-distance individual quality inhering in the quality complex).

Note that the approach described above can be generalized to the case of relations expressing arbitrary configurations of intrinsic qualities, such as weights or colors. If we consider spatial position also an intrinsic quality (as done in DOLCE, although the choice might be debatable), then relations describing spatial configurations (patterns) may be also be reified in terms of quality complexes.

3.2 Extrinsic descriptive relations

Considering now extrinsic descriptive relations, their main difference from the intrinsic ones is that at least one of the qualities inhering in the two relata is a *relational* one, which is *existentially dependent* on the other one(s). Take for example *loves(John, Mary)*. Its weak truthmaker is a *quality complex* that includes John's love towards Mary (a mental disposition understood as a relational quality), and whatever other quality (relational or non-relational) it actually depends on (such as Mary's

¹²The mereological sum of x and y is an entity z such that whatever overlaps z also overlaps x or y (see, for instance, [2], chapter 5)

beauty) or depends on it (such as Mary's embarrassment in reaction to John's love). The internal structure of such quality complex has been discussed in detail in [1].

Note that, as we have seen, the same *relationship* (i.e., the same weak truthmaker) may make different kinds of *relational propositions* true. Indeed, at different times, we can describe it in different ways: as a mutual love, as a non-mutual-love, as a passionate love, as a mostly inexistent love, etc. All the corresponding propositions would share the same weak truthmaker, i.e., the same love relationship exhibiting qualitative changes in time.

4. Relationships and their context: scenes and events

Let us shift now our attention to *events*. In our earlier papers, as more or less customary in the philosophical literature, we used the term 'event' in its most general sense, i.e., as a synonym of *perdurant* or *occurrent* (contrasted respectively with *endurant* and *continuant*). Here, while describing the interplay between events and relationships, we shall reserve this term for a more specific use. Shortly put, *events emerge from scenes; individual qualities and relationships are the focus of events*.

4.1 Scenes

The Cambridge dictionary defines a scene as "*a part of a play or film in which the action stays in one place for a continuous period of time*". Of course the word has several more meanings, but this is the one that fits best the technical notion we would like to introduce. For us, a *scene* is whatever happens in a suitably restricted spatio-temporal region. Our intuition is that a scene is a perdurant of a particular kind, being the object of a unitary perception act. So, its main characteristic is that it is a *whole*, from a perceptual point of view. We leave it open what the specific unity conditions for this whole are. A scene may last a few milliseconds, corresponding to a "one shot" presentation, or perhaps a whole life, if we see it as a macroscopic perception act. The important facts are: (1) *A scene cannot be instantaneous: it always has a time duration bound to the intrinsic time granularity and temporal integration mechanisms of the perception system considered* (we do not perceive the single frames of a movie, nor the internal dynamics of a sound); (2) *A scene is located in a convex region of spacetime. It occurs in a certain place, during a continuous interval of time*.

In conclusion, we see a scene as a maximal perdurant located in a convex region of spacetime: it contains all perdurants occurring there as parts. For example, consider Davidson's example [6] of a sphere rotating and heating up during a certain time interval. What the example describes is a scene, including whatever occurs in that time interval within the spatial location delimited by the sphere's surface. In the next section we shall see how two further perdurants (events, in the strong sense defended here) can be distinguished as proper parts of that scene.

4.2 Events

The etymology of the term 'event' is from Latin: *ex-venire* (to come out). If we take this etymology seriously, we have to ask where do events come from. Our answer is that they come from scenes: they emerge from scenes through a *focusing process*. We claim that all ordinary events, like those described by most natural language verbs, have a focus. This means that their participants are not involved in the event, so to speak, in an homogeneous way, but rather there are different levels of involvement, which concern also their parts and qualities. So we can distinguish some *core participants*, and others that are not involved at all in the event, except in a very indirect way. For example, consider a person writing. Her body clearly participates to this process, but some of its parts (say, the eyes) are clearly more involved than others (say, the mouth). Should the same person be writing while eating a sandwich, the mouth would be involved in the eating and not in the writing.

Consider now a scene we can perceive from a house window: a simple one like a meadow in a sunny day, or a more complex one like a busy street market in a working day. Several events may capture our attention: a butterfly passing by, a cloud showing a particular shape for a while, a person buying some food, a vendor yelling... So, we may say that many events emerge from the same scene, each one with different *focus*.

But what is this focus, exactly? One way of seeing it is as a *minimal participant* to that event. For instance, consider Titanic's collision with an iceberg, discussed by Borghini and Varzi [18]: of course there are large parts of the ship (say, the rear part) and large parts of the iceberg that are loosely involved in the event, while other parts (a suitable part of the iceberg and a suitable part of Titanic) are definitely involved. These would be the minimal participants. However, as discussed there, serious problems of vagueness and indeterminacy would emerge: how to select such minimal participants? As they put it, "*Exactly what parts of Titanic hit what parts of the iceberg?*"

In our view, a way to address this problem is to shift our attention from the participants to their *qualities*: for example, we can say that, *for sure*, the Titanic's mass and the iceberg's mass were involved in the event, while, for sure, the Titanic's color and the iceberg's color were not involved. Of course, vagueness and indeterminacy problems cannot be completely eliminated, since, for instance, determining the exact location of the hit event would still be a problem. However, for the purpose of extracting an event from a scene, we claim that pointing to some objects' qualities is enough to describe *exactly* the event we want to talk of, i.e., to let it emerge from the scene.

In other words, an event is determined by a couple $\langle r, f \rangle$, where r is a spatiotemporal region, and f is the event's *focus*, consisting of a collection of individual qualities, which we shall call *focal qualities*. To see this, consider again the example of the sphere that rotates while heating up: assuming that r is the spatiotemporal region occupied by the sphere during this phenomenon, we can isolate the focus of the rotation event in a collection of individual qualities, namely the spatial locations of the sphere parts, while the focus of the heating event is clearly the sphere's temperature. In other words, if we have two different foci, we have two different events emerging from the same scene, each one with different sums of qualities as a focus.

In conclusion, what we suggest is to stop considering 'event' as synonymous of 'perdurant', but rather distinguish two broad categories within perdurants, depending on whether they have a focus or not. The former will be *events* (in this new strict sense), the latter *scenes*. The reason they are different lies in their different principle of individuation: two different scenes must have a different spatiotemporal location, while two different events may share the same spatiotemporal location. So, to quote an observation by Quine [19], if the sphere is rotating rapidly and heating slowly, we have an event that is rapid and *a different one* that is slow, while if we had a single event of course we couldn't say it is both rapid and slow.

This way of considering events allows therefore for a very fine-grained approach: an event is whatever happens to a suitably selected set of individual qualities in a particular spatiotemporal region. So, the simplest event we can describe (and imagine) would be a change (or a state) of a single individual quality, say a light's intensity changing from dark to bright, or remaining bright for a while. Indeed, in our view events are *manifestations* of individual qualities.

4.3 Reifying events as the context of relationships

Let us now go back to relationships. We have advocated the view that the focus of an event is a sum of individual qualities. In the case of relational events, i.e., events involving multiple participants, this sum of individual qualities is typically constituted by relational qualities inhering in the multiple involved participants. These relational qualities form quality complexes that are reified relationships. Consider for instance, on one hand, the *marriage* between John and Mary as a relationship and, on the other hand, the event (the marriage process) that is the sum of the manifestations of the qualities (e.g., commitments and claims) constituting this relationship. We can see such event as *carved out* of a broader scene, involving John and Mary's lives, by having the marriage relationship as the focus. Analogously, Barack Obama's *presidential mandate* relationship would be the focus of Obama's term, while Paul's enrollment relationship to the University of Trento would be the focus of Paul's student life in the scope of that enrollment. All these events are carved out of complex extended scenes by being the manifestation of qualities that constitute their focal relationships.

Now, if every relational event such as the ones just described has relationships as focus, wouldn't be enough to just reify these relationships? In other words, what is the practical relevance of having also events, besides relationships, in our domain of discourse? A first reason is to make clear what the role of the relata is. Consider for instance a service offering relationship, which in a recent paper [20] we modeled as a complex sum of commitments and claims. Intuitively, a service offering has an *agent*, who is the *provider*, and a *beneficiary*, who is the *customer*. But the provider is not the agent *of the relationship*. He is the agent of an *offering event*. Indeed, roles are usually understood as *ways of participation*¹³ to an event. So, being the agent of an offering event means having a commitment that is part of the focus of that event.

¹³ We understand participation as a formal relation linking endurants to perdurants [13].

A second reason to have events in a conceptual model is the possibility to talk of the broader context of the relationship. Coming back to the example mentioned in the Introduction, consider a *works-for* relationship, modeled as a sum of duties and claims. If we want to express a constrain concerning the location where the work occurs (say, a particular office) we cannot just add an attribute to the relationship, since such location is not directly involved in the relationship, but rather it is a participant of the event focused on by the relationship. Indeed, the point is exactly that there are much more participants involved in a working event than those directly involved in the relationship: the job of the relationship is just to focus on the core participants (picking up some of their specific qualities). Thus, if we want to be able to talk of the other participants, we need both the relationship and the event.

A third reason is that we need events if we want to talk of specific temporal constraints concerning the way a relationship evolves in time. For instance, to express the constraints concerning the weekly schedule, we may need to introduce specific events corresponding to working slots as proper parts of the main event focused by the *works-for* relationship: duties and obligations usually hold for a continuous interval of time, while the working slots are not contiguous.

Finally, we may need to explicitly modeling events while dealing with extrinsic non-descriptive relations, especially merely historical relations such as *born-in*. Being non-descriptive, such relation does not need to be reified as such (we could say it is a relation without a relationship), but yet modeling the born event may have several practical advantages.

5. Final Considerations

In previous work [2,4,5], we have shown how reified relationships are essential for addressing many classical and recurrent modeling problems, how their explicit representation has a direct impact on the domain expert's understanding of the real-world semantics [12], and how they may help avoiding a number of occurrences of anti-patterns in the modeling of relations [21]. In our view, the work we presented here sheds new light both to the theory and the practice of reification, by clarifying which relationships deserve reification in the framework of a general ontological theory of reification and truthmaking, by clarifying the nature of descriptive relationships as quality complexes that can change in time, and by establishing a systematic, principled connection between relationships reification and events reification. The novel understanding of events we have proposed, where events emerge from scenes by means of a focusing mechanism based on relationships, further clarifies the whole picture, and gives us –we believe– the right tools to model complex scenes involving multiple emerging events.

We are aware that we still need a complete formal characterization of our theory. However, we believe the conceptual clarifications present in this paper are a first step to establish solid foundations for practical applications both in knowledge representation and conceptual modeling.

References

- [1] N. Guarino, G. Guizzardi, “‘We Need to Discuss the Relationship’: Revisiting Relationships as Modeling Constructs”, Proc. *CAiSE* 2015, Stockholm, 2015.
- [2] G. Guizzardi, *Ontological Foundations for Structural Conceptual Models*. 2005.
- [3] P. Chen, “English Sentence Structure and Entity-Relationship Diagrams,” *Information Sciences*, vol. 29, no. 2, pp. 127–149, 1983.
- [4] G. Guizzardi, H. Herre, G. Wagner, “On the General Ontological Foundations of Conceptual Modeling”, Proc. Of ER’2002, Tampere, 2015.
- [5] G. Guizzardi, G. Wagner, and H. Herre, “On the Foundations of UML as an Ontology Representation Language,” in *Engineering Knowledge in the Age of the Semantic Web*, Proc. of EKAW’2004, Northamptonshire, 2004.
- [6] D. Davidson, “The individuation of events,” *Contemporary readings in the foundations of metaphysics*, p. 295, 1998.
- [7] B. Thalheim, *Entity-Relationship Modeling*. Springer Science & Business Media, 2000.
- [8] P. M. Simons, “Relations and Truthmaking,” *Aristotelian Society Supplementary Volume*, vol. 84, no. 1, pp. 199–213, Jun. 2010.
- [9] D. M. Armstrong, *Universals and Scientific Realism, Volume 2: A Theory of Universals*. Cambridge University Press, 1978, pp. 1–169.
- [10] G. E. Moore, “External and Internal Relations,” *Proceedings of the Aristotelian Society*, pp. 1–15, Dec. 1919.
- [11] F. MacBride, “Relations,” in *Stanford Encyc. of Philosophy*, 2016, pp. 1–42.
- [12] M. das Gracas da Silva Teixeira, R. de A. Falbo, de Alme, and G. Guizzardi, “Analyzing the Behavior of Modelers in Interpreting Relationships in Conceptual Models: An Empirical Study,” presented at the OntoCOM, 2014, pp. 1–12.
- [13] S. Borgo and C. Masolo, “Foundational choices in DOLCE,” in *Handbook on ontologies*, S. Staab, Ed. Springer, 2009, pp. 361–381.
- [14] Neuhaus, F., Grenon, P., Smith, B., A Formal Theory of Substances, Qualities and Universals, 3rd International Conference on Formal Ontologies in Information Systems (FOIS’2004), Turin, 2004.
- [15] F. MacBride, “Truthmakers,” in *Stanford Encyc. of Philosophy*, 2014, pp. 1–69.
- [16] J. Parsons, “There is no ‘truthmaker’ argument against nominalism,” *Australasian Journal of Philosophy*, vol. 77, no. 3, pp. 325–334, 1999.
- [17] F. Moltmann, *Abstract Objects and the Semantics of Natural Language*. Oxford University Press, 2013.
- [18] Borghini, A., A. C. Varzi, “Event Location and Vagueness”, *Philosophical Studies*, 128(2), p. 313-336, 2006.
- [19] W. V. Quine, “Events and Reification,” in *Actions and Events: Perspectives on the Philosophy of Donald Davidson*, E. LePore and B. P. McLaughlin, Eds. *Actions and Events: Perspectives on the Philosophy of Donald Davidson* 1985.
- [20] J. C. Nardi et al., “A commitment-based reference ontology for services,” *Information Systems*, vol. 54, no. C, pp. 263–288, Dec. 2015.
- [21] T. P. Salles, G. Guizzardi, *Ontological Anti-Patterns: Empirically Uncovered Error-Prone Structures in Ontology-Driven Conceptual Models, Data & Knowledge Engineering (DKE) Journal*, 2015.