Reification and Truthmaking Patterns

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Abstract. Reification is a standard technique in conceptual modeling, which consists of including in the domain of discourse entities that may otherwise be hidden or implicit. However, deciding what should be reified is not always easy. Recent work on formal ontology offers us a simple answer: put in the domain of discourse those entities that are responsible for the (alleged) truth of our propositions. These are called *truthmakers*. Re-visiting previous work, we propose in this paper a systematic analysis of *truthmaking patterns* for properties and relations based on the ontological nature of their truthmakers. Truthmaking patterns will be presented as generalization of reification patterns, accounting for the fact that, in some cases, we do not reify a property or a relationship directly, but we rather reify its truthmakers.

Keywords: ontology-driven conceptual modeling, reification

1 Ontological Analysis as a Search for TMs

Deciding what to put in the domain of discourse is a fundamental choice for conceptual modeling and knowledge representation. The things that are relevant for our conceptualization of reality—those that we implicitly assume to exist—are typically much more than those our language explicitly refers to. So, our *cognitive domain* is much bigger than our *domain of discourse* [12]. For example, when we say that John and Mary are married, our language only refers to them, although we *know* that there has been a wedding event and that there is an ongoing marriage relationship. It is up to us to introduce these further entities in our domain of discourse, should we need to represent and reason about them. Such process of making hidden entities explicit is called *reification*. Note that the new entities do not originate from a generic decision to expand the domain, but rather from a transformation of a language construct (typically, a predicate) into a domain element (a "first class citizen").

Reification is a standard technique in conceptual modeling and knowledge representation. Classic examples are the reification of relationships [24,3,23] and events [4,6]. But how to decide what should be reified? Recent work on formal ontology offers us a simple answer: put in the domain of discourse those entities

that are responsible for the (alleged) truth of our propositions. These are called *truthmakers* (TMs for short) [17].

Discovering TMs may be not always simple, of course, and requires some acquaintance with the basic tools of *formal ontological analysis*. Indeed, we can see conducting ontological analysis as a way of employing some special *detective magnifying lens*, which helps us in searching for TMs. Putting ourselves in this detective spirit, the basic questions we need to ask to analyze a proposition P are similar to the famous *Wh-questions*: *What* is responsible for making P true? *When* and *Where* will P be true? Of course, the answers to these questions depend on the kinds of properties and relations we use in our language. In this paper we shall adopt a systematic approach to account for the various *truthmaking patterns* (TMPs) associated to different kinds of properties and relations. A TMP is for us a generalization of a *reification pattern*, which accounts for the fact that, in some cases, when we want to 'talk' of a property or a relationship, we don't reify *it* directly, but we rather reify its TMs.

In the following, relying on earlier work [9,10,11] which will be revised and presented here in a systematic form, we first focus on properties and their TMs, distinguishing between strong and weak truthmaking, introducing qualities and descriptive properties, and presenting a number of TMPs at different levels of expressivity. Then we extend the analysis to relations, discussing the formal distinctions among them according to the ontological nature of their TMs, and presenting the corresponding TMPs. Finally, we conclude with some considerations on the practical implementation of TMPs in a conceptual modeling environment.

2 Properties and their truthmakers

We introduced the notion of truthmaking in a deliberately general way, saying that a TM is something that is *responsible* for the truth of a proposition. Strictly speaking, only propositions have TMs (they are the only *truthbearers*). However, in the case of atomic propositions, constituted of a property (or relation) plus its argument(s), we find it useful to see the TMs of such propositions as the TMs of the corresponding properties or relations, i.e., as something *in virtue of which* a property or a relation holds for certain entities; so, we shall talk interchangeably of TMs of properties or relations (holding for certain entities), and TMs of propositions. This move allows us to make distinctions among properties and relations according to the nature of their TMs.

2.1 Strong and weak truthmaking

Let us consider first the TMs of properties (we shall focus here on atomic properties, excluding logical combinations of them). What is it *in virtue of which* a property holds? Several attempts have been made by philosophers [17] to formally account for what *'in virtue of'* means. According to the mainstream doctrine, the TM of a property holding for a certain individual is something *whose very existence* entails that the property holds. The nature of such TM

depends however on the kind of property, so that relevant distinctions may be drawn among properties based on the nature of their TMs.

Consider for instance two propositions such as (P1) *'a is a rose'* and (P2) *'a is red'*, where a denotes a particular rose. The very existence of a is enough for making P1 true, so a is a TM of P1. For P2, in contrast, the mere existence of a is not enough for P2's truth. What is its TM? A popular answer [17] is that it is a particular *occurrence of redness*, that is, a particular *event*[4] (intended in the most general sense that includes states).

So, *being a rose* and *being red* are properties whose TMs are of a very different nature. As we shall see, the latter is a *descriptive* property, while the former is a *non-descriptive* property. Intuitively, non-descriptive properties account for *what* something is, on the basis of its *nature and structure*; descriptive properties account for *how* something is, on the basis of its *qualities*. However, to better account for this and other intuitions concerning the different kinds of properties, we need to go deeper in the nature of their TMs.

There is indeed another notion called *weak truthmaking*, introduced by Josh Parsons [26], according to which a TM makes a 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). Differently from the *strong truthmaking* relation mentioned above, the weak truthmaking relation does therefore hold *contingently*.

Let us explain the difference between the two notions by considering again the example above. Suppose that a is red at time $t1$, and becomes brown at time $t2$. According to the mainstream TM theory, the *strong* TM of *a is brown at* $t2$ will be very different from that of *a is red at* $t1$, being a different event that is an occurrence of brownness and not an occurrence of redness[5]. According to Parsons' theory, however, the *weak* TM at both times is the rose itself: since the rose changes while keeping its identity, it is the very same rose, *in virtue of the way it (contingently) is* at $t1$ and at $t2$, which is a TM of the two propositions. A weak TM is something that, because of the way it intrinsically is, makes a proposition true; in Parsons' words, *the proposition cannot become false without an intrinsic change of its weak TM*.

So, whereas under the strong view there are two different TMs (namely two different events), under the weak view there is only one entity, namely the rose itself, responsible for the truth of the two propositions at different times.

2.2 Individual qualities, descriptive properties, intrinsic properties

We have seen from the previous example that the rose undergoes a change, while keeping its identity, from $t1$ to $t2$. What kind of change? Of course, a change in its *color*. So, as discussed in [10], there is something more specific than the whole

[4] Of course, there may be many of such events. Each of them would be a TM.

[5] Even if the color does not change, multiple strong TMs are necessary as time passes by, since each occurrence is different from the previous or future occurrences.

rose that is responsible for the truth of the two propositions: their *minimal*[6] weak TM is the rose's *color*. Indeed, it is exactly *in virtue of* its color that the rose is red at $t1$ and brown at $t2$. This color is modeled as an *individual quality* in DOLCE [2] and in UFO [14].

Individual qualities as weak TMs. Individual qualities (qualities for short) may be seen as specific aspects of things we use to compare them. They *inhere* in things, where inherence is a special kind of *existential dependence* relation, which is irreflexive, asymmetric, anti-transitive and functional [14]. They are directly comparable, while objects and events can be compared only with respect to a certain *quality kind* (e.g., to compare physical objects, one resorts to the comparison of their shapes, sizes, weights, and so on). Qualities are distinct from their *values* (a.k.a. *qualia*), which are abstract entities representing what exactly resembling qualities have in common, and are organized in spaces called *quality spaces*; each quality kind has its own quality space. For instance, weight is a quality kind, whose qualia form a linear quality space. At different times, qualities can keep their identity while occupying different regions of their quality space; they are considered therefore *endurants* in UFO. Quality spaces may have a complex structure with multiple dimensions, each corresponding to a simple quality that inheres in a complex quality. Typical examples of complex qualities are colors and tastes, but we shall also consider mental entities such as attitudes, intentions and beliefs as complex qualities, collapsing, for the sake of simplicity, UFO's distinction between *qualities* and *modes* [14, p. 213].

An important class of qualities are *relational qualities*, which, besides being existentially dependent on the thing they inhere in, are also existentially dependent on something else. An example may be *John's love for Mary*, which inheres in John but is existentially dependent on Mary. Another example would be *Mary's commitment to marry John*, which inheres in Mary and is externally dependent on John. As we shall see, relational qualities typically come in bundles called *relators*.

Summing up, individual qualities, which were introduced for different reasons in DOLCE and in UFO, can be seen now under a new perspective, in their role of weak TMs for descriptive properties. From the above discussion, it is natural to say that an quality is what in virtue of which a descriptive property holds, legitimating therefore the interpretation of 'in virtue of' in terms of minimal weak truthmaking. Note also that, for the needs of ontological analysis, looking for qualities as minimal weak TMs has a clear advantage over looking for strong TMs: while negative truths are notoriously a problem for the strong truthmaking view, so that it is difficult to individuate the strong TM of *a is not red*, it is immediate to see that its minimal weak TM is its color, and not, say, its weight.

Descriptive properties. Let us now define descriptive properties more carefully. As a first attempt, we may define them as properties holding in virtue of

[6] Space does not allow to discuss the notion of minimality in detail. In short, we assume that an entity x is *internal* to y iff x *inheres in*, *is a proper part of* or *participates to* y, and *external* to y otherwise. Then, if t is a TM for a proposition P, it is a *minimal TM* for P iff no entity internal to t is itself a TM of P.

one or more individual qualities inhering in their argument, so that *being red* is descriptive, while *being an apple* is not. However, some observations are due. First, it seems plausible to assume that a descriptive property may hold for an object x in virtue of a quality inhering in a proper part of x, rather than in x itself. So, *having a big nose* counts as descriptive since it holds in virtue of the nose's size, while *having a nose* is non-descriptive since it holds in virtue of the object that has the nose, which is not a quality.

Second, we should account also for descriptive properties that hold in virtue of relational qualities. Considering a generic descriptive property holding for John, there are three possibilities: First, the weak TM consists of just one relational quality inhering in John, as in the case of *being in love with Mary*; Second, the truthmaking qualities are distributed between John and an external entity. This is the case of *being married with Mary*, which presupposes the existence of commitments and obligations (and possibly love) inhering in Mary and depending on John, as well as reciprocal ones inhering in John; Third, there is only one truthmaking quality inhering in something external to John, and existentially depending on it. This is the case of so-called Cambridge properties [5], like *being loved by Mary*. To include the last two cases, we refine our definition as follows: a property P is *descriptive* iff, for every x, *P(x)* holds in virtue of (at least) a quality q being existentially dependent on x.

Intrinsic properties. The notion of intrinsic property is well-established in philosophy, despite some debate on precise definitions holding for arbitrary properties [19]. We shall say that a property holding for x is *extrinsic* iff it requires the existence of something else *external* to x in order to hold (where *external* is defined as in footnote 6), and *intrinsic* otherwise. The *intrinsic/extrinsic* distinction turns out to be orthogonal to the *descriptive/non-descriptive* one, and each of the four combinations has its own peculiarities in terms of TMs.

Being red and *being married* are examples of, respectively, intrinsic descriptive and extrinsic descriptive properties. In the former case the minimal weak TM is a non-relational quality, in the latter it is a relational quality. *Being an apple* or *having a nose* are examples of intrinsic non-descriptive properties, whose argument coincides with the minimal weak TM. *Being proper part of a car* and *being Italian* are examples of extrinsic non-descriptive properties. The minimal weak TM for the former is a car, while the one for the latter (which is an *historical property*) is a birth event.

2.3 Truthmaking patterns for properties

Let us now discuss the practical impact of the above considerations on reification choices concerning properties, commenting the *truthmaking patterns* (TMPs for short) that emerge once we decide to put TMs in the domain of discourse. For the sake of space, we discuss here only two of the four combinations of descriptive/non-descriptive and intrinsic/extrinsic properties mentioned above, since no reification is necessary for intrinsic non-descriptive properties (their weak TM being already present in the domain of discourse), while the case of

extrinsic descriptive properties is very similar to that of external descriptive relations which we shall discuss later. We shall introduce three broad classes of patterns: *partial* TMPs, in turn distinguished in *strong* or *weak*, depending on the kind of TMs reified, and *full* TMPs including both strong and weak TMs *as well as the relationship between them*. All the patterns will be discussed by means of examples.

Intrinsic descriptive properties. Note that these properties do rarely correspond to classes, because they do not carry a principle of identity [13,14]. So, the property of *being red* for a rose is typically expressed as an attribute-value pair within the class *Rose* (Fig. 1a)[7], where the attribute name implicitly denotes the color quality [8]. We have three reification options, corresponding to different TMPs. A *weak* TMP emerges when the quality is reified as a separate class (Fig. 1b). Note the 1-1 cardinality constraint, showing that a quality inheres in exactly one object, and an object has exactly one quality of a given kind. A *strong* TMP is exemplified in Fig. 1c, where an event of "color occurrence" is reified. The first option is generally more flexible, making it possible to describe the way the quality interacts with the world (*Mary likes the color of this rose*), or further information about the quality itself (*the color of a rose is located in its corolla*). The second option is however necessary when we need to account for temporal information (e.g., how long the redness lasted), or for the spatiotemporal context (what happened meanwhile and where...).

To achieve the maximum expressivity, a third option is that of a *full* TMP, including both strong and weak TMs plus the relationship among them (Fig. 1d). Concerning the latter, note that there is a formal ontological connection between qualities and events, discussed in [10]: events can be seen as *manifestations* of qualities, and qualities as the *focus* of events.

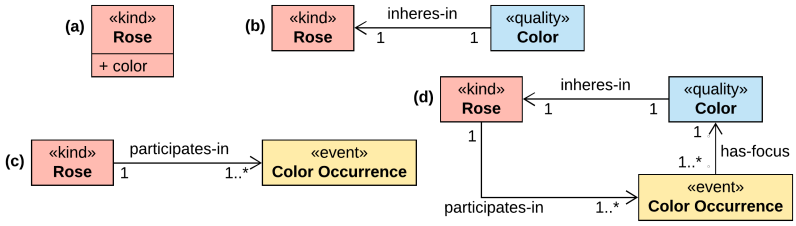

Fig. 1. Truthmaking patterns for an *intrinsic descriptive property*.

Extrinsic non-descriptive properties. For those of them that are anti-rigid, it certainly makes sense to reify the event during which they hold, i.e., their strong TM. For example, a strong TMP applied to the class *InstalledCarPart* (Fig. 2a) would include the class *CarPartInstalled* (Fig. 2b), which denotes the

[7] For clarity purposes, all models here are represented in OntoUML [14]. No commitment on OntoUML is however assumed.

state of having that part installed. A weak TMP that includes the car itself as a weak TM is exemplified in Fig. 2c[8]. The full TMP is shown in (Fig. 2d).

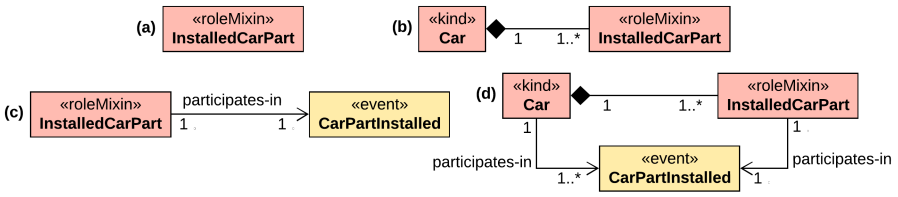

Fig. 2. Truthmaking patterns for a *non-descriptive property*.

3 Relations and their TMs

In his early work, Guizzardi borrowed from [16] a crisp distinction between *formal* and *material* relations, describing the former as holding between two or more entities "directly without any further intervening individual" [14, p. 236], and the latter as requiring the existence of an intervening individual. His modeling proposal was to systematically introduce—for all material relations—a specific construct, called the *relator*, standing for such intervening individual.

In the philosophical literature, the formal/material distinction varies significantly among different authors both in content and terminology, and overlaps with other distinctions. In the following, building on recent work [9,10], we shall revise these distinctions in the light of TMs analysis, aiming at clarifying some conceptual and terminological problems which resulted in some confusions and inconsistencies in the way the relator construct was used in the past [11]. We shall discuss here three orthogonal distinctions, presented in compact form in Fig. 3: *internal/external*, *essential/contingent*, and *descriptive/non-descriptive*.

3.1 Kinds of relationships

The formal/material distinction defined above overlaps with two main distinctions proposed in the literature: *internal/external* and *essential/contingent*. They both originate from a core idea of internal relations as holding only in virtue of the 'internal nature' of their relata. However, different definitions have been proposed depending on how such nature is understood [18]. A first definition, due to Moore [21], says that a relation is internal iff it necessarily holds just in virtue of the *mere existence* of its relata, i.e., it is *essential* to its relata. A second definition, originally due to Russell [27], says that *a relation is internal iff it is definable in terms of the intrinsic properties of its relata, and external*

[8] The choice of reifying a weak TM only arises for those non-descriptive properties whose minimal weak TM does not coincide with their argument. In such cases, the weak TM is typically an argument's proper part (say, a nose for *having a nose*) or something that includes the argument as a proper part.

otherwise. We shall adopt Russel's definition for *internal/external*, using *essential/contingent* for the distinction based on Moore's definition. Note that using both distinctions in the same classification framework forces us to adopt a fine granularity, classifying relationships and not relations, since, as we shall see, it is possible that, within the same relation, some individual relationships are essential and others are contingent.

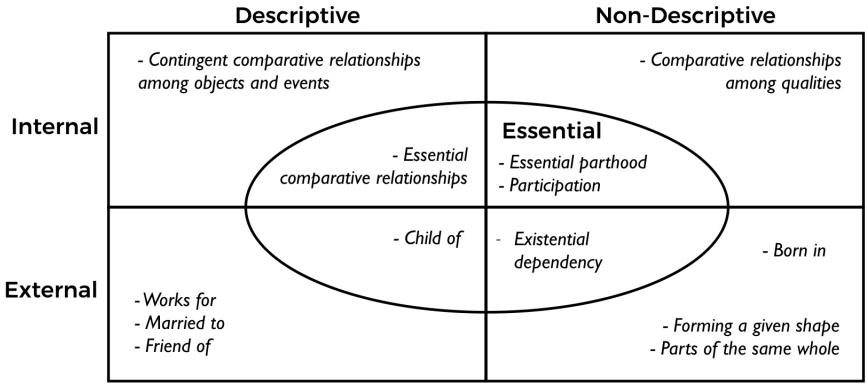

Fig. 3. Kinds of relationships (revised from [10]).

Let us see now how Guizzardi's formal/material distinction, which is crucial for his notion of relator, is mapped to the two definitions above. In his book [14, p. 236], he pointed explicitly to Moore essential/contingent distinction while talking of formal relations, but, in retrospective, what he actually had in mind was more in line with Russel's internal/external distinction, since he included within formal relations also comparative relations like *taller than*, which is not essential as it does not necessarilyt hold when the relata exist. For him, a material relation holds in virtue of the existence of a *relator* composed of particularized properties called *modes* (*qualities* according to our analysis) that inhere in the relata and are historically dependent on a common external *foundation* (an event). The typical example he makes is that of a marriage relationship, whose relator (the marriage itself) is composed of modes (mutual commitments and claims between the spouses) existentially dependent on a common foundation (a wedding event). So, Guizzardi's 'material' is narrower than 'external', and, since the formal/material distinction is exhaustive, his 'formal' turns out to be broader than 'internal'.

Let us now go back to the main reason for the formal/material distinction in conceptual modeling, which is deciding whether or not a relationship can be reified. In a recent paper [10], Guarino and Guizzardi showed that *none* of the distinctions considered so far (essential/contingent, internal/external[9],

[9] In the original paper [10], we labeled this distinction 'intrinsic/extrinsic', aiming at extending to relations the terminology adopted for properties. However, in the philosophical literature 'external relation' is not synonym of 'extrinsic relation', since the latter requires the existence of something completely external to the relata.

formal/material) can help in this decision. Their analysis was mainly motivated by the confusing behavior of *comparative relations*. They were considered as formal by Guizzardi, and therefore not deserving reification. However, there may be good reasons to *talk* about them [9]: for instance, one may want to keep track of the difference in height between a mother and her son, or of the temperature difference between two bodies. So, comparative relations seem to share something in common with other relations that deserve to be reified, although it is difficult to characterize them in terms of the distictions considered so far.

On one hand, as observed by Simons [28], within comparative relations some individual relationships are essential, but others are contingent. 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 their mass essentially), but the mere existence of John and Mary is not enough to conclude that $taller(John, Mary)$ holds, since they do not have that particular height essentially. Moreover, even within the same relation, some individual relationships (like *heavier(p,e)*) may be essential, while others (like *heavier(John,Mary)*) may be just contingent.

On the other hand, although all comparative relations are internal (since they are definable in terms of the intrinsic properties of their relata), those among objects or events hold in virtue of the qualities of their relata, while those among qualities (e.g., perfect resemblance) hold in virtue of the relata themselves, so they don't deserve reification (otherwise we would have an infinite regress). In conclusion, the distinctions mentioned so far are not able to discriminate between reifiable and non-reifiable relations.

3.2 Descriptive Relations and Relators

Analogously to the case of descriptive properties, we define a descriptive relation as *a relation that holds in virtue of some qualities that are existentially dependent on one or both its relata*. The mereological sum of such qualities forms what we call a *relator*, which (recalling the discussion in Section 2) is therefore the *minimal weak TM* of the relation. As Fig. 3 shows, the descriptive/non-descriptive distinction is orthogonal to those discussed so far. So, there are descriptive relations that are internal (such as comparative relations among objects or events), and others that are external (those originally called *material relations* by Guizzardi). The relators in these two cases, however, are very different. Since internal relations are defined as derivable from *intrinsic* properties of their relata, the relators of internal descriptive relations are just formed of qualities depending only on the relatum they inhere in. On the contrary, relators of external descriptive relations include at least some qualities that, besides depending on the relatum they inhere in, are also depending on the other relatum. The latter is the notion of relator discussed in Guizzardi's thesis, which was generalized and simplified in a previous paper [10], in order to work for all kinds of descriptive relations, and here has been analysed in terms of truthmaking. The link between a relator and its relata was originally called 'mediation', but recently we decided to adopt a more neutral term, 'involvement'. An entity is involved in a descriptive relationship, reified as a relator, if one of its qualities is part of such relator.

Having relators (i.e., reified relationships) in the domain of discourse has been recognized as a solution to many practical problems in conceptual modeling, including disambiguation of cardinality constraints, transitivity of part-whole relations, and proper modeling of anadic relations, among many others [14]. Moreover, having relators as full-fledged endurants (being them bundles of qualities, which are endurants themselves) allows us to describe their behavior in time exactly like an object [9]. So, for example, relators can undergo different phases, have essential and accidental qualities of their own, and change in a qualitative way while remaining the same.

3.3 Truthmaking patterns for relations

Similarly to the case of properties, let us now discuss the reification options and the corresponding TMPs concerning relations. We shall only consider quadrants 2, 3 and 4 of Fig. 3, since the TMs of relationships in quadrant 1 are their own arguments, so that no further reification is necessary.

Internal descriptive relations. The main representatives of this class are comparative relations among objects or events. A first option is to reify their weak TM, i.e., their relator, composed of exactly two qualities of the same kind. For example, for the *heavier-than* relation, the relator is the class *WeightRelationship* shown in (Fig. 4b).

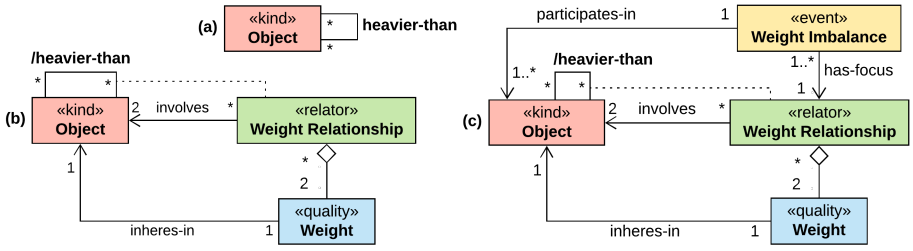

Fig. 4. Applying weak and strong truthmaking patterns to *comparative relations*.

Note that, since relators are weak TMs, multiple relations can be derived from the same relator, depending on the actual values of the qualities composing the relator. Consider for instance Fig. 4b. Since it is a weight comparison relationship, one could also derive relations such as *lighter-than*, *same-weight-as*, *twice-as-heavy*, and so on. In a sense, the relator generalizes the relation, maintaining the possibility to represent all the relevant cases by means of the qualities. Moreover, reifying the relator helps when one wants to make explicit which qualities ground the relation (e.g. *heavier-than* is derived from a comparison of weights). As discussed in depth in [14], explicitly acknowledging from which qualities a comparative relation is derived allows us to also account for the specific meta-properties on that relation. For example, *heavier-than* is a total order relation because it is founded on weight qualities, which take their values (qualia) in a linear (i.e., totally ordered) weight space.

Fig. 4c shows the addition of a strong truhmaker to the previous case, which achieves the maximum expressivity. Adding the *WeightImbalance* event (which is actually a state, i.e., a static event) allows us to capture more explicitly the state of affairs corresponding to a *heavier-than* relationship, and specify as well details concerning its actual duration its spatiotemporal context.

External descriptive relations hold in virtue of at least one relational quality inhering in at least one relatum. We distinguish two main cases: *single-sided* relations holding in virtue of one or more qualities inhering in just one relatum, and *multi-sided* relations holding in virtue of at least two qualities each inhering in a different relatum. An example of the first kind is an attitudinal relation such as *desires*, represented in Fig. 5a. A weak TMP is shown in Fig. 5b, where a desire quality inhering in an agent and depending on some resources is reified. Note that we have represented it as a quality, but it could be seen as as well as a relator consisting of just one quality. The addition of a strong TM, resulting in a full TMP, is shown in Fig. 5c. The event labeled 'DesireEvolution' describes whatever happens in reality whose focus is that particular desire, such as the arising of the desire and its satisfaction.

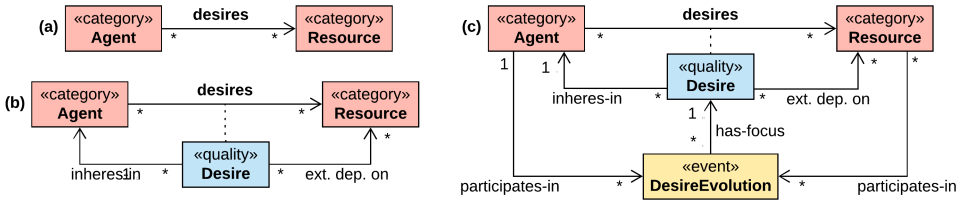

Fig. 5. Weak and full truthmaking patterns for a *single-sided relation*.

Multi-sided relations are arguably the most frequent case of external descriptive relations. Reifying their TMs is often necessary to model social and legal relationships, such as marriages, economic contracts, employment relationships, and so on. An example of full TMP is presented in Fig. 6, which describes a *subscribes* relation holding between service providers and service customers. The relator is shown as a contractual relationship consisting of reciprocal commitments and claims inhering in the customer or the supplier (and externally dependent on each other).

Note that, just by explicitly representing the contract, this model clarifies the cardinalities of the *subscribes* relation. Here we assume that contracts are always bilateral, i.e., a contract involves exactly one customer and one provider. Thus, this pattern rules out the possibility of multi-party contracts that could be inferred otherwise. This is an example of how the explicit representation of relators can eliminate the aforementioned problem of cardinalities ambiguity.

The pattern described by Fig. 6 may also be applied to role-playing relations such as *president-of* between a person and an organization. In this case the relator accounts for the social commitments and obligations related to the particular role, while the event accounts for the period of time when the role is played. So,

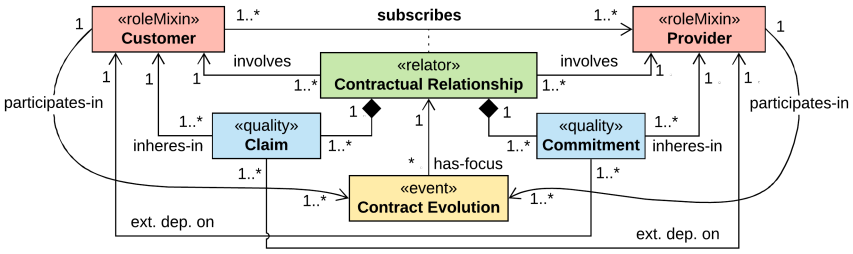

Fig. 6. The full truthmaking pattern for a service subscribing relation.

this pattern can be seen as the well-founded version of the "*time indexed person role*" defined in [7].

External non-descriptive relations. Unlike the cases we have just discussed, the TMs of these relations are completely external to their relata, in the sense that they do not inhere in them, are not parts of them and do not participate to them (footnote 6). One example is the *born-in* relation holding between Tiago and Brazil. If we put on our "detective lenses" to inspect both Tiago and Brazil, we will not be able to find any quality in virtue of which the relation holds. The same would happen for other relationships such as *painter(SistineChapel,Michelangelo)*, or *veteran(Jack,VietnamWar)*. These are all examples of *historical* relationships, holding in virtue of an event in the past in which at least one of the relata participated.

Fig. 7 depicts a pattern in which the TM of the *born-in* relation, holding between a *Person* and a *Country*, is reified by means of a *Birth* event. The reification of TMs for historical relations is particularly useful when one needs to represent additional properties of these events, such as their duration or the presence of other participants (e.g. the doctor who assisted a birth). It may also be useful to do so for properly representing cardinality constraints, similarly to the case of relators. Finally, if one accepts the classical view that events are immutable entities [9], differentiating between TMs that are events and TMs that are endurants allows us to represent these entities' properties in a way that properly accounts for this constraint (e.g., in UML, representing all relevant properties of events as readOnly attributes).

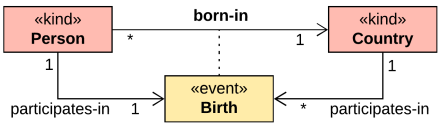

Fig. 7. An application of the *historical relation* pattern.

Complex truthmaking configurations. In certain cases, the TM is not just a single entity, like the birth event, but rather a *complex truthmaking configuration*. Take for instance the *colleague-of* relation, between people working in the same

organization. For this relation, the weak TM is a larger entity of which the two relata are parts, namely the organization itself, while the strong TM is the actual event of working for the same organization at the same time, so that the relation is *derived* from a particular configuration of data that are external to the relata. More complex cases of truthmaking configurations have been discussed in [11] in the context of an ontological analysis of the REA accounting model [20].

Differently from the other cases we discussed in this section, *complex truthmaking configurations* do not follow a common structural pattern. Still, we presented them as a separate case to highlight that some relationships may not be simply reified by means of a single entity, but rather by a complex truthmaking configuration.

4 Conclusions

Differently from other approaches that look mainly at reification techniques from the modeling language point of view [3,15,24,25], we have focused in this paper on understanding the ontological nature of what should be reified, by systematically investigating why properties and relations hold, and providing guidelines for reification choices according to the nature of their TMs. A crucial contribution in this analysis was the recognition of qualities as minimal weak truthmakers, which turned out to be a very useful application of Parsons' quite original views.

We also clarified Guizzardi's distinction between formal and material relations, proposing a new classification of relations based on the orthogonal distinctions *descriptive/non-descriptive* and *internal/external* (a refinement of that presented in [10] that helped us to develop systematic TMPs aimed at facilitating the ontological analysis of actual modeling cases. These patterns may be easily incorporated in conceptual models based on foundational ontologies that support the notion of individual quality, such as DOLCE [2], UFO [14], or BFO [1]. In particular, we plan to implement them in the OntoUML [14] language and in its modelling evironments, such as the Menthor Editor [22], to support modelers in systematically investigating and representing the TMs of properties and relations.

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