

Relations among Roles

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Abstract

In this paper we discuss the possible types of relationships between participant roles in related situation types. We first discuss principles that might determine which roles are present in one type of situation, given the roles present in a related type of situation. While no simple general rules seem to exist, there are useful rules for particular cases. In addition, we discuss how relationships between roles themselves parallel relations between other elements in ontologies. Apart from the subrole relation, we consider relations analogous to meronymy and antonymy, which are rare in the domain of roles, and a complementarity relation between roles, which is fairly common.

1. Introduction

How are participant roles in one type of situation related to the roles in another? What implications do the relations between roles in different situation types have for the relations between other elements of ontologies? We will focus here on two topics that bear on these issues. First, we discuss which principles might determine, given the set of roles appropriate for one situation type, which subset of those roles are appropriate for a second, related situation type. Second, we examine the extent to which relationships between roles parallel those we find between other kinds of elements in ontologies.

2. Goals and assumptions

The way we have described the two topics above presupposes certain characteristics of an ontology (or related resource such as WordNet). We first briefly present these assumptions here, and pose the more detailed questions that we will address in this paper.

2.1. Participant roles, situation types, and hierarchies

We view participant roles for present purposes as relations between an entity and a situation.¹ Thus we will often refer to the entity as a participant in the situation.² We also assume that for each role there can be type restrictions on the kinds of entities and situations that are appropriate arguments for that role. A *perceiver* role, for instance, is restricted to sentient entities in perception situations. This in turn rests on the assumption that situations and entities can be grouped into types, a strategy that has proven fruitful as a central organizing principle in many ontologies (e.g., the Cyc ontology, the SENSUS ontology, Mikrokosmos, the ontology developed in Sowa (2000), and numerous more specialized

ontologies). Here we assume that types of entities and situations are hierarchically arranged, with multiple inheritance permitted (multiple inheritance is pervasive in the Cyc ontology but rare in WordNet).³

2.2. Subroles

In part because roles have type restrictions on the entities and situations that can serve as their arguments, it is reasonable to talk of subroles. One advantage of structuring roles in this way is that we can provide for arbitrarily specific roles for situation types anywhere in the situation-type hierarchy, while maintaining very general roles, which prove useful, for example, in stating the linguistic regularities in linking from semantic roles to syntactic arguments of predicates. The type restrictions on a subrole's arguments must be at least as restrictive as those on its super-roles. In addition, it is natural to assume that a participant playing a role in a situation also plays all of its super-roles:

$$(1) \quad R \subset R' \text{ implies } \forall x,e: R(x,e) \rightarrow R'(x,e)$$

This entails a homomorphism under subsumption from the hierarchy of situation types to the hierarchy of roles, and from the hierarchy of entity types to the hierarchy of roles. The reverse implication—that all roles R and R' for which the condition on the right hand side of (1) holds are in the subrole-/super-role relation—is less obvious. This is an issue we briefly touch on below.

2.3. Role projectability between situation types

In section 3, we examine the problem of role projectability; that is, what principles and structures in an ontology determine, given the set of roles appropriate for one situation type, the set of roles of a related situation type. For example, are there any general statements we can make about the roles in subsituations, given the roles

¹ We use the term *situation* to speak of events and states. An event type is merely a situation type whose instances are events.

² We will not delve into the question of whether the entity actually must exist, or if it does, must temporally and spatially overlap the situation.

³ Examples from the Cyc ontology are from the OpenCyc release of April, 2002, which can be examined or downloaded at www.opencyc.org. Version 1.7 of WordNet can be obtained from www.cogsci.princeton.edu/~wn/.

in a situation? This is particularly important in cases where it is debatable whether to analyze one situation type as a subtype of another or the second as a subsituation of the first (for instance, is *eating a meal* a subtype of *eating*, or is it better analyzed as containing a subevent of eating, along with other subevents such as serving oneself, and if the latter is the preferred analysis, how do the roles of the eating subevent project to the roles of eating a meal?). Another set of cases involves groups of similar situations, such as a group of *walking* events, for which we might wish to project some roles but not others. Finally, we also consider the interaction of role projectability and multiple inheritance.

We can classify projectability issues along three dimensions, as shown in the following table:

	situations	entities
type-level	sub/super-types of situations	sub/super-types of entities
individual level	sub-situations/super-situations	sub-entities/super-entities

Thus we can examine, for example, whether roles appropriate for a particular type of situation are appropriate for any subtypes of it, or we can examine whether a role played by a particular entity in a situation is also a role played by entities of which it is a part. Type-level projection is concerned with generalization and specialization relations between types (or hypernymy and hyponymy relations in lexical resources like WordNet), while individual-level projection is concerned with mereological (or meronymic) relations between individual situations and entities. One straightforward case is that of roles projecting from situation types to their subtypes, which is entailed by (1). We will not examine all of the possible options for projecting roles here (some of them are highly implausible in any case), but the table helps to situate the issues we examine in sections 3 and 4.

2.4. Parallelism in relations between roles and relations in other elements of ontologies

Often independently of concerns about the relations between concepts, scholars in linguistics and philosophy have been concerned with determining and classifying the roles of participants in situations. When situations and entities are arranged in type hierarchies, it is natural to inquire whether participant roles can be similarly arranged (see, among others, Parker-Rhodes (1978), Ostler (1979), Somers (1987), Lehmann (1997), and Sowa (2000)). In addition to subtype-supertype relations, however, we also find other types of relationships frequently modeled in ontologies. This leads to our second objective, which is to compare the structures of the participant role hierarchy to the other two. To what extent does the role hierarchy parallel the others, and which relationships commonly posited among situation and object types are applicable to roles as well? This will be discussed in section 4.

3. Some cases of role projectability

In this section we consider three cases of role projectability between situations and subsituations. The first concerns the case of a situation that can be regarded as composed of a group of situations of some common

type. We suggest that roles of the group situation can be systematically related to those in the subsituations; the latter are subroles of the former. We next examine a more general case motivated by Lehmann's (1998) discussion of situations and roles, in which multiple inheritance in the situation-type hierarchy is pervasive. We argue that freely allowing this kind of multiple inheritance creates complications for the role system and should probably be constrained more than Lehmann envisions, or recast as a form of embedding the parent situation types as subsituations in another type rather than as multiple inheritance. Finally, we note the case of related telic and atelic situation types, which seems to require projection of roles from situations to subsituations, rather than inheritance from situation types to subtypes.

3.1. Groups of events of a common type

One frequent case of situations and subsituations is that of a group of situations of a given types, treated as a group, which itself can be regarded as a situation. This kind of operation is frequently represented in ontologies; Cyc's *GroupFn* is one example.⁴ What can we conclude about the roles in the group situation, given the roles in its elements? One possibility is that they are identical. But this seems problematic. Suppose that the role *R* is defined for the situation type of the group's elements, and that in the group event *g*, the participant playing *R* is the mereological sum of all the participants playing role *R* in each of the elements of *g*. We will write this as $R(y,g)$, where *y* is the sum of the individuals playing this role in each of the elements. This is simply a case of the *cumulativity* or *summativity* property of roles (Krifka, 1992, 1998). While for some roles this is a reasonable move, it vitiates the definition of others. It may not cause any difficulties, for example, to regard a group of children running around a playground as the collective *agent* in a group *running* event. However, the *path* role in such an event is a discontinuous set of trajectories, while for a single child running, and for motion of a single body in a continuous time interval generally, the trajectory is continuous. This property of paths is important to maintain; Krifka's (1998) analysis of telicity in motion event relies on it, for example. Another example concerns *source* and *goal* roles in groups of motion events. It is useful to have a rule that either the *source* and *goal* of a motion event are distinct locations, or that the *moving object* has not changed its position (if the motion is a complete revolution in a circle, for instance). But this rule will not apply to groups of motion events; two runners might exchange places, each ending up in the other's starting location. The *source* and *goal* would then be identical in the group event.

A more palatable alternative is to assume that for every role *R* such that $R(x,e)$ for some *x* in each element *e* of *g*, there is a super-role of *R*, *R'*, such that $R'(g,y)$, where *g* and *y* are the mereological sums, as above. These super-roles can have some of the properties of the original roles but need not have all of them. For example, the super-role of the *path* role could have discontinuous trajectories as its

² This represents some kinds of group situations adequately, but not all. Situations involving joint action or intent, for example, are not always readily decomposed into subsituations of a closely related type.

value, and those of the *source* and *goal* roles would have weaker distinctness conditions. At the same time, nothing precludes using the original roles to describe a situation that can be regarded both as a group of subsituations and as a single situation of the same type as those subsituations; in this case the same participant (a group of entities) will play the role *R*, and hence *R'*. A potential drawback to this approach is that, if we adopt the definition of subrole in (1), we are then committed to treating the type of groups of situations of type *S* as a supertype of *S* (the two types could be identical in some cases, such as at the top of the situation-type hierarchy). However, we see no obvious problems with this move, although this condition is not typically found in ontologies.

3.2. Multiple inheritance and roles

When a situation type is a child of more than one parent type, there are two possible outcomes with regard to the roles in the parent types. One is that two roles from two parent types merge, so that a single participant in an instance of the child type plays both of these roles. From two parent situation types such as *eating in a restaurant* and *eating breakfast* we can construct a type inheriting from both, *eating breakfast in a restaurant*, in which the eater and eaten roles of both parent types are merged; that is, there is a single eater participant and a single eaten participant in a situation of *eating breakfast in a restaurant*. In this case, the roles in the child type must be subroles of the roles in the parent types. This is represented graphically in Figure 1.

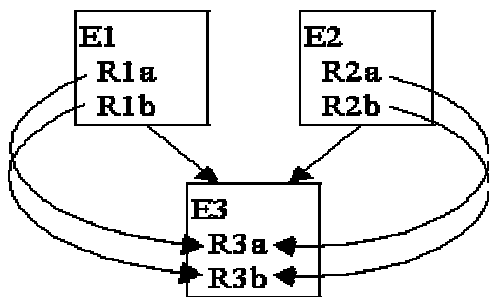


Figure 1. Merged roles in situation-type inheritance

A second possibility is that a role from one parent type does not merge with any other role, remaining distinct in the child type. In Cyc, for example, the type *CausingAnotherObjectsTranslationalMotion* is a subtype of *Movement-TranslationEvent*, which has the roles *objectMoving* and *trajectory*) and of *ActionOnObject*, with the roles *doneBy* and *objectActedOn*. The trajectory and *doneBy* roles remain distinct in the child type. As for the participant that is caused to move, it plays the roles of *objectActedOn* and *objectMoving* in an instance of *CausingAnotherObjectsTranslationalMotion*, but these two roles are not necessarily merged. There is no role reified within the Cyc system that inherits from these two roles. Instead, a rule states that the same participant plays both roles in situations of the type *CausingAnotherObjectsTranslationalMotion*. This second possibility is shown in Figure 2.

This has some implications for some of the ontological structures in Lehmann (1997). Lehmann exemplifies a situation-type hierarchy with increasingly complex types that inherit from multiple parents. For example, there are event types labeled “father gets harmed and angry child then gets revenge”, a subtype of the situation types “father gets harmed” and “an angry child gets revenge”.⁵ Now if roles are inherited from types to their subtypes, this implies that the child type has all the roles of its two parent types. If this kind of type construction is fully productive in the situation-type hierarchy, however, it leads to the uncomfortable conclusion that roles always project from subevents to the events they are part of, since each conjunct can be considered a subevent. Consider the example of taking a trip in a car. We define event types of unlocking a car and driving a car in our hierarchy; the former type has a key as an instrument. Now we define the type of taking a trip in a car, inheriting from these two types of unlocking and then driving a car. By inheritance, this type also will have a key as an instrument, which is the undesirable situation we encountered above. This issue becomes particularly acute when there are two participants in the complex event type that are assigned the same role as a result of inheritance. Consider an event of taking dictation, where one person is reading aloud and another is copying down the words. The reader or writer in the parts of this event can both be considered agents, but we will certainly wish to distinguish these two roles in taking dictation. One solution here, of course, is to provide distinct, more specific roles, such as *reader* and *writer*. But this strategy is not always available; when two events of the same type are combined, the roles in the resulting type will be the same. As an example of this, picture a situation where two people compare versions of a text by having one read aloud and then the other, or a “call and response” situation where one person echoes another’s words.

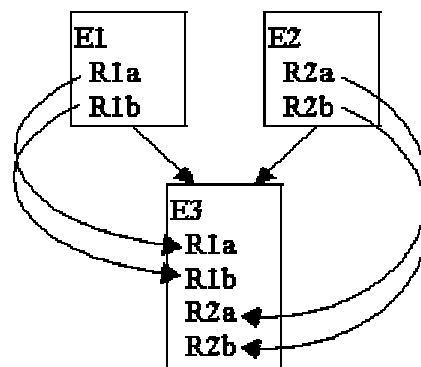


Figure 2. Distinct roles in situation-type inheritance

We could circumvent these problems in several ways. One is to postulate distinct roles for each situation type. Thus a key would play a role in the complex event type just mentioned, but it would not be the same role that it plays in the simpler subevent *unlocking a car*. This

⁵ We disregard here the issue of how the temporal order of these two events in the subtype is specified. There must be some mechanism for doing so, however, since the reverse temporal order would describe a very different type of complex event.

allows us to be fully productive in creating complex situation types, at a cost of complicating our system of roles considerably. The number of roles is obviously indefinitely large, as the potential for creating successively more complex event types is unlimited, and there remains a problem of determining when two roles are necessarily filled by the same participant. For instance, a subtype of *unlocking a bicycle* is *unlocking a bicycle that is locked with a Kryptonite lock*. We can classify an instance of such an event in either fashion. This subtype has a distinct role for the key, but we want to equate the roles in the two event types, rather than worrying about whether there are two distinct keys. This representation, in which there are 4 roles, but only two participants, is shown in figure 3.

The large number of roles, and their uniqueness to individual situation types under this option, might become more palatable if we adopt a feature-based analysis of roles, along the lines of Somers (1987), Ostler (1979), Parker-Rhodes (1978), or Sowa (2000). From a linguistic standpoint, for instance, something like such features would be needed to account for regularities in the mapping from roles to syntactic arguments of verbs and nominalizations (see Dowty (1991) and Wechsler (1995) for similar accounts that can cast in a feature-based model). But in some sense we have merely shifted the problem from projectability of roles to projectability of features. If the features of a key as an instrument in unlocking a car are projected to its role in driving, why is it so odd to say that “we drove to the store with the key”?

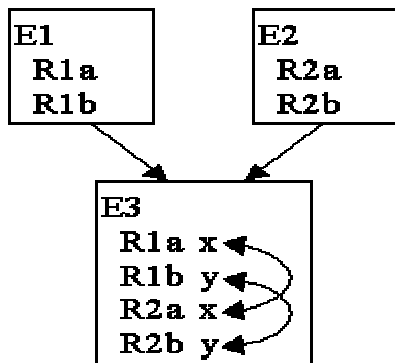


Figure 3. Distinct roles, shared by identical participants in subtype

Another option would be to structure the set of roles more richly, so that both sets of roles are inherited in a complex event, maintained as two separate structures (with additional roles potentially added as well). This option is in the spirit of feature structure representations, in which structures can be embedded recursively (Lehmann may allude to something similar when he refers to "structural specification"). A representation of this kind, in which the role-sets of the parent events are embedded within new role features in the child event, is shown in figure 4. The roles *R3a* and *R3b* within *E3* are filled by subevents; they might be relations such as *cause* and *effect*, for example. This allows roles to be inherited, albeit in a non-uniform way, which depends on how the parent situation types are combined in the child type.

Furthermore, it is necessary to specify when a single participant fills roles in each part of the situation. In the type “father gets harmed and angry child then gets revenge on perpetrator”, the same individual (the perpetrator) plays a role in both subevents.

Yet another approach would be to restrict the situation-type hierarchy to a set of types for which role inheritance makes sense. The trouble with this is that it seems too restrictive for many purposes. We sometimes do wish to refer to “composite” event types, like commuting to work on a bicycle, moving from one city to another, or holding a presidential election. But some kind of compromise position may be possible. We might maintain the kind of role inheritance that appears useful by designating one parent type as the “principal type”, whose roles are inherited. For commuting by bicycle, the principal parent might be something like riding a bicycle, and the roles of the bicycle, the rider, the origin, and the destination would be inherited. Other, “minor” events involved in commuting, like locking and unlocking the bicycle, would not be involved in role inheritance. A subgraph of the hierarchy of situation types, filtered by “main event” or “principal type”, links might be homomorphic to the role hierarchy. This approach seems reasonable for many of the situation types that we would be likely to reify in an ontology. It may apply less well to elaborate and complex events with many participants, such as political elections, which have many specialized roles, and would not necessarily inherit many of them from their parents representing their subevents. In some of these complex event types, the notion of a “main event” might not make much sense.

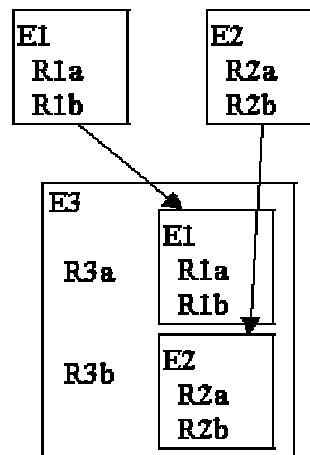


Figure 4. Embedded role-sets in subtype

From a linguistic standpoint, multiple inheritance in the situation-type hierarchy interacts with issues of linking; that is, the syntactic realization of predicates and their arguments. Subject selection is one good example; verbs denoting commercial transactions refer to situations in which there are two *agents*, as do causative verbs in the many languages that allow causativization of verbs denoting agentive situations. In each of these cases an accurate account of subject selection must appeal to more than the agentive status of a participant, since more than one participant plays an agentive role (see (Dowty 1991), (Wechsler 1995).and the Framenet system developed by

Fillmore and others for some approaches to this problem). Designating one of the subevents as the “main” or “salient” event for linguistic purposes, as in Framenet, accords well with the foregoing suggestion, although linguistic evidence is only a rough guide in these matters.

3.3. The inheritance of properties

One final issue regarding roles and subroles concerns how strictly we wish to enforce inheritance of properties. The OntoClean proposals of Guarino and Welty (2002), for example, place high importance on transmitting various properties dependably in inheritance. For instance, they argue against a pervasive characteristic of Cyc, that individual object types commonly inherit from the stuff types of which the objects are composed (thus *Ocean* is a subtype of *Water* in Cyc). When we examine the comparable situation in the realm of situations, we are led to the conclusion that telic situation types, such as eating an apple or painting a wall, should not be regarded as subtypes of atelic types such as eating or painting. The latter types are cumulative: two eating events may be combined and treated as a single eating event, but two events of eating an apple cannot be regarded as a single larger event of eating an apple.⁶ This suggests that, parallel to the object and stuff types, telic and atelic event types should not be in a subtype-supertype relationship. If so, then telic event types will not inherit the roles of corresponding atelic event types. Instead, we could adopt a projectability rule that states: if *e* is an event of telic event type *T*, and *T* is “composed” of events of atelic type *A* (just as oceans are composed of water), then *e* also has those roles. In some cases, there may be no roles specified for events of type *T*, independently of type *A*. In others, such as many telic movement event types, additional roles are present, including *source* and *goal* roles.

In this case, then, we are led to a conclusion that is roughly the reverse of what we advocated in the case of groups of situations. For group situations, a consideration of roles for the group and for the subsituations comprising it led us to suggest that the group situation type is a supertype of the type of the elements. For the case of atelic and telic situation types, which might initially appear to be in a supertype-subtype relation, a re-examination of this assumption leads us to posit projection of roles from (atelic) subsituations to (telic) situations.

In sum, we see that there are unlikely to be simple general principles regulating the projection of roles between situations and their sub- or super-situations, although there do appear to be some useful, more specific principles covering some cases of interest.

4. Parallelism between roles and other elements in ontologies

In this section we explore what parallelisms may exist between the hierarchy of participant roles and other types of ontologies. Besides supertype-subtype relations, mereological relations are crucial in ontologies and in lexical resources like WordNet. Lexical resources also

frequently employ an antonymy relation between words, though it is less clear that this is coherent ontological relation and ontologies emphasize this much less. In this section we will investigate to what extent these other relations can be applied to roles. In doing so, we will continue to mention issues of role projectability, this time with respect to entities and their parts.

4.1. Specialization/generalization (hyponymy/hypernymy)

Concept specialization is represented in WordNet with hyponymy links, and in Cyc with the predicate *genls* (and some extensions of it for relations). These apply both to entity types (or nouns in WordNet) and situation types (or verbs in WordNet, which then refers to this relation as “troponymy”). The comparable relationship for roles is simply the subrole relation; if one role is a subrole of another, then any participant that plays the first role in a situation necessarily also plays the second. This is the chief organizing relation for the hierarchy of roles, as it is for object and situation types.

However, we would like to remark here on one more linguistically relevant issue, since much of this same machinery is brought to bear on computational lexicons, including WordNet. Because the mapping from semantic roles to syntactic arguments is not completely semantically determined and displays some arbitrary variation, we cannot assume that hyponyms of a verb will exhibit the same mapping as that of the verb itself. In some cases, for example, an argument is incorporated in the verb (e.g., “spread butter on the bread” vs. “butter the bread”, “put the money in the pocket” vs. the “pocket the money”). In others, the mapping is simply different (e.g., “eat oysters” vs. “dine/gorge on oysters”). This means that syntactic patterns are not necessarily reliable indicators of participant roles, and although hyponymy usually does imply inheritance of participant roles, corresponding roles may not occupy corresponding syntactic positions.

4.2. Partial roles (meronymy/holonymy)

Meronymy/holonymy, the lexical part/whole relation, and other mereological relations in ontologies, appear to be more complex, with several discernable subtypes. For example, Winston, Chaffin, and Hermann (1988) differentiate seven types of meronym: component-object (branch/tree), member-collection (tree/forest), portion-mass (slice/cake), stuff-object (aluminum/airplane), phase-process (adolescence/growing up), feature-activity (paying/shopping), and place-area (Baltimore/Maryland). Iris, Litowitz, and Evens (1988) acknowledge only four, however: functional part (wheel/bicycle), segment (slice/loaf), member (sheep/flock) and subset (meat/food), which is really specialization rather than meronymy. Likewise Cyc distinguishes numerous part/whole relations, including ingredients, physical and abstract parts, and subevents. The WordNet hierarchies employ just a single meronym link type, used only in the noun hierarchy. Meronymy applies just as usefully, however, to situation types (or verbs in WordNet), as we have been assuming throughout this paper. The type of meronymy called “phase-process” by Winston, Chaffin and Hermann

⁶ Note that one and the same event can be regarded as both atelic or telic; eating an apple is certainly also eating. The telicity distinction is at the situation-type level, not at the individual level.

(1988) relates pairs of nouns and gerunds such as *adolescence/growing_up*. Feature-activity meronymy relates pairs of gerunds such as *paying/buying* or *steering/driving*. In short, events can be said to have component parts just as objects have them. The analogy to meronymy in the domain of participant roles is much less obvious than the specialization parallel, however.

We can begin by offering a definitions of “partial roles”, as a mereological counterpart to the definition of subroles in (1):

- (2) R' is a partial role of R iff:
 $R(x,e) \rightarrow \exists x',e': x'$ is a part of x and e' is a subsituation of e and $R'(x',e')$

Unlike physical part and subsituation relationships, which are ubiquitous and obviously crucial to ontologies, there are relatively few instances of roles in this relationship that we are aware of, beyond the trivial case where $R = R'$, $x = x'$, and $e = e'$. Two cases are exemplified in the following sentences, where the participant denoted by the object of ‘with’ or ‘by’ is a part of another participant. Thus the “instrument” role is a partial role of *agent* in a. and the “body part” role is a partial role of the *grabbed* participant (or *theme*, or *affected object*) in b:

- (3) a. I bumped the vase with my elbow.
 b. I grabbed the iguana by the tail.

A third case of partial roles involves the *moving object* in movement events. In such events the parts of the object also move during at least some subintervals of the event, so the role *moving object* is partial to itself in a non-trivial way. In a parallel fashion, some roles in states are non-trivially self-partial. If someone owns a car for a year, that person owns the engine for the first six months, and if a beam supports a roof for a year, it is plausible to infer that a section of the beam supports a section of the roof for any period within that year.

Despite these cases, it appears that this type of part/whole relationship between roles is rare, and not particularly useful in inference. Possibly this is due to the relational character of roles, mediating between situations and their participants. We will now consider a more widespread phenomenon, the projection of role from participant entities to larger entities of which those participants are parts.

4.3. Projection of roles from entities to super-entities

We now examine the question of which roles can be projected from parts to wholes and vice versa; that is, if an object plays a role in a situation do larger objects of which it is a part and smaller objects that are parts of it also play that role in the situation? It should be clear that when this is the case, the role in question violates Krifka’s uniqueness of objects property (Krifka 1992, 1998). Two kinds of roles for which this does seem to be true are roles of *source* and *goal* in motion events. For example, the following inferences seem valid:

- (4) I flew from Baltimore to Boston. therefore,
 I flew from Maryland to Boston. and

I flew from Baltimore to Massachusetts.

This inference has limits, in that the super-region cannot include both the origin and the destination of the trip, however, so the following are aberrant:

- (5) #I flew (from the U.S.) (to the U.S.) and,
 #I flew from the U.S. to Boston. and,
 #I flew from Baltimore to the U.S.

The *path* role, in contrast, can be projected down to parts of the trajectory, but not to larger paths:

- (6) Kim hiked (all of) the John Muir Trail. therefore,
 Kim hiked the Tahoe-Yosemite Trail.

As Krifka (1992, 1998) has pointed out, we can make similar inferences from parts to wholes in the case of roles that involve contact or perception, as the following examples illustrate:

- (7) John touched the door handle. therefore,
 John touched the door.
 (8) Kim rammmed Sandy’s bumper. therefore,
 Kim rammmed Sandy’s car.
 (9) The jar contacts the countertop. therefore,
 The jar contacts the counter.

Note also that in situations involving both motion and contact, the contact inference is allowed even if the motion is not:

- (10) I shook a link of the chain. therefore,
 I touched the chain (even if I didn’t shake it).

As for roles involving perception, the same pattern seems to apply, though the inference seems less solid:

- (11) Fred saw the elephant’s trunk. therefore,
 Fred saw the elephant.
 (12) Alice smelled the roasted chicken. therefore,
 Alice smelled the meal.

As the story about the blind men and the elephant suggests, however, there is some uneasiness about such inferences. Perception differs from contact in this respect.

Finally, there are situation types in which one participant stands in a relationship of superiority to another, denoted by verbs such as ‘exceed’, ‘surpass’, ‘dwarf’, and verbs prefixed with ‘out-’. In these cases, it arises virtually a matter of definition that the superior participant’s role projects to objects of which it is a part, and the inferior one’s role to its parts. This is exemplified in the following sentences:

- (13) Nitrous oxide levels exceeded the Federal standards. therefore,
 Smog levels exceeded the Federal standards.
 (14) Bach outlived Vivaldi. therefore,
 The Bach family outlived Vivaldi.

- (15) Russia dwarfs Korea. therefore,
Russia dwarfs North Korea.

There are many roles for which projection to parts or wholes does not follow, except in some metaphorical or metonymic sense, including most roles involving agency, motion, and affectedness. In sum, “spatial” roles (including those that are appropriate for situation types whose linguistic realization is metaphorically based on spatial relationships) exhibit some projection properties that should prove useful in inference. But there is no direct parallel among roles to part/whole relationships of the type that apply ubiquitously to entities and situations.

4.4. Antonymy/opposition

Another relation in WordNet, more explicitly lexical, is antonymy, although as Miller (1998) points out, it is not a fundamental an organizing relation between nouns. True antonymy is present in the verb hierarchy, as well as among adjectives. Change-of-state verbs, for example, have antonymous counterparts quite similar to nouns, although the verb pairs don't normally share parents (e.g., ‘lengthen’/‘shorten’ and ‘strengthen’/‘weaken’). Relations of opposition occur as well, where there is no common superordinate or entailed verb unique to the pair (e.g., ‘give’/‘take’, ‘buy’/‘sell’).

Antonymy is closely tied to lexical properties and not a coherent ontological relationship, but some aspects of it can be singled out and represented as conceptual relationships. For example, reversative actions (*zipping* and *unzipping*, *loading* and *unloading*, *arriving* and *leaving*, *creating* and *destroying*) exemplify a fairly coherent notion of opposition that bears on participant roles. We cannot say that the event types in each pair have the same roles; for example, *loading* and *arriving* both have a *goal* role, but may lack a *source*, while *unloading* and *leaving* are the opposite. But it is probably fair to say that each role of an event type has a counterpart in the corresponding reversative event type. The same may hold true for other sorts of opposites (e.g., *helping* and *hindering*, *benefiting* and *suffering*, *believing* and *doubting*), though in many of these cases we are more likely to say that the role's counterpart is itself. It seems less meaningful to posit a counterpart relationship between roles in some other types of situations sometimes thought of as “opposites” (being awake or asleep, liking and disliking, and many others), let alone antonyms in the domain of properties and objects.

4.5. Complementary roles

Another relation between two roles that seems worthwhile is what we term *complementarity*. For some situation types, we know that when one role is present, another role must be also. We then say that this second role is complementary to the first. Complementarity may unidirectional or bi-directional, but most of our examples will involve the latter case. Some examples of such roles are *buyer* and *seller*, *buyer* and *payment*, *moving object* and *path*, *driver* and *vehicle*, and *perceiver* and *perceived*. One application of a complementarity relation in inference should be fairly clear; it allows us to postulate the existence of a participant filling a role when the participant playing the complement role is known to be present. However, this sort of inference is probably

equally simply performed with reference to situation types, as long as they specify which roles are necessary and appropriate. The complementarity relation bears some resemblance to meronymy and to the “partial role” relations; it could even be considered a type of partial role relation applied to situations, disregarding the requirement in (2) that participants playing each role be in a part-whole relationship. Complementarity certainly has counterparts in the entity and situation domains. The existence of a hole depends on the existence of a cavity wall, and the two transfer subevents of a commercial transaction seem complementary in much the same way that the roles are.

Roles that are complementary and that, in a given situation type, are entailed to be filled by the same participant, may violate the reverse of the implication in (1). That is, if R' is a complementary role of R , and a situation type is constrained so that $R(x,e)$ and $R'(x,e)$ for any situation e of that type, then a bi-directional interpretation of (1) would treat R as a subrole of R' .⁷ There may be legitimate grounds, however, to distinguish two participant roles in such situations. For example, someone who is talked into performing an action is both a *addressee* and a *performer* (of the action). It is possible in such cases to create a role specific to that type inheriting from the two roles R and R' , but it does not always seem desirable to do so. We leave this question open.

5. Conclusions

We have seen that an examination of the relations among roles can be fruitful in illuminating other aspects of ontologies and lexical resources. Considering the question of role projectability has shown that permitting multiple inheritance to operate without constraint in the situation-type hierarchy is problematic, and that other mechanisms do not cause the same difficulties for inheritance of roles from situation types to their subtypes. We have also seen how role inheritance interacts with two particular cases of situations and subsituations: a group of like situations and telic situations composed of atelic subsituations. In these two cases, role projectability reveals interesting relationships among situation types in ontologies.

Roles parallel situation and entity types in constituting a hierarchy, but, perhaps because of their inherently relational nature, the parallelism beyond that is limited. While we can formulate coherent definitions of relationships between roles that parallel the mereological relations that are so pervasive among situations and entities, their usefulness is less apparent. In contrast, the complementarity relation between roles is widespread and its utility in inference clear.⁸

6. References

- Chaffin, R., Hermann, D.J. and Winston, M.E., 1988. An empirical taxonomy of part-whole relations: Effects of the part-whole relation type on relation identification. *Language and Cognitive Processes*, 31, pp. 17-48.

⁷ If the two roles are complementary to each other, then each would be a subrole of the other, hence they would be the same role.

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- Dowty, D., 1989. On the Semantic Content of the Notion 'Thematic Role'. In G. Chierchia, B. Partee, and R. Turner (eds.), *Properties, Types, and Meaning*. Dordrecht: Reidel.
- Dowty, D., 1991. Thematic Proto-Roles and Argument Selection. *Language* 67:3, pp. 547-619.
- Fellbaum, C. (ed.) 1998. *Wordnet: An Electronic Lexical Database*. Cambridge, MA: MIT Press
- Guarino, N., and Welty, C., 2002. Evaluating Ontological Decisions With OntoClean. *Communications of the ACM (CACM)*, 45:2, pp. 61-65.
- Iris, M.A., Litowitz, B.E. and Evans, M., 1988. Problems of the part-whole relation. In M. Evans (ed.) *Relational models of the lexicon*, Cambridge: Cambridge University Press.
- Krifka, M., 1992. Thematic Relations as Links between Nominal Reference and Temporal Constitution. In I. Sag and A. Szabolcsi (eds.), *Lexical Matters*. Stanford, CA: CSLI Publications.
- Krifka, M., 1998. The Origins of Telicity. In S. Rothstein (ed.), *Events and Grammar*. Dordrecht: Kluwer Academic Publishers.
- Ladusaw, W., and Dowty, D., 1988. Toward a Nongrammatical Account of Thematic Roles, In W. Wilkins (ed.), *Syntax and Semantics 21: Thematic Relations*. San Diego: Academic Press.
- Lehmann, F., 1997. Big Posets of Participations and Thematic Roles. In P. Eklund, G. Ellis, and G. Mann (eds.), *Conceptual Structures: Knowledge Representation as Interlingua*. Heidelberg: Springer.
- Miller, G.A., 1998. Nouns in Wordnet. In C. Fellbaum (ed.), *Wordnet: An Electronic Lexical Database*. Cambridge, MA: MIT Press.
- Ostler, N., 1979. *Case Linking: A Theory of Case and Verb Diathesis Applied to Classical Sanskrit*. Ph.D. dissertation, MIT.
- Parker-Rhodes, A., 1978. *Inferential Semantics*. Atlantic Highlands, NJ: Harvester Press.
- Pustejovsky, J., 1995. *The Generative Lexicon: A theory of computational semantics*. Cambridge, MA: MIT Press.
- Somers, H., 1987. *Valency and Case in Computational Linguistics*. Edinburgh: Edinburgh University Press.
- Sowa, J., 2000. *Knowledge Representation: Logical, Philosophical, and Computational Foundations*. Pacific Grove, CA: Brooks Cole Publishing Co.
- Wechsler, S., 1995. *The Semantic Basis of Argument Structure*. Stanford, CA: CSLI Publications.