Relations, O-roles and applied ontology

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Abstract: Relational facts are best understood by appealing in a most general fashion to o-roles, i.e., ontological counterparts of the thematic roles appealed to in linguistics, such as agent, patient, instrument, theme, source, goal, and the like. Once relatedness is appropriately appreciated and o-roles enter the picture, the way relational facts are represented in first-order logic (FOL) appears inadequate and adjustments are called for. However, applied ontology still typically relies on FOL and on the conception of relations encapsulated in it. Some programmatic ideas are then put forward with the intent of going beyond FOL in this respect and promoting the search for a set of o-roles to be acknowledged in top-level or foundational ontologies.

Keywords: Relations, thematic roles, first-order logic, applied ontology.

1. *Introduction*

In information technology there is a more and more widespread recourse to applied ontologies (Guarino, Oberle and Staab 2009), or "controlled vocabularies for representing the entities in a given domain" (Arp, Smith and Spear 2006: 6), for example in biology and medicine, social organizations, geography or history. An applied ontology codifies information in a formal language that is meant to be rigorous and unambiguous, for purposes of automated search and processing. In building up an applied ontology one may take advantage of a "top level" (Arp, Smith and Spear, 2006) or "foundational" (Borgo and Masolo 2009) ontology. As Borgo and Masolo (2009: 361) put it,

> Foundational ontologies are ontologies that: (1) have a large scope, (2) can be highly reusable in different modeling scenarios, (3) are philosophically and conceptually well founded, and (4) are semantically transparent and (therefore) richly axiomatized. Foundational ontologies focus on very general and basic concepts (like the concepts of object, event, quality, role) and relations (like constitution, participation, dependence, parthood), that are not specific to particular domains but can be suitably refined to match application requirements.

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Arp, Smith and Spear on the one hand, and Borgo and Masolo on the other, advertise two different foundational ontologies, namely BFO and DOLCE, respectively. And there are other foundational ontologies on the market today, such as GFO, OPENCYC and SUMO.[1]

As Borgo and Masolo explain, in working on a given domain, one ends up using a specific application-oriented language suitable for real time reasoning, whereas in foundational ontology one relies on "a formal language with clear semantics and adequate expressive power", wherefrom one can readily translate into the application-oriented language. The formal language that is typically used is the language of first-order logic (FOL). In this language the attribution of a property, expressed by a *monadic predicate term P*, to a certain item, designated by an *argument term a*, has the form $P(a)$, and the attribution of a relation, expressed by an *n-adic predicate term R*, to *n* items designated by the *argument terms* $a_1, \ldots, a_n$, has the form $R(a_1, \ldots, a_n)$. Thus, for example, in talking about the DOLCE ontology, Borgo and Masolo (2009: 373) tell us that "*x* is part of *y*" is rendered as "$P(x, y)$". There can be idiolectic variations, but they do not alter the basic syntactic principles of FOL. For example, in SUMO, instead of the form $R(a, b)$, one finds the form (*predicate A B*), where *predicate* is an English verb such as "likes", and thus we are told that "F likes T" is rendered as "(likes ?F ?T)" (Pease 2009: 5; we need not care for present purposes about the use of question marks in this formula). Similarly in BFL, instead of the form $R(a, b)$, one finds the form *a predicate b*, and thus we are told that "*a* is adjacent to *b*" is to be represented as "*a* adjacent-to *b*", and "*a* derives from *b*" as "*a* derives_from *b*". (Arp, Smith and Spear: 61).

In my view, this recourse to FOL in representing relational attributions incorporates a misguided conception of the nature of relations and of the relational eventualities or facts[2] that we represent with the relational statements that result from such attributions. For there are some very basic phenomena underlying relatedness that this conception appears to ignore or misinterpret and that accordingly are not adequately captured by the FOL formalism. This state of affairs can be corrected, I shall argue, by appealing to ontological counterparts of what linguists call *thematic roles*.[3] I call such counterparts

[1] See the following sites: http://www.loa-cnr.it/DOLCE.html; http://www.ifomis.org/bfo; http://www.onto-med.de/ontologies/gfo.html; http://www.opencyc.org; http://www.ontologyportal.org/.

[2] Following Parsons (1990: 20), I use here "eventuality" as an umbrella term for states, processes and events, which are normally taken to occur in time. And I use "fact" in an even more encompassing sense, so as to include eventualities as well as other items which, like eventualities, can be taken to be truthmakers, but which are not typically taken to occur in time, e.g., 2's being greater than 1, or a certain moment of time's being later than another one.

[3] See, e.g., Allen 1988, Croft 1991, Heydrich 1980, Jackenfoff 1983, Parsons 1990, Reinhardt

onto-thematic roles, or in brief *o-roles*.[4] By appropriately invoking them, the phenomena in question can be captured and a more suggestive formalism can be concocted. There are already in applied ontology proposals that appeal to o-roles,[5] although it seems to me that there is not a full appreciation of how they can help us in understanding relatedness and consequently in the task of codifying relational information in a controlled way guided by a foundational ontology. In particular, it is taken for granted that o-roles are themselves relations, which link eventualities to the very objects that figure as participants in such eventualities, in a way that is best represented by a recourse to the typical way in which we represent relational attributions in FOL (so that "$r(x, e)$" corresponds to object x's being related to eventuality e by the o-role r).[6] Moreover, there are in these proposals divergences on which o-roles should be admitted and how precisely they should be deployed, which are analogous to the divergences that one find in the linguistic literature on thematic roles. In this paper, I would like to contribute to promoting the use of o-roles in applied ontology as follows. First, I shall focus on the basic phenomena of relatedness and clarify why the way relational attributions are rendered in FOL may lead us astray when we try to appreciate these phenomena. Secondly, I shall illustrate how these phenomena are explained by invoking o-roles, understood as entities that capture similarities across different relational facts in pretty much the same way in which universals capture similarities across different individuals. And while so illustrating I shall propose a notation that takes for granted that there are o-roles and exploits them in a way that completely avoids the FOL rendition of relational attributions. Thirdly, I shall touch on the difficult issue of which o-roles should be postulated by taking as guidance the idea that o-roles capture similarities across different facts, while coupling it with the thought that appropriate analyses of relational facts can avoid an unduly proliferation of idiosyncratic o-roles that are unfit to capture such similarities. Finally, I shall focus on the

2002. A recent rich list of thematic roles is provided by Martha Palmer at http://verbs.colorado.edu/~mpalmer/projects/verbnet.html.

[4] Other authors who have assumed that there are such ontological counterparts of thematic roles either call them *thematic roles*, just like the syntactic functions, or call them *thematic relations*. The first option generates an ambiguity that is better to avoid. The second option derives from taking for granted that such counterparts are relations linking eventualities to their participants. For reasons that we shall see, I do not want to make this assumption, and thus I prefer my more neutral terminology.

[5] See in particular Goy, Magro and Rovera 2018, and references therein. See also Sowa 2000, Smith *et al.* 2005: 16, Racciatti 2017.

[6] O-roles are typically viewed in this way whenever they are postulated at the semantic level by linguists and philosophers working at the interplay of language and ontology. See in particular Parsons 1990, on which Goy, Magro and Rovera explicitly rely.

reasons that one may have against taking o-roles to be relations and consider what they could possibly be if they are not relations.[7]

2. *Problems with FOL*

Suppose for example that

(1) Adam kisses Beatrice,

and thus there is a kissing eventuality involving Adam and Beatrice that makes (1) true. Or suppose that

(2) Adam gives Carole to Beatrice,

so that there is a giving eventuality involving Adam, Beatrice and Carole, who is, let us suppose, Adam's and Beatrice's little daughter. In FOL, with predicates adapted from English verbs or nouns as in SUMO or BFO, such eventualities would be represented as follows:

(1a) kiss(a, b);
(2a) give(a, c, b);

where "kiss" and "give" are a dyadic and a triadic predicate, respectively. The underlying assumption is that predicates have a fixed adicity (arity or degree).

This way of proceeding, however, is, I claim, unsatisfactory. The main reason is that this sort of representation does not adequately capture what has been called *relational order* (see Orilia 2011, 2014),[8] a phenomenon typically associated to non-symmetric relations. The eventuality represented by (1) has relational order in that it is distinct from another eventuality involving the same *participants* and the same relation (the same *canonical constituents*), such as the one represented by

(1') Beatrice kisses Adam.

In both cases in fact Beatrice, Adam and kissing are the canonical constituents. Yet, the two eventualities must differ somehow. We thus say that they differ in relational order. Similarly, the eventuality represented by (2) has relational order in that it is distinct from other eventualities with different

[7] I build here on previous works of mine on relations (e.g., 2000, 2011, 2014), where one can find historical connections to philosophers such as Leibniz, Russell and Hochberg, who appeal to something like o-roles.

[8] The phenomenon has also been called *differential application* (see MacBride 2016).

relational order and involving the same canonical constituents, such as those represented by these sentences:

(2') Beatrice gives Carole to Adam;
(2'') Carole gives Beatrice to Adam.

The way in which we represent such eventualities in FOL is unsatisfactory, because it captures the difference in relational order in a completely arbitrary way. For instance, we might have chosen (1a) to represent the eventuality in which Beatrice is the kissing participant and Adam the kissed one. Similarly, (2a) might have been chosen to represent the eventuality in which Carole is the one who is given something and Beatrice is the given entity. Obviously, any time we represent eventualities in this way, we must specify via an explicit convention how to interpret the order with which we write the terms designating the participants. This is cumbersome and certainly hinders the transference of information. More importantly, it makes us miss important generalizations and inferences.

Suppose for convenience that a certain hammer is named *Hammie* and a certain nail *Nailie* and consider this sentence:

(3) Donald hits Nailie with Hammie.

There seems to be something in common that the eventualities represented by (1) and (3) have, namely that the participant Adam in the former and the participant Donald in the latter seem to have an analogous role, namely an active or agent role; more precisely, in the terminology introduced above, an agent *o-role*. Moreover, the two eventualities have something in common in that Beatrice in the former and Nailie in the latter seem to have a correlative passive or patient o-role.

We may think that this can be captured by adopting a specific convention regarding the order with which we write terms in FOL. We may decide for example that the first term always stand for an item with an agent o-role and the second with a patient o-role. That won't do, however. To see it, consider

(4) Adam is adjacent to Beatrice.

In FOL we would render this as

(4a) adjacent(a, b)

or as

(4a') adjacent(b, a).

With (4a) we would then imply that Adam has an agent o-role and Beatrice a patient o-role; and with (4a') we would imply the opposite. But neither should be implied, for adjacency does not involve an activity in which an item is active and another one passive.

Thus, there is a similarity, their involving an agent and a patient, which links the eventualities represented by (1) and (3), and which is not shared by the eventuality represented by (4). But there is a deeper respect in which the latter is different, namely *lack of relational order*, a phenomenon that typically emerges with symmetric relations such as being adjacent. Note in fact that we can rule out that there is an eventuality that differs from the one in question and yet has the same canonical constituents. Yet, this difference is not adequately captured in FOL. There is nothing in (4) that suggests that it stands for an eventuality that lacks relational order. Indeed, the FOL notation may suggest otherwise, given that the difference in the order with which we write the terms after the predicate is typically exploited, as we saw above, to express a difference in the eventualities that we manage to represent.

Consider now

(3') Donald hits Nailie.

We should admit that (3) implies (3'). The passage from (3) to (3') is an instance of an inference that has been called *argument deletion* (see Orilia 2000). Here is another example of argument deletion: that John went from Paris to Milan implies that he went to Milan. Clearly, the phenomenon is extremely general and should be captured.

Unfortunately, argument deletion is hard to capture in FOL. To see this, consider that FOL requires that we employ a triadic predicate, say, hit3, to render (3') and a dyadic one, say, hit2, to represent (3'):

(3a) hit3(d, n, h);
(3'a) hit2(d, n).

But since "hit3" and "hit2" are two different predicates, (3a) cannot be taken to imply (3'a), unless we assume some very specific meaning postulates that relate "hit3" and "hit2".

Another problematic aspect of the conception of relations embodied in FOL has to do with the so-called converse relations. To illustrate it, I shall focus for simplicity's sake on dyadic relations. It is typically assumed that, for any dyadic relation R, there is a corresponding converse relation R^* such that $R(x, y)$ is equivalent to $R^*(y, x)$. Indeed the FOL notation suggests this. Suppose that, for example, we stipulate that (1a) is understood in such a way that, just

because "kiss" is followed first by the term "*x*" and then by the term "*y*", it so happens that "*x*" stands for a kissing item and "*y*" for a kissed item. If so, why can't we introduce another relational term, "kiss*" that abides by a different convention? Namely a convention according to which, if "kiss*" is followed first by the term "*y*" and then by "x", it so happens that "*y*" stands for a kissed item and "*x*" for a kissing item. Surely we can do this and thus take (1a) to be equivalent to:

(1a') kiss*(b, a).

Now, although (1a) and (1a') are assumed to be equivalent, they can hardly be taken to stand for the same eventuality, for the former represent an eventuality involving the relation kiss and the latter an eventuality involving the relation kiss*. Indeed, natural language may suggest this multiplication of relations and eventualities. First of all, this could happen because a verb in the passive mode seems to stand for a relation that is the converse of the corresponding verb in the active mode. For example, "is kissed by" may be taken to stand for the converse of "kisses". Moreover, there are many relational terms that seem to be one the converse of the other. For instance, "on" and "under", "before" and "after", "greater" and "smaller". Yet, There is also a clear intuition to the effect that (1) and

(1/pass) Beatrice is kissed by Adam

stand for precisely the same eventuality, just as, say, "t1 is before t2" and "t2 is after t1" stand for the same fact. But this intuition is hard to capture if, for any predicate, we bring in a corresponding converse predicate.

3. *Enter o-roles*

In order to analyse and describe various grammatical and syntactic data that cut across different languages, linguists have postulated and appealed to certain syntactic functions, typically called *thematic roles*. Examples are *agent*, *patient*, *theme*, *source*, *goal*, *instrument,* and others. These functions are attributed to noun phrases occurring in sentences such as the ones we have seen above. For example, "Adam", "Beatrice", and "Carole" have, respectively, the source, goal and theme thematic roles in (2); and "Donald", "Nailie", and "Hammie" have, respectively, the agent, patient, and instrument thematic roles in (3).

We can successfully tackle the problems of the previous section, if we assume that there are corresponding o-roles and consequently appeal to symbols representing them in our formal language for ontology.

In order to handle the examples considered above, we need the following o-roles: agent, patient, source, theme, goal, instrument (I use for them the same words used for the corresponding thematic roles, assuming that the context will prevent misunderstandings). In the next section we shall see more precisely why we pick these o-roles for the examples in question. For the time being, let us appreciate how, by using them, we can provide a formal representation of relational attributions more perspicuous and efficient than the one provided by FOL. I shall assume for convenience the following abbreviations: "agt" for "agent", "pat" for "patient", "th" for "theme", "src" for "source", "instr" for "instrument".

In the notation that I wish to propose, we can represent the attribution of properties as in FOL and change the way we represent the attribution of a relation as follows: $R(r_1(a_1), \ldots, r_n(a_n))$, where R is a relational predicate term, which is not taken to have a fixed adicity, and each $r_i(a_i)$, which we may conveniently call an *enrolled term*, is such that r_i is an expression corresponding to an o-role, a *role predicate*, and a_i an argument term, whether a variable or a constant. With these conventions, the examples (1)-(4) of the previous section would be rendered as follows:

(1b) kiss(agt(a), pat(b));
(2b) give(src(a), th(c), goal(b));
(3b) hit(agt(d), pat(n), instr(h));
(4b) adjacent(th(a), th(b)).

It is important to note that the divergence from FOL mainly regards atomic formulas and the way in which natural language sentences that are considered as basic or atomic are to be translated into atomic formulas of our notation. Otherwise, one can rely on FOL as usual. Let us now see how the problems we noted in the previous section can be handled.

The first point to be noted is that, after having brought o-roles into the picture, the order with which we write the object terms need not be taken to have a significance to be made explicit by an *ad hoc* convention. Accordingly, two expressions A and A' should be considered equivalent, when A is of the form $R(r_1(a_1), \ldots, r_n(a_n))$ and A' results from A by rearranging the order with which the enrolled terms occur in the latter. We may call this the rule of *transposition*. Thus, for example, on the basis of transposition, (1b) is equivalent to

(1b/trans) kiss(pat(a), agt(b)),

which is to be understood as telling us that (1b) and (1b/trans) stand for the same eventuality. Similarly, the following can be taken to stand for the same eventuality:

(2'b) give(src(b), th(c), goal(a));
(2''b) give(src(c), th(b), goal(a)).[9]

With o-roles available, relational order and lack thereof are captured as follows. The former is simply the occurrence of different o-roles in the same fact, whereas the latter is the repeated occurrence of the same o-role in the same fact. For example, the eventuality represented by (1a) has relational order in that the agent o-role and the patient o-role occur in it, the former *with respect to* Adam, and the latter *with respect to* Beatrice; whereas the eventuality represented by (4b) lacks relational order in that the theme o-role occurs twice in it, once with respect to Adam and once with respect to Beatrice. We shall see in §5 how to cash out the idea that an o-role, *r*, occurs in an eventuality with respect to something, *x*, or, conversely and equivalently, that *x* occurs in the eventuality *as r*.

We noted that an eventuality can differ from another one in relational order, while having the same canonical constituents. This can be captured on the basis of the idea that arguments occur in a fact as having a certain o-role. To illustrate, consider the eventuality corresponding to (1'), which we represent as follows:

(1'b) kiss(agt(b), pat(a));

In this eventuality Beatrice occurs as agent and Adam occurs as patient. In contrast, in the eventuality represented by (1b) Adam occurs as agent and Beatrice as patient. And thus the two eventualities differ even though they have the same canonical constituents, namely, Adam, Beatrice and the loving relation.

Since in this notation there is no need to assign a fixed adicity to relation terms, a general rule that grants argument deletion can be easily assumed. It allows us to infer a formula of the form $R(r_2(a_2), \ldots, r_n(a_n))$ from one of the form $R(r_1(a_1), r_2(a_2), \ldots, r_n(a_n))$. On the basis of it (after taking advantage of the rule of transposition), (3b) implies

(3'b) hit(agt(d), pat(n)),

which in our notation corresponds to (3').

[9] We may take (1b) and (1b/trans) to express different propositions, just as we may take (1) and (1/pass) to express different propositions. However, to the extent that they are true, and thus there is an eventuality that makes them true, we should assume that they are made true by the very same eventuality. We could avoid the rule of transposition, if we legislated at the grammatical level that enrolled arguments may be written only in a certain order; if, for example, the order is alphabetic, then (1b/trans) is ruled out as ungrammatical, since "agt" precedes "pat" alphabetically.

A further advantage of the introduction of o-roles is that the problem of converse relations disappears. There should be no temptation to think that there are, e.g., two distinct relations, one corresponding to "kisses", and one to "is kissed by". Both predicates can be taken to correspond to a single kissing relation, typically associated to the o-roles agent and patient. The difference in using the active or the passive mode has simply to do with a difference in how the items playing these two roles are linguistically presented. In one case the agent item is introduced before the patient item; in the other case, it is the opposite and the term for the patient item is preceded by the preposition "by". Similarly, there should be no temptation to think that there are two distinct relations, one corresponding to "before", and one to "after"; or that there are two distinct relations, one corresponding to "sells" and another to "buys". The two pairs of terms should rather be taken to correspond to single relations, before/after and selling/buying. For reasons explained in the next section we may take source and goal to be the o-roles for items related by before/after; and source, goal and theme the o-roles for the seller, the buyer and the object that changes its owner, respectively.[10]

4. *Which o-roles should we acknowledge?*

As we have seen, o-roles help us capture similarities and differences across different facts: both a kissing and a hitting fact involve agents and patients, whereas an adjacency fact does not, and should rather be taken to involve another o-role. O-roles are then very much like universals, as the latter analogously capture similarities and differences across objects; for example, triangularity is instantiated by two triangular objects, but not by a circular object. Thus, the postulation of specific o-roles should be guided by the goal of acknowledging similarities that allow us to group together different facts, despite their involving different relations and arguments. In an effort to compile an appropriate inventory, a good starting point is provided by the thematic roles introduced by linguists and thus it makes sense to assume that there are o-roles corresponding

[10] It may be moot in some cases whether or not one should deny that there are two distinct relations corresponding to the two members of such pairs. For instance, Parsons (1990: 84) has argued that, when somebody sells and correlatively somebody buys, we need distinguish a selling fact and a buying fact, since, say, the selling is done with regret, and the buying with joy. It seems to me however that the reasons that may *prima facie* incline us towards such distinctions can usually be explained away with appropriate analyses. We could say, e.g., that the source and the goal of the selling/buying in question are, respectively, regretful and joyful. By allowing for adverbial modifiers of the o-role expressions, we could express this as follows: selling/buying(regretful-src(x), th(y), joyful-goal(z)). Of course, we need special axioms governing the use of such modifiers, but we set aside these formal details here.

to the most important and general thematic roles. However, in an attempt to capture similarities, I would like to understand them in a most general fashion, typically going beyond the level of generality that is usually recognized by linguists. In particular, I shall take for granted that there are the o-roles considered in the previous section, understood as in the following table:

NAMES AND EXAMPLES	EXPLICATION
Agent. *John* loves Mary. Mary was encouraged by *Tom*. *Tom* and *Mary* lifted the table. *The stone* broke the window. The door was opened by *the wind*.	Participant whose activity is causally responsible for the coming to be of the eventuality. It may be animate and exerting conscious control over the eventuality or inanimate such as a machine or a force.
Patient. John loves *Mary*. *Mary* was encouraged by Tom. Tom and Mary lifted *the table*. The stone broke *the window*. *The door* was opened by the wind.	Participant somehow affected by the activity of the agent or agents involved in the eventuality.
Instrument. John opened the can with *a screw*.	Tool that helps the agent to perform an activity.
Location. Tom is in *Paris*. The meeting took place in *January*. *Tom*'s heart is beating regularly. *Mary*'s ring is beautiful.	Place where a participant is located; time of an eventuality; whole comprising a part; possessor of an object.
Theme. *Tom* is in Paris. *The book* and *the box* are adjacent. *The box* and *the vase* are at a certain distance. *Tom* and *Mary* are married. *The meeting* took place in January. Tom's *heart* is beating regularly. Mary's *ring* is beautiful. *Tom* went to New York. *The ring* was given to Tom.	Participant at a location (broadly understood, e.g., part of a whole, occupant of a social or legal role) or participants having respective locations; participant undergoing a change of location.

Source. *Tom* went from Paris to New York. *January* is before February. *The accident* caused the injury. Tom's *weight* is more than Mary's weight. *Mary* gave the ring to Tom. Carole is an offspring of *Adam* and *Beatrice*.	Starting point of a change of location or of a real or ideal path somehow involving a direction, whether spatial, temporal, causal, social or legal, or from lesser to larger amount.
Goal or destination. Tom went from Paris to *New York*. January is before *February*. The accident caused *the injury*. Tom's weight is more than Mary's *weight*. Mary gave the ring to *Tom*. *Carole* is an offspring of Adam and Beatrice.	Location toward which a change of location is directed. This is understood in a most general sense, just as for source.

This list is not meant to be exhaustive. Linguists have individuated many other thematic roles and presumably for at least some of them it makes sense to postulate corresponding o-roles. Moreover, there may be o-roles that have no corresponding thematic roles in current linguistics. All this need to be further investigated. Here however I shall focus on another important issue. There are many relational facts for which it does not seem possible to find appropriate o-roles in the above list or in any extension of it based on the inventories of thematic roles typically produced by linguists. Such facts might then suggest an unduly proliferation of rather idiosyncratic o-roles, anchored to the very relations, or at least relations of very similar kinds, that suggest their introduction. This should not be welcome in the light of the leading idea behind the recourse to o-roles, namely that they allow us to capture similarities across facts involving different relations.[11] It seems to me however that in these cases, these idiosyncratic o-roles can be avoided if the facts in question are appropriately analysed. I shall illustrate this with a few examples, although the problem deserves a more thorough investigation.

[11] For example, in Parsons 1990 we find o-roles such as on, onto, into, under, etc. And I myself (Orilia 2011) have considered idiosyncratic o-roles of this sort.

Let us go back to our friends Adam, Beatrice and their little daughter Carole, and suppose that there are some facts involving them that correspond to these statements:

(5) Adam is husband of Beatrice;
(6) Carole is to the left of Adam;
(7) Carole is on Adam;
(8) Carole moves from under Beatrice onto Adam.

In all these facts the participants are not involved in the same way and thus we seem to need distinct o-roles to account for this. For example, Beatrice is not Adam's husband; Adam is not to the left of Carole, and so on. But which o-roles should we appeal to? For lack of more general o-roles that seem fit, one may be tempted to introduce *ad hoc* roles and represent the facts in question along these lines:

(5a) married(husband(a), wife(b));
(6a) aligned(left(c), right(a));
(7a) adjacent(on(a), under(a));
(8a) move(agt(c), under_source(b) on_goal(a)).

I shall now show how appropriate analyses can avoid the postulation of o-roles of this sort. As regards (5), we can assume that there is a symmetric relation of being married that does not induce relational order and for which we can use the theme the o-role, and then rely on the fact that a husband is male:

(5b) married(th(a), th(b)) & male(a).

As regards examples (6)-(8), it is important to appreciate that the facts in question involve objects that, presupposing the earth's surface as a reference point, are either horizontally or vertically aligned. Let us then assume that there are relations such as being horizontally or vertically aligned, with theme as o-roles, since the objects related by them are taken to be located in space somewhere. As regards (6), we should also note that, in seeing pairs of objects as related in such a way that one is to the left of the other, we are presupposing the existence of left and right parts of the relevant individuals, parts which may accordingly be said to have the properties *lefter* and *righter*, respectively. Recall further that the table of §4 proposes that (i) the source and goal o-roles be used for the directionality going from a lesser to a greater amount, and (ii) the theme o-role be used for distance relations. This is relevant since we can take (6) to tell us something like this: a and b are horizontally aligned and the distance between Carole and the left part of Adam is less than the distance between Carole and the right part of Adam. In symbols:

(6b) hor_align(th(a), th(b)) & $\exists x \exists y \exists D \exists D'$(part(th(x), loc(b)) & lefter(x) & part(th(y), loc(b)) & righter(x) & D(th(a), th(x)) & D'(th(a), th(y)) & <(src(D), goal(D'))).

Consider (7) now. In order to properly analyse the corresponding fact we should recall that, when an object, *x*, is on another object, *y*, they are vertically aligned and touch each other, i.e., they are adjacent; but they can be distinguished in that one is nearer than the other to the earth surface (and typically touches such surface). Thus, (7) can be understood along these lines: Carole and Adam are vertically aligned, adjacent, and the distance between Adam and the earth is more than the distance between Carole and the earth. In symbols:

(7b) vert_align(th(a), th(c)) & adjacent(th(a), th(c)) & $\exists x \exists D \exists D'$(D(th(a), th(e)) & D'(th(c), th(e)) & <(src(D), goal(D))).

Let us turn to (8). We can avoid *ad hoc* o-roles such as from_under and onto, if we understand the fact represented by (8) as involving in turn two other facts and a passage from one to the other; one is a state consisting of Carole's being under Alice and the other is a state consisting of Carole's being on Adam. In the light of what we said above, the latter is to be represented by (7b) and the former by: vert_align(th(c), th(b)) & $\exists x \exists D \exists D'$(D(th(a), th(e)) & D'(th(c), th(e)) & <(src(D), goal(D'))). Let us conveniently represents the two facts in question with two simple terms, "s1" and "s2". Then, the appropriate representation of (8) is:

(8b) move(src(s1), goal(s2)).

5. *What are o-roles?*

O-roles are typically viewed as relations between eventualities of a certain kind, say of the kiss or give kind, and participants in such eventualities (Parsons 1990). With this way of seeing the matter, (1) and (2), for example, would be rendered as follows:

(1c) $\exists e$(kiss(e) & agt(e, a), pat(e, b));
(2c) $\exists e$(give(e) & src(e, a), th(c), goal(e, b)).

If we follow this road, we could take the notation that I have proposed above as merely abbreviatory. Thus, for example, (1b) and (2b) would simply be shorter ways of writing (1c) and (2c), respectively. I see however two main problems with this proposal.

First, this way of looking at things suggests to us that when, e.g., John hits Tom with a certain knife, k, there is a single hitting eventuality, e, which has

John as agent and Tom as patient, and, in addition, is such that k is an instrument in it. However, we may have reasons to distinguish between *two* eventualities, one, e1, which is simply a hitting which has John as agent and Tom as patient; and another, e2, which has John as agent, Tom as patient, and k as instrument. For suppose that, since Tom was hit, he moves and, since he was hit with a knife, he bleeds. We may want to say that it is e1, and not e2, that causes Tom to move, for Tom's moving would have occurred even if the hitting would have been performed without a knife. On the other hand, we may want to say that it is e2, and not e1, that causes Tom to bleed, for Tom's bleeding would not have occurred if the hitting had not been performed with a knife. And thus e1 and e2 cannot be the same event.

Second, this approach does not solve, but merely postpones, the problem of understanding what relational order really is. For it assumes that there are relational facts such as agt(*e*, a) or pat(*e*, b), which appear to have relational order; if o-roles are relations, undoubtedly they are non-symmetric relations, and one may be tempted to say, e.g., that *e* and a have different o-roles that in the fact agt(*e*, a).

I am thus more inclined to conceive of o-roles in a different way. The idea is to view them as *sui generis* properties that objects exemplify by virtue of exemplifying a certain relation. For example, when Adam kisses Beatrice, Adam exemplifies kissing in a certain way, as agent, and Mary in another way, as patient. So that, when Adam kisses Beatrice, by the same token Adam is an agent and Beatrice is a patient. In this approach we can take the notation proposed in §3 at face value. That is, we take $R(r_1(a_1), r_2(a_2), \ldots, r_n(a_n))$ as perspicuously representing a certain fact, which is an exemplification of R by $a_1, a_2, \ldots, a_n$ (which occurs in such a way that the following monadic facts also occur: $r_1(a_1)$, $r_2(a_2)$, …, $r_n(a_n)$). The relational fact in question is different from, say, the one represented by $R(r_2(a_2), \ldots, r_n(a_n))$, which is instead an exemplification of R by $a_2, \ldots, _n$. The latter fact may be seen as a "smaller" fact somehow "contained" in the former. With this approach, we can distinguish the event e2 that causes Tom's bleeding, namely hit(agt(j), pat(m), instr(k)), and the event e1 that causes Tom's movement, namely hit(agt(j), pat(m)). Moreover, we need not deal with further relational facts such as agt(*e*, a) or pat(*e*, b), which may induce the introduction of additional o-roles. Or we could view facts such as agt(*e*, a) or pat(*e*, b) in a different way, by taking the monadic facts consisting of the exemplification by an object of a certain o-role to be constituents of relational facts. In this perspective, for example, "agt(*e*, a)", could be understood along these lines: constituency (th(agt(a)), loc(*e*)).

6. *Conclusion*

I have argued that relational facts are best understood by invoking very general o-roles that allow us to capture similarities across different relational facts, without taking for granted that o-roles are themselves relations involved in additional relational facts. In doing this, I have dwelled on a number of paradigmatic examples that have led me to some tentative proposals regarding which o-roles should be postulated and how they should be deployed in understanding specific relational statements. A large and possibly cooperative research effort is needed to go beyond the merely programmatic intents of this paper, so as to ensure (i) a comprehensive list of precisely understood o-roles over which there can be widespread agreement in the ontological community at large, and (ii) the requirement of semantic transparency for a formalism that employs o-roles in the way that I have suggested.

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