On the Ontological Nature of REA Core Relations

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Abstract. In this paper we review and discuss some recent attempts at ontological re-engineering of REA in the light of the UFO ontology and the OntoUML language, focusing in particular on different choices concerning the UFO notion of *relator*. We also take this as an opportunity to clarify and revise Guarino and Guizzardi's general theory of reification and truthmaking proposed in the past.

Keywords: REA accounting model, ontological analysis, relators

1 Introduction

REA (Resources, Events, Agents) is a well-known accounting model with an established community of users. It was proposed by W. McCarthy in 1982 [15] and evolved as an ISO standard in 2007 [16] after a re-visitation in the light of ontological principles [4]. Since then, various scholars contributed to enhance REA's understandability and applicability [3,10,11,22], aiming at the same time at considering REA (or a suitably extended and revised version of it) as a foundation for business modeling and enterprise modeling in general. More recently, two groups of authors [1,2] attempted an ontological re-engineering of REA in the light of the UFO ontology and the OntoUML language, developed by Giancarlo Guizzardi and his group [7]. However, mapping the REA primitives on the UFO primitives was not an easy task, so that different choices were made.

In particular, as shown in Table 1, rather different choices were made about the nature of resources, events and commitments, and especially about the REA core relations: *duality*, *reciprocity*, *stockflow*, and *participation* [16, p. 17]. The different choices mainly concern the UFO notion of *relator*, which is a very powerful notion but also one that is sometimes difficult to grasp.

The original motivation of this paper—which is still its main purpose—was to reconcile these different views by clarifying the ontological nature of REA core relations, and especially the *duality* relation, which, despite its fundamental role, is sometimes considered as a bit mysterious. In this perspective, we decided

Table 1. REA's core relations and related classes mapped to UFO.

REA Class	Gailly et al.[2]	Fischer & Schwaiger [1]	This Paper
Economic Resource	Role	Kind	RoleMixin
Economic Event	Relator Univ.	Kind	Event Univ.
Commitment	Relator Univ.	Kind	Mode Univ.
Stockflow	Mediation Rel.	Formal Rel.	Internal Non-Descriptive Rel.
Participation	Mediation Rel.	Formal Rel.	
Duality	Formal Rel.	Material Rel.	External Non-Descriptive Rel.
Reciprocity	Formal Rel.	Material Rel.	

to discuss the mapping choices mentioned above in the light of a recent revisitation of the original Guizzardi's notion of relator, and more in general of the foundations of relationship reification [5,6].

There is however an additional motivation that led us to write this paper. Analyzing the subtleties of REA relations gave us the opportunity to test the generality and the limits of our new account of relators and relationship reification based on [6], and at the same time to acknowledge the difficulty of using relators in concrete cases. We decided therefore to make a further clarification effort (especially with respect to the terminology adopted), whose results are presented here for the first time, although in a compact form. So, this paper can be also seen as a compact presentation of our revised theory of relationship reification, with concrete examples taken from the REA domain.

In the next section we recap the distinctions among different kinds of binary relations discussed in the literature, focusing on how they can help us to decide which relations can be reified, and clarifying some terminological ambiguities concerning the original Guizzardi's distinction between formal and material relations. Then we discuss the ontological nature of the four REA core relations (and their arguments) in detail, pointing to some misconceptions on their mappings to UFO categories that sometimes accumulated in the REA literature, partially influenced by the terminological confusion mentioned above. Finally, we conclude with the proposal of an integrated OntoUML model that links together the duality and the reciprocity relation, explicitly grounding the former in the contractual relationship among the trading partners.

2 Kinds of Relationships

In his early work on UFO, Guizzardi borrowed from Heller and Herre [9] a crisp distinction between *formal relations*, intuitively understood as holding between

two or more entities "directly without any further intervening individual" [7, p. 236], and *material relations*, which require the existence of an intervening individual. A modeling proposal at the core of OntoUML 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, most notably that between *internal* and *external* relations. The original idea behind internal relations is that they hold in virtue of the 'nature' of their relata. However, different opinions exist on whether such nature is determined by the actual intrinsic properties of relata (whether essential or not), or just by their essential properties. Accordingly, internal relations are defined in two main ways [13], which we shall label with $internal_1$ and $internal_2$. The first definition is due to Moore [17], and it says that a relation is $internal_1$ iff it necessarily holds just in virtue of the mere existence of its relata, and $external_1$ otherwise. In other words, an $internal_1$ relation is *essential* to its relata. The second definition, due to Russell [20] and slightly refined by Lewis [12], says that a relation is $internal_2$ iff it is definable in terms of the intrinsic properties of its relata, and $external_2$ otherwise.

Let us see now how Guizzardi's distinction among formal and material relations, which is crucial for his notion of relator, is mapped to the two definitions above. To avoid confusions, we shall use the terms *essential/contingent* as synonyms of $internal_1/external_1$, using just *internal/external* as synonyms of $internal_2/external_2$. In his book [7, p. 236], Guizzardi pointed explicitly to Moore while talking of formal relations, but, in retrospective, what he actually had in mind was more in line with Russel's and Lewis' tradition, since for him formal relations included comparative relations like *taller than*, which is not essential since it may not necessarily hold when the relata exist. However, he defined formal relations as the complement of material relations, and his definition of the latter [7, p. 241] is stricter than that of external relations, since for him a material relation holds in virtue of the existence of a *relator* composed of particularized properties called *modes* that *inhere* in the relata and are existentially dependent on a common external entity called *foundation*. The typical example he makes is that of a marriage relationship, whose relator is composed of modes existentially dependent on a common 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'.

As a result, relations like *being both observed by John* or *being both parts of the same whole*, which are external since they can't be derived from the properties of their relata, turn out to be formal according to [7], because there is nothing that inheres in the relata in virtue of which the relation holds. In other words, there is no *truthmaker* inhering in the relata, so there is no relator. Rather, the truthmaker is *outside* the relata, since it inheres in John or in the whole that includes the two parts. As we shall see, this is exactly what happens with

REA's duality relation, which was intuitively classified as material by Fisher and Schwaiger [1], but turns out to be formal according to Guizzardi's definitions.

Let us now go back to the main reason of the formal/material distinction in conceptual modeling, which is deciding whether or not a relationship can be reified. In a recent paper [6], Guarino and Guizzardi showed that *none* of the distinctions considered so far (essential/contingent, internal/external[4], formal/material) can help in this decision. Their analysis was mainly motivated by the confusing behavior of comparative relations.

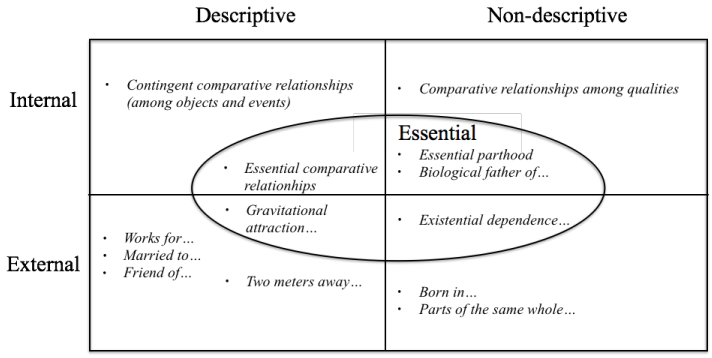

Fig. 1. Kinds of relationships (revised from [6]).

On one hand, as observed by Simons [23], some comparative relations turn out to be 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 that particular 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, Simons noticed that, 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, despite comparative relations were considered as formal in Guizzardi's sense, and therefore not deserving reification, there may be good reasons to *talk* of them [5], and therefore reify them: 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 the other relations that deserve to be reified. According to Guarino and Guizzardi, this commonality lies in the fact that they are both *descriptive relations*, which hold in virtue of some particular *aspects* inhering in the relata[5]. So, their new proposal (with respect to the original Guizzardi's work) is that it is the mereological sum of these aspects that acts as

[4] intrinsic/extrinsic in the original paper.

[5] In Guizzardi's work, such aspects have been called *moments*, and include *individual qualities* and *modes*.

relator, accounting both for the fact that the relation holds and for the *way* the relata are linked together, which may vary in time. Under this view, the relator of a *taller than* relationship is the sum of the heights (*individual qualities*) of the two relata, while for a marriage relationship the relator is a sum of externally dependent *modes*, corresponding to the mutual commitments and obligations inhering in the two partners.

Summing up, a complete picture of the various distinctions discussed so far is shown in Fig. 1, which revises a similar picture published before [6, p. 241]. Note that, to account for the problem mentioned above concerning the different behavior of individual relationships belonging to the same comparative relation, strictly speaking the picture describes kinds of *relationships*. Relationships are classified along two main orthogonal distinctions: internal/external and descriptive/non-descriptive. Descriptive relationships are those deserving reification, which now include all comparative relationships among objects and events. The ellipse shows how essential relationships are positioned orthogonally with respect to the two main dimensions, so that just distinguishing them does not help in the reification choice.

Let us now briefly discuss the four quadrants shown in Fig. 1. The upper left quadrant includes all comparative relationships holding among objects and events (some of which are essential, as we have seen). The upper right quadrant includes comparative relationships (such as *resemblance*) holding among qualities, as well as essential relationships like essential parthood or biological fatherhood. The bottom left quadrant includes relations such as *married to*, holding in virtue of actual modes of their relata, but also historical relations such as *author of*, which holds in virtue of some past mode (of the author). Other interesting examples of relations belonging to this quadrant are those holding in virtue of an *emergent aspect* that inheres in the *sum* of relata, and not in any of the relata themselves. *Being two meters away* is an example of such emergent (or *systemic*) relation, whose truthmaker is a distance quality that inheres in the sum of two bodies. Gravitational attraction is an example of a similar relation which is also essential. Since the truthmakers of these last two relations are not relators in the original sense, Guizzardi's material relations are therefore just a subset of those belonging to this quadrant. Finally, the bottom right quadrant includes 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 parts of the same whole*, which hold in virtue of something external that doesn't affect the relata. As we shall see, this is the case of the duality relation.

3 The Duality Relation

This relationship is at the core of the REA ontology, so its correct ontological analysis is clearly crucial. Let us first clarify the nature of its arguments, which are *economic events*. REA defines them as "occurrences in time wherein ownership of an economic resource is transferred from one person to another person" [16]. Strangely enough, as we see from Table 1, Gailly and colleagues [3] classified

them as relators, seeing them as "mediating entities for the relation between an economic resource and two economic agents". Maybe the reason of this choice was that the first version of UFO did not elaborate on the notion of events (a.k.a. *perdurants*), which were later covered, for example, in UFO-S [19]. In any case, events cannot be relators.

To see this, consider the way relators are defined [7, p. 240]: a relator is a mereological aggregation of 'modes' that inhere in the relata and are existentially dependent on a common external entity. In the case of a marriage, such modes include for example the commitments and claims John has towards Mary, which inhere in him and depend on Mary, as well as the corresponding modes inhering in Mary and depending on John. Now, there is no part of an economic event that inheres in an economic resource or an economic agent. So, economic events do *not* mediate resources and agents. In addition, it is important to note that, in UFO, relators are assumed as continuants in time (*endurants*) and not occurrences in time (*perdurants*), and this fact is indeed crucial to model their genuine change in time [5]. So, no event can be a relator (despite the fact that there is an intimate connection between events and relators as discussed in depth in [6,8]).

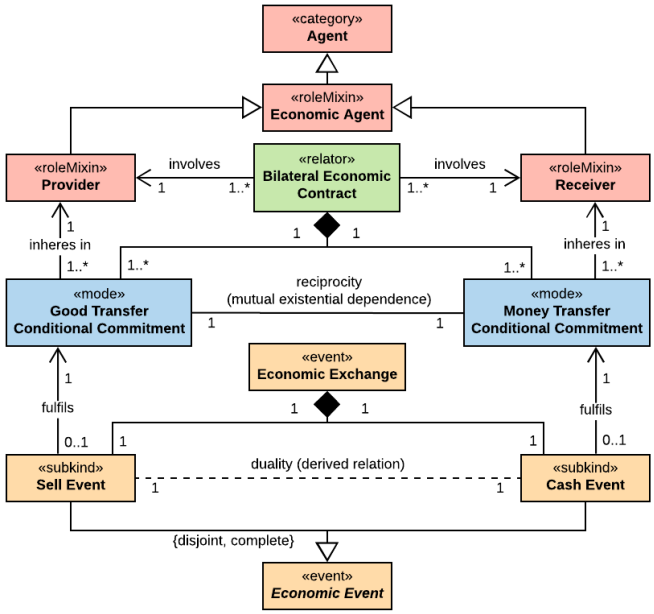

Fig. 2. OntoUML fragment showing the link between duality and reciprocity.

Let us now discuss whether duality can be reified as a relator: Gailly and colleagues say no, seeing duality as a formal relation, while Fisher and Schwaiger say yes (Table 1). Since it can't be derived from intrinsic properties of the two events, duality is not an internal relation. Neither is it a descriptive relation, since

it does not hold in virtue of specific aspects inherent in the relata. Therefore, it belongs to the bottom-right quadrant of Fig. 1, that of non-descriptive external relations. Moreover, this is not an essential relation, because the simple existence of an increment event and a decrement event involving resources of the same value is not enough to conclude that a duality relationship holds between the two, since the two events may not be related. However, there is a link between the two events, which consists in the fact that one is the fulfillment of a debt commitment which in turn depends on a credit commitment. So, Fisher and Schwaiger are right in observing that such link "comes from the contracting that underlies each business transaction" [1], and that "this contracting mediates between the economic agents in an economic event", but this is not enough to reify the relation, since, being it non-descriptive, its truthmaker is external to the relata. We conclude that duality is a *derived relation*, which can be inferred on the basis of the reciprocity relation, once we know what commitments the single events fulfill.

Besides the duality relation, a further ontological constraint that links an increment event and its dual decrement is the fact that they are both part of the same *economic exchange* event. This was indeed the choice made in a former paper by Schwaiger [22], which was unfortunately changed in the OntoREA version. We believe that putting explicitly this mereological constraint in the model is important to avoid undesired interpretations (note that in the original REA model no constraints are put on the duality relation). A simplified OntoUML model showing this account of duality and its link with reciprocity (to be discussed below) appears in Fig. 2.

4 The Reciprocity, Participation and Stockflow Relations

In the REA documentation [16], reciprocity is defined as an "association between economic commitments where the promise by one partner to execute an economic resource transfer in the future is reciprocated by the other partner promising a requited transfer in the opposite direction". Gailly and colleagues consider it as formal relation, while Fischer and Schwaiger make the opposite choice. Concerning the relation's arguments, commitments are considered as relators by the former authors and as instances of a kind by the latter. The first choice is not argued very much by the authors, and is possibly a misunderstanding due to the fact that they cite an early version of [4]. In any case, it is not absurd to consider a single commitment as a relator, reifying a one-sided commitment relationship, but what counts in our case is the bilateral contractual relationship resulting from reciprocal commitments, so it seems definitely more appropriate to consider single commitments just as modes (of a certain kind) being part of a contractual relationship (Fig. 1).

Going back to reciprocity, this is modeled as a material relation in OntoREA© [1]. They say that "this relationship acts as *truthmaker* for the relation[6] between

[6] Relationship in the original text.

economic commitments", but they also note although the authors note that such relationship has a double nature, due to the truthmaker role played ultimately by the contract among the two involved agents. Fig. 1 shows how this apparent redundancy (or ambiguity) can be eliminated: a (bilateral) contractual relationship is a descriptive external relationship between two agents, reified by a relator that has two mutually existentially dependent *conditional commitments* [14] as parts: a commitment to transfer a good if the buyer commits to pay, and the reciprocal commitment to pay if the seller commits to transfer the good[7]. The relation between the two commitments is of *mutual existential dependence*, which is an external non-descriptive relation, and therefore is not reified. The two mutual commitments, together, form the truthmaker of the contractual relationship.

Concerning the participation and stockflow relations, let us first observe that they are both specializations of a more general notion of participation, used in UFO and several other ontologies to model the relation between objects and events. So, both agents and resources participate in economic events (of course with different roles).

Participation is an essential relation, which holds just in virtue of the existence of its relata: if an economic event exists, its very existence implies that it has some participants. The two papers mentioned in Table 1 agree in this respect, but Gailly and colleagues made a stronger choice that has no grounds in UFO, assuming that participation is a mediation relation. This is due to their choice of considering events as relators mediating between agents and resources, whose problems have been discussed in Section 3.

5 Conclusions

Space doesn't allow for much further discussion. We are happy that OntoUML is being used more and more for REA-based ontologies, and business ontologies in general. Analyzing the literature helped us to isolate some subtle OntoUML antipatterns [21] which will be hopefully automatically checked by the OntoUML environment [18] in the future.

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[7] We are assuming a simplified picture. See [14] for an in-depth ontological analysis.

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