Sentences, Situations and Propositions*

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1. Introduction

The relation between sentences and what they describe is an important theoretical and practical representational issue. This issue comprises two primary components: An ontological issue about what the major classes of entities to be represented are, and a formal issue of how best to represent them. Some semantic network systems make a point of providing entities corresponding to propositions, and some provide entities corresponding to situations, although the distinction between the two is sometimes confused. Both propositions and situations are useful, but for quite different purposes. Also, the representation of situations and propositions can be done in various ways, some of which have important representational advantages.

Situations on the whole have been relatively neglected. When they are provided at all, the ontology of situations has generally been too limited. One way to overcome these limitations is to introduce an operator that associates a situation with any logical sentence, as advocated by Schubert and Hwang (1989). Unfortunately, such an approach appears to introduce serious difficulties.

Instead, I suggest that the best solution is simply to extend the usual ontology of situations somewhat, while maintaining a separate set of entities that correspond to propositions. The components of this proposal are by and large familiar. However, considering them together gives a somewhat novel picture. For example, it seems that the notion of intensions becomes unnecessary. Some of the implications of an extended ontology of situations are explored, including the relation of propositions to situations and the notion of equality of situations.

2. Background

In this section I review some of the issues that have been used to motivate certain representational choices. I believe most of this material well-known. However, I review and elaborate on it here to emphasize what is at stake in these representational decisions, and what problems remain with various approaches currently in use.

Many theories of natural language presume that sentences describe events, states or processes. (Events, states and processes have been collectively called "eventualities" by Bach (1983); the term "situation" has also become popular in this context (Barwise and Perry, 1983). I will use the latter term informally here as a superordinate category encompassing actions, events, states, processes, and whatever else sentences may refer to, but without importing any particular theoretical baggage.) For both theoretical and practical reasons, it is useful to conceive of situations as entities to which one may refer or about which one may say things. On the other hand, sentences are purported to have a logical form of a predicate-argument nature, with the matrix verb serving as the predicate and its complements specifying the arguments. However, this logical form is propositional, and does not readily provide an entity to designate the underlying

*This research was sponsored by the Defense Advanced Research Projects Agency (DoD), monitored by Space and Naval Warfare Systems Command under Contract N00039-88-C-0292 and by the Office of Naval Research, under contract N00014-89-J-3205. I would like to thank Peter Norvig, Pat Hayes, Len Schubert, and Laura Michaelis for helpful comments that contributed to this work. Nigel Ward, Paul Jacobs and Stuart Shapiro provided many detailed comments on and corrections to a previous version of this paper.

situation.

For example, consider a simple sentence like the following:

(1) Jan gave Lynn a cigar.

The logical form commonly attributed to (1) is some variant of the following:

(2) Give(jan,lynn,cigar1)

(where temporal information and the facts that "jan" and "lynn" are people and "cigar1" a cigar are ignored for the time being). Now suppose (1) were followed by

(3) This made Terry furious.

We would like some way to say that the pronoun "this" refers to the event described in (1). However, there is no readily apparent way of expressing this fact given the representation of (1) as (2). The problem is that while (2) expresses the logical structure of the sentence, it does not provide any object designating the reported event. We might be tempted to have the predicate corresponding to the verb "make" take a proposition as an argument, and then represent (3) as the following:

(4) Make(Give(jan,lynn,cigar1),furious)

But this approach doesn't help, because we have no way of asserting that this was the same event as the one described in (1), and not some other, albeit similar, occurrence.

A second motivation for having entities corresponding situations is to capture important generalizations across varying linguistic forms. For example, consider the following utterance:

(5) Jan giving Lynn a cigar made Terry furious.

Here the phrase "Jan giving Lynn a cigar" has a quite similar content to that of (1). However, the stance of a speaker using this sentence to its content is different: Both sentences describe an event of Jan giving Lynn a cigar, while the speaker of (1) is asserting the occurrence of the event, and that of (5) presupposing it (or, as Schubert et al. (1979) would say, the *propositional content* is the same, while the *pragmatic aspects* differ). Whatever representation we choose should make this similarity of content apparent, while allowing us to express the difference in attitude taken toward this event.

This need becomes even more apparent when we consider lexical nouns that encode events (Parsons, 1985). Some nouns, like "punch" and "destruction", seem to describe the same events as certain verbs, e.g., "punch" "destroy". This claim is supported by the observation that sentences like the following appear to have the same truth conditions, if we adjust for presupposition:

(6) The Romans destroyed the city, resulting in much grief.
(7) The destruction of the city by the Romans resulted in much grief.

Whatever meaning difference one can discern between the noun and the verb does not appear to be attributable to a difference in the events they encode. Hence the representational reflex of attributing a predicate to a verb and an argument position to a complement would pave over a crucial and obvious generalization.

A third argument for representing the designatum of a sentence as an entity is a corollary of the first two. Namely, there are often a number of different things to say about a situation, and we need some way of saying only some of them, and, of saying additional things about that situation later on. In particular,

elements of a sentence frequently specify the time, place and manner of a situation, as well as its modality and the speaker's attitude toward the situation. Some of these may be thought of as higher-order predicates. However, such an approach is problematic in some cases.

In particular, consider the problems that arise from distinguishing adjuncts from complements. Many proposals attribute argument positions to a predicate in accordance with the complement structure of the verb associated with that predicate; adjuncts are dealt with in some other manner. Thus, in (1) above, we presumed that the predicate corresponding to the verb "give" is a three-place predicate because this use of the verb takes three complements. However, suppose we had continued the sentence with "in New York". Since this phrase is an adjunct, we would not have provided an argument position for it. Indeed, such a solution would not easily be possible, since an arbitrary number of such adjuncts can be present. Moreover, the adjunct seems to predicate something about the whole event, rather than constitute a component of it, as was the case for the complements.

We can accommodate such adjuncts into the representation by introducing a higher-order "in" predicate, one of whose arguments would be the predication describing the entire situation (or, alternatively, the application of some functional operator to this formula, denoting the situation) and the other, the location. However, this proposal is awkward for many reasons, not the least of which is that we would then have at least two semantically unmotivated but formally distinct "in" predicates, one which applies to formulas, and the other to individuals (cf. Shapiro 1971b).

The situation is compounded by cases in which the adjunct does not appear to apply to the entire situation. For example, consider the following sentences:

(8a) Jan stumbled into the room.
(8b) Jan threw up in the sink.
(8c) Jan bled on a shirt.
(8d) Jan sliced the salami onto the bread.

Note first that treating the prepositional phrases as complements appears untenable. If we did so, then we must make one of two assumptions: We could assume that each verb corresponds to a predicate with one more argument than had been obvious, and that this argument is omitted most of the time. However, this proposal would lead to the wrong analysis of at least some cases; for example, Jan stumbling doesn't require that Jan stumbled directionally. Alternatively, we can assume that each verb corresponds to several different predicates (e.g., "bleed" and "bleed-directionally", and "throw-up" and "throw-up-directionally"). But this proposal requires a gratuitous meaning postulate to sanction the inference from the n+1-place predicate to the n-place predicate (e.g., to sanction "Jan bled" from "Jan bled on a shirt"). Both alternatives seem unmotivated, at best.

Thus, we must consider the prepositional phrases in (8) to be adjuncts. However, if adjuncts are not to be incorporated in the associated predicate, we are left in the following situation. We can once again attempt to treat the adjunct as a higher-order predicate. For example, we might represent (8c) as the following:

(9) Onto(Bleed(jan),shirt1)

But then prepositions like "into" and "onto" get a radically different treatment when they are complements from when they are adjuncts, even when there is no semantic justification for doing so. This situation is worse than the case above in which the prepositional phrase modified the whole sentence, because here, there is presumably no difference at all in meaning between the use of the prepositional phrase in sentences like (8d) and those in which it is a complement, such as the following:

(10) Jan threw the ball onto the roof.

In sum, when the distinction between being a complement and an adjunct does not correspond to a

distinction in meaning, but is merely a fact about whether or not a verb happens to subcategorize for a particular type of constituent, then the difference should not be reflected in the underlying logical form. But doing so appears to be problematic if the designatum of the matrix verb and complements are thought to correspond to a predication.

Note that a version of this problem applies whenever we have the quite common case of a verb that can describe the same situation with several different complement structures. For example, consider the following sentences:

(11a) Jan opened the jar.
(11b) Jan opened the lid (to the jar).
(12a) Jan tied the string.
(12b) Jan tied a knot (in the string).

If we proposed having a predicate per valence description, we would once again require a meaning postulate to recognize that the (a) sentences follow from the (b) sentences. Thus, one goal of whatever representation we adopt should be to do without an additional postulate when the inference is analytic.

Before going on, note that the various problems just presented are essentially invariant with the other choices one can make about representation. For example, if one believes that the meaning of "give" should be decomposed into primitives, and that only the latter can appear in the description of events, then all the same problems persist.

3. Proposed Solutions

To summarize, the problem is to determine what representations we can use for the situations described by utterances so that proper generalizations can be captured. In particular, the grammatical form of lexical items should not have an undue influence, lest we should be incapable of capturing generalizations that hold between various parts of speech or about terms that admit various complements and adjuncts.

3.1. Situation-based Approaches

A well-known solution to some of the problems mentioned above was proposed by Reichenbach (1947) and elaborated by Davidson (1969,1980). Basically, this amounts to postulating another argument for every event predicate. According to this account, the logical form of (1) includes not (2) but rather

(13) Exists x (Give(jan,lynn,cigar1,x))

where x is construed as an event. We will discuss extending this sort of analysis to states below, but for the time being we will assume that such an extension is straightforward.

This particular formalism can be characterized as "situation-based" and "predicate-based". By situation-based, I mean that the system provided entities corresponding to individual situations (e.g., the variable in (13)). By "predicate-based", I mean that the situations are specified by altering each domain predicate in some fashion, in this case, by the inclusion of an additional argument. An example of a use of such a notation is Hobbs (1986).

It is the situation-based character of the formalism that provides a solution to some of the concerns voiced above. If we skolemize (13) to produce a constant x1, say, then we have our unique referent. We could postulate that the logical form corresponding to (3), with the referent of the pronoun established, was not (4) but rather the following:

(14) Make(x1,furious)

Similarly, "Jan giving Lynn a cigar" might be represented as x1 with the same formula predicated about it as in (13). In other words, the "giving" event described in (1) and (5) has the same logical form, although (1) asserts that this event transpired while (5) presumes it.

Also, it is trivial to add in first-order format information about the event. For example, specifying the proper time might be done by something like the following:

(15) Before(x1,NOW)

Similarly, the logical form of verbal adjuncts is easy to accommodate in such a formalism. For example, the sentence

(16) Jan gave Lynn a cigar in New York.

might be construed as follows:

(17) Exists x (Give(jan,lynn,cigar1,x) & In(x,newyork))

3.2. Aspectualized Representations

These last two observations point to some degree of arbitrariness in deciding on the argument structure of various predicates, to which the situation-based notation offers an attractive solution. Instead of having to predetermine a fixed number of arguments for a given predicate, we assume that each predicate has only one argument, namely, the situation. Other aspects of the situation (for example, if it were an action, who its actor is) are added by additional predications completely analogously to the way time and location were added above. In this formulation, (1) is given the logical structure

(18) Exists x (Give(x) & Agent(jan,x) & Patient(cigar1,x) & Recipient(lynn,x))

In (18), the argument positions of the main predicate are exchanged for a set of two-place predicates. This style of representation is called "slot-assertion notation" by Charniak and McDermott (1985). Indeed, one may view the use of these predicates as a notational variant that allows us to make a predication with a variable number of arguments (with more than one possibly being in the same argument "position") . I will use the informal term *aspectual* (Wilensky 1986) for any two-place predicate introduced into a representation for the purpose of separating the assertion of an aspect of a situation from the assertion that something is a particular kind of situation. Aspectuals are meant to include the arcs of some semantic network systems (in particular, those arcs emanating from nodes denoting situations) and the slots of most frame-based systems.

The particular aspectuals used in the example above are the familiar relations imported from case theory. But nothing in our argument depends on the choice of these predicates, although one must eventually specify a set that is appropriate for the particular situation involved. Some theories assume only a small set of quite general aspectuals; others prefer a much larger set that depends on the situation, for example, "Giver", "Givee", "Given" for "Give" situations. We make no commitment here, and use whatever aspectuals are useful for expository purposes.

With this representation, verbal complements can now be given the same logical treatment as verbal adjuncts: Both are represented by predication using aspectuals. E.g., extending (18) to incorporate "in New York" involves adding a predication that looks formally identical to those corresponding to the complements.

Representations for non-sentential verbal adjuncts can be given analogously. For example, (8c) above could be represented as the following:

(19) Exists x,y,z (Bleed(x) & Experiencer(jan,x) & Patient(y,x) & Blood(y)
& Onto(y,z) & Shirt(z))

Representing the adjunct requires only the addition of the last two predications, and the representation of the sentence without the adjunct is identical to (19) without these predications*.

Thus, such a notation allows us to represent adjuncts and complements in a logical structure that captures what is being expressed, as opposed to how these elements are packaged into the language. The latter difference is maintained in the grammar, where it belongs, but not in the logical form.

Note also that the resulting notation treats situations analogously to physical objects, persons, etc. For example, had our representation of (1) been more elaborate, and included information about the nature of the entities corresponding to the noun phrases in the sentence, it might have been more like the following:

(20) Exists x,jan,lynn,cigar1
(Give(x) & Agent(jan,x) & Person(jan)
& Patient(cigar1,x) & Cigar(cigar1)
& Recipient(lynn,x) & Person(lynn))

Here "Person(jan)" denotes the fact that Jan is a person analogously to "Give(x)" denoting that x is a giving event. In both cases we would have to make further predications to express additional facts about the nature of the entities. For example, we would need an additional predication to express that the first name of the person Jan is "Jan", just as we needed an additional predication to express that the patient of the giving event was a cigar.

This uniformity is particularly important in capturing the unity of a preposition like "in", when we have the intuition that the same spatial meaning is being used regardless of the arguments. Thus, the representation of the phrase "the pen in the box" can make use of exactly the same "in" as that of "The pen broke in the box". Both have the following logical form:

(21) In(x,box1)

where "x" is alternatively a pen, or the event of a pen breaking.

Finally, the analytic inferences involving verbs with different valence structures can be handled appropriately. We specify the structure of the underlying event by specifying the set of aspectuals it accommodates. Verbs with multiple valences hence may specify the same event, but supply the arguments to different aspectuals. An event-class corresponding to the verb "open", e.g., might have aspectuals for the object constituting a barrier or container, the object moved to create the opening, etc. Then the representations for "open the jar" and "open the lid" could be identical except for the aspectuals that the uses of the verb specify; i.e., the first would relate an opening event to a jar via a "containing-object" aspectual, and the second would relate an opening event to a lid via a "object-moved" aspectual. Similarly, in the case of optional complements, when a complement is omitted, the representation is identical except for the omission of a predication using the corresponding aspectual.

Note that the key property of the representation that solves many problems for us is that it is amenable to

*One might argue for a more elaborate analysis of "onto" both for (8c) and (10). For example, another plausible analysis is that there are events described by the sentences (bleeding and throwing, respectively) and that these caused additional events (blood moving onto a shirt and a ball moving onto a roof). The important point is that parallel analyses are available for the two sentences using either analysis.

"aspectualization", i.e., we can predicate different aspects of a situation separately. A situation-based, predicate-based system does not necessarily have this property, as we noticed when a predicate provides argument positions corresponding to complements. However, a situation-based, predicate-based system in which domain predicates take only situations as arguments is aspectualized. Henceforth, when I refer to predicate-based representations, I will assume they are aspectualized, unless otherwise noted.

3.3. Category-based Approaches

Another way to have representations that are amenable to aspectualization is to have within one's system entities corresponding to categories, including categories for situation types, e.g., "Giving" and "Event", as well as "Person" and "Book". We would also introduce a predicate, say AIO (An Individual Of) relating an individual to a category it belongs to. Then, instead of (20) we would have the following:

(22) Exists x,jan,lynn,cigar1
(AIO(x,Giving) & Agent(jan,x) & AIO(jan,Person)
& Patient(cigar1,x) & AIO(cigar1,Cigar)
& Recipient(lynn,x) & AIO(lynn,Person))

Such formulas, or perhaps, the skolemized versions of them, can be viewed as the basis for many semantic network and "frame-based" systems, in particular, of all those formalisms that have some explicit relation meaning "an individual of". I will call a proposal in which there are individuals corresponding to categories of situations a "category-based" representation*. I would construe Simmons (1973), Rumelhart, Lindsay and Norman (1972), Hendrix (1975), Schank (1975), Bobrow and Winograd (1977), Roberts and Goldstein (1977) and Brachman (1979) as all adopting category-based schemes of some sort.

This classification is akin to what Israel (1983) calls "inheritance-based networks". However, the above systems vary in the degree to which inheritance per se is prominent in them; for example, inheritance is rather conscientiously avoided in Conceptual Dependency (Schank, 1975), while it is quite prominent in KRL (Bobrow and Winograd, 1977) and KL-ONE (Brachman, 1979). What all these systems do have in common is the idea of an individual of a category corresponding to a situation type.

One advantage of category-based representations is the availability of categories for predication. For example, the representation for a classic sentence like "The Saber-toothed tiger is extinct" could involve a reference to the concept "Saber-toothed-tiger". However, I will not make a substantial case here for the advantages of category-based over predicate-based representation, except to note that an aspectualized representation seems inherent in the category-based representation, whereas a predicate-based approach must be tailored to have this property.

Some semantic networks make a habit of providing categories, but no individuals corresponding to situations. Rather, in these formalisms, the emphasis is on nodes representing propositions. For example, Cercone (1975), Schubert et al. (1979) and especially Shapiro (1979) fall into this category. Such systems are sometimes called "propositional semantic networks", although this term seems to be used to emphasize the point that, in such a system, every accessible assertion is a node (Maida and Shapiro, 1985), rather than as a contrast between systems have nodes for propositions versus those that have nodes for situations. To be sure, such systems are not necessarily hostile to the inclusion of individuals corresponding to situations; they just do not make a commitment to provide such individuals. While having individuals corresponding

*Allen (1987) interprets the categories of semantic networks as corresponding to logical predicates rather than individuals. Perhaps this is because the semantics of the terms corresponding to categories might be problematic for some, who like to interpret formulas over models that somehow correspond to the world (what I have called a "direct correspondence" theory (Wilensky, 1986)). In this case, "Giving", etc., probably have to be construed as sets. However, semantic network theorists (e.g., Maida and Shapiro (1985)) often prefer to interpret formulas with respect to some normative cognitive agent (a "cognitive correspondence theory"). In this case, "Giving" is supposed to be the concept of giving; each individual of such a category denotes a conception of an individual event; the actual events, etc., are generally not designated at all.

to propositions is a useful idea we will return to later, it does not address the problem of providing referents for situational anaphora.

Note that propositional and situation-based representations will often use the same labels for arcs, but with a quite different semantics. For example, Shapiro (1971a), Schubert et al. (1979) and Shapiro (1979) use arc labels as uninterpreted syntactic markers. Thus, in SNePS (Shapiro, 1979), one can have a node representing the proposition in "John loves Mary", and relate this node to nodes for John and Mary using arcs labels "Agent" and "Object", respectively. However, propositions do not have agents or objects, so the arc "Agent" is simply an indicator of the first argument of the predication represented by the node. This fact is clearer in Schubert et al. (1979), in which the corresponding arcs would be simply be labeled "A" and "B". I do not regard such uninterpreted arcs as aspectuals.

In sum, *situation-based* representations provide situations as part of the meaning of utterances; *propositional representations* provide propositions. Only situation-based representations address the problem of providing referents for situational anaphora. *Predicate-based* systems introduce situations into the notation by providing argument positions for situations in various predicates; *category-based* systems introduce situations by providing objects corresponding to categories, and a predicate or some other apparatus that one can use to specify that some entity is an individual of a category or a type of situation. Furthermore, it is convenient if our representation is *aspectualized*, i.e., if we can separate the assertion that something is a situation from other facts about that situation, such as which roles are played by which participants. Both situation-based and propositional representations come in aspectualized and non-aspectualized varieties, although category-based situational representations seem to be naturally aspectualized; also, the aspectuals of aspectualized propositional representations are just syntactic markers for argument positions of a relation, while the aspectuals of situation-based notations encode relations between situations and participants.

4. A Problem

Situation-based representations provide objects corresponding to situations; these are convenient when subsequent utterances refer to previously mentioned events. However, an important characteristic of situation-based proposals is that their vocabulary is generally *lexically determined*. That is, the vocabulary of predicates or categories is approximately that of the word senses of the various verbs, etc., recognized as designating situations. However, as Schubert and Hwang (1988) point out, such representations do not yield an object for sentences involving logical operators or quantifiers, but only for atomic formulas. They give as an example the following sentence:

(23) Everyone looked at Mary.

They note that standard situation-based representations would provide no object for the event described by this sentence, even though such an event may be referred to subsequently, if followed, for example, by a sentence like (3) above:

(3) This made Terry furious.

Schubert and Hwang propose a solution to this problem in the form of *episodic logic*, in which symbols designating situations are related to propositions capturing the logical structure of the sentence via connectives introduced just for this purpose. In particular, the connective '**' relates a proposition to a situation it "characterizes". For example, (23) would be represented* as

(24) Exists e1 (**(All x (Person(x) -> Look-at(x,mary)),e1))

*These authors use the terms "event", "situation" and "episode" interchangeably. Also, I have omitted temporal information here which the authors include in their analyses. Finally, Schubert and Hwang use an infix notation I have eschewed for uniformity's sake.

Here "e1" is the situation with characterization "Everyone looked at Mary". This gives us a handle on the entire situation, just as the word-style representations did on events requiring only atomic formulas. For example, we can represent the following sentence

(25) This made her blush.

as describing the situation

(26) Exists e2 (Cause(e1,e2) & **(Blush(mary),e2))

allowing the scope of the existential in (24) to extend a bit further than the parenthesis would ordinarily allow.

Schubert and Hwang also propose a more fundamental operator, "*", that is used to relate a situation to a partial description. To illustrate the significance of characterizing versus partial descriptions, they note that, if it were everyone looking at Mary *derisively* that made her blush, then (24) with "**" replaced with '*' would still be true, even though (23) together with (25) would not be.

I call Schubert and Hwang's proposal a "proposition-based-situation" proposal. That is, they define situations as objects that correspond to logical propositions. Note that what I am calling a proposition-based-situation solution has little to do with what has sometimes been called a "propositional semantic network", which Maida and Shapiro (1985) describe as a network "in which *every* assertion that can be stored or accessed ... is ... represented by a node". Rather, I use the term to refer to proposals in which situations are defined by an operator that relates them to a logical formula.

Schubert and Hwang's proposal is very attractive because it allows one to have situational objects corresponding to arbitrary propositions. However, it is not unproblematic. First, while it provides a way to refer to the entire situation, it does not provide a way to refer to its individual components. For example, in (24), each individual looking action is not readily accessible. This is problematic for several reasons. One is that there is no obvious way to specify case relations as in (20). That is, we cannot explicitly represent the fact that Mary was the patient of any number of individual looking actions. Another is that there is no obvious way to relate one of these individual events to the entire situation. For example, if (23) were followed by

(27) and someone looked at her derisively.

then how do we express the fact that the event underlying (27) is not unrelated to the event described in (23)?

We are also back to a system in which complements and adjuncts are treated quite differently. Schubert and Hwang represent verbal complements as arguments to the corresponding predicate, but advocate having temporal modifiers that take episodes as arguments. Thus, they use

(28) Before(e1,NOW)

to express the fact that episode e1 occurred in the past. And, as in the example above, causal relations hold between episodes. But then the representational implications of being a complement versus an adjunct, and all the associated problems discussed above and conveniently eliminated by either predicate- or category-based representations are reintroduced. That is, the representation is not aspectualized.

Even worse, it is not clear that the semantics of "**" and "*" can be made coherent. In particular, what it means to "characterize" a situation seems problematic. Schubert suggests* that the situation described

*Personal communication. Schubert and Hwang have revised their ideas considerably since the initial publication of their 1989 paper. In particular, "**" now means "completely describes", i.e., that everything else one an say about an event

by

(29) Looking down the barrel of the gun, John fired the gun.

is characterized by the representation corresponding to the main clause, but not by that corresponding to the dependent clause. However, the same would then presumably apply to a sentence like the following:

(30) John fired his gun looking down the barrel.

But this sentence could be followed with

(31) This enabled him to focus clearly on the target.

This sentence is problematic since we have no event characterized by "looking down the barrel", and only such events are supposed to be the bearers of useful causal information.

Indeed, the whole purpose of introducing the notion of characterizing an event seems to be to avoid the annoying problem of figuring out, when one event is predicated to cause another, what is really being asserted to have caused what, since an indefinite number of predications might apply to the two events, but most of these are not presumed to describe factors that have any causal role. However, there appears to be no in-principle basis for deciding whether a predication is characterizing or not. In any case, events or situations are entities in the world, so their characterization couldn't matter with respect to causality.

The power of a proposition-based-situation representation may also be problematic. In particular, it raises the question of how in principle we decide what gets reified. For example, that event e1 causes event e2 was itself not reified above. But this seems to be a perfectly good situation. Of course, their notation makes it easy to express this fact:

(32) Exists e3 (*(Cause(e1,e2),e3))

But when are such expressions meaningful? For example, consider what would it mean to say something like the following:

(33) Exists e (*(Time(e1,NOW),e))

We can paraphrase (33) as "The situation of event e1 occurring at the present". But it is not clear what situation in the world e can be referring to. That is, if situations are in the world, then it wouldn't be meaningful to distinguish an event, which occurs at a certain time, and the situation of that event occurring at a certain time.

Part of the difficulty here may be that Schubert and Hwang's notation is intended to be situational, but the objects associated with formulas are better interpreted as propositions rather than as events. That is, what the notation really allows us to do is to tag propositions for subsequent reference. But propositions and events are quite different animals. Hence a number of problems arise, for example, the need to identify which of the multiple propositions that can be given the same identifier are implicated in causal relations and the like. I will elaborate on this point below.

Some of these problems might be superficial. For example, the problem of describing situations so that causal relations between them can be handled using Schubert and Hwang's representation might be circumvented as follows. We drop the notion of characterization altogether, and define a new predicate, say

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completely described by a proposition is entailed by that proposition. This proposal is somewhat similar to one I propose below re equality of situations. However, I believe that the other difficulties of proposition-based-situation representations, except perhaps the difficulty involving causation, are still problematic for this new proposal.

"Reason-for". Using this predicate, we could express the meaning of the sentence

(34) Everyone looked at Mary, causing her to blush.

by the formula:

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(35) Exists e1,e2 ( *(All x (Person(x) -> Look-at(x,mary)),e1) &
                    *(Blush(mary),e2) &
                    Cause(e1,e2) &
                    Reason-for(Cause(e1,e2),
                               *(All x (Person(x) -> Look-at(x,mary),e1))))
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That is, we separate the fact that one event caused another from the reason that it caused it (in this case that it was a certain category of event). In general, depending on one's theory of causation, the details of the description of the reason might vary. Using such a representation, we can harmlessly assert that one event caused another, but we would have to rely on the additional information in the "Reason-for" predication to determine how the causation related to various facts that were known about these events.

Similarly, while the representation does not make explicit facts like the relationship of individual looking events to the overall situation, it is still possible to add this information. However, the other difficulties appear to be intrinsic. In particular, it does not appear to be possible to re-aspectualize the representation. For example, the episodic logic representation of

(36) Jan looked at Lynn.

would be

(37) Exists e (*(look-at(jan,lynn),e))

Now, suppose we tried to regain an aspectualized form by removing arguments from "look-at" and moving them to aspectual predications of "e". Doing so would yield the following form:

(38) Exists e (*(look-at(),e) & Experiencer(jan,e) & Patient(lynn,e))

But this is essentially a category-based notation, with predicates of no arguments substituting for categories and the operator "*" having the corresponding semantics to the predicate "AIO". (I explore the implications of this observation below.) Moreover, * has lost its ability to relate an arbitrary proposition to an event; should we try to quantify over experiencers, as was the case in the original sentence (23), we would no longer have an object that corresponds to the whole event.

Another possibility along this line would be to have both predicate- or category-based situations *and* proposition-based situations within the same representation. That is, we could have both entities that are predicated to be situations via a first-order predicate, plus an entities that are related to formulas via an operator. Indeed, Moore (1989) makes just such a proposal. In his proposal, however, events and situations are different objects. Simply put, events consist of lots (typically an infinitude) of different situations. Moore's primary motivation for introducing such an ontology is to accommodate linguistic data about the interpretation of adverbs. In particular, he is concerned with accounting for the observation that, while many manner adverbs have both sentential and predicate readings with verbs that denote events, they typically do not have both readings with the copula. For example, the following sentences show a predicate and sentential interpretation of the same adverb:

(39) John sang strangely.
(40) Strangely, John sang.

However, only the sentential reading is available with the copula:

(41) Strangely, John was at the party.
(42) *John was at the party strangely.

Moore's explanation for this phenomenon is that event verbs have both events and situations as part of their denotation, while the copula has only the situation. Specifically, he proposes that "John sang" be given the following logical form:

(43) Exists s (Fact(s,Exists e (Sing(john,e))))

"Fact", like Schubert and Hwang's "*" operator, relates situations to arbitrary formulas. (Moore restricts his discussion to adverbs whose sentential interpretation is factive, hence the terminology.) Then the remainder of (39) and (40) is expressed by stating "Strange(e)" and "Strange(s)", respectively. Strange events are supposed to be interpreted as strange in manner, while strange situations are to be interpreted as strange in that they occurred. On the other hand, "John was at the party" might get expressed as the following:

(44) Exists s (Fact(s,At(john,party)))

Since there is no event, there is only the situation available for predication. And predicating "Strange" of s here yields the appropriate sentential interpretation.

There are many problems with Moore's argument, however. First of all, there are numerous counterexamples to the claim that with adverbs, the copula only allows sentential interpretation. The best examples involve so-called "tough" adjectives. For example:

(45) The problem was surprisingly hard.
(46) Surprisingly, the problem was hard.

In (45), it is the degree of difficulty of the problem that is surprising, whereas in (46), we are surprised to find that the problem was difficult at all.*

Indeed, predicate rather than sentential modification is common with the copula, even if both with the same adverb is rare:

(47) The light was on brightly.
(48) The book was on the shelf precariously.

Note that both of these sentences are amenable to subsequent, factive, sentential modification by other adverbs:

(47) Strangely, the light was on brightly.
(48) Curiously, the book was on the shelf precariously.

However, Moore's analysis would seem to predict that such examples would not occur.

The inability of some adverbs to serve as manner adverbs with the copula (and other stative verbs) most likely falls out of specific facts about meanings of the terms, as opposed to general ontological issues

*One might object that the adverb modifies the adjective here, and not the verb, as is the case for event verbs. However, this is exactly what one would expect from the copula; moreover, the adverb modifies the underlying predication (i.e., "Hard(problem1)") analogously to the way we have postulated a predicate adverb would modify the underlying predication of an event-verb sentence.

involving situations versus events. Thus, it is not that there is no event/situation distinction with respect to sentences with the copula; rather, the state described by the utterance and various adverbs, e.g., "being at" and "strangely", are just generally semantically incompatible. Presumably, reasons such as this also explain why "loudly", etc., only has a predicate-modifying reading and "probably", etc., only a sentential one. (See Ernst (1984, 1986) for a compelling analysis of such phenomena.)

A second problem with Moore's analysis is the difficulty of giving a coherent interpretation to predicates associated with adverbs this way, e.g., how do we give the semantics to the predicate "Strange" so that it means one thing when said of an event and another thing when said of a situation? Namely, "Strange" of an event is supposed to mean "strange in manner", and "Strange" of a situation is supposed to mean "strange in that it happened", but it is not clear where this semantics comes from. That is, Moore's proposal appears to simply sweep the manner/sentential distinction under the rug.

Indeed, a fundamental ontological distinction between event and situation seems unwarranted, and is certainly not justified by linguistic evidence. States and events seem to be two kinds of situations, and while they have different properties, they do not require and should not entail thoroughly distinct representational devices.

In sum, the prospect of using both predicate- or category-based situations and proposition-based situations within a single notational system seems dim. A pure proposition-based-situation analysis leaves us with the problems of not being able to represent the individual events of a complex event like that described by (23), and with an unaspectualized representation that reintroduces many nasty problems, such as adjunct/complement asymmetry.

5. A Solution

I propose one solution to the problem of how best to represent situations, which I term an ontological solution, because it gets around the problem pointed out by Schubert and Hwang by hypothesizing more kinds of entities. In particular, we posit entities for the situations corresponding to sentences involving logical connectives or quantifiers. For example, recall sentence (23) above:

(23) Everyone looked at Mary.

Let us posit that this sentence corresponds to a situation class called "Complex-event". "Complex-event" has exactly the same status as a category like "Giving". However, it is amenable to any number of "sub-event" predications. Then (23) could have the following characterization:

```
(49) Exist c1 (AIO(c1,Complex-event) &
        All x (AIO(x,Person) -> Exists l (AIO(l,Looking-at) &
                                Actor(x,l) &
                                Patient(mary,l)) &
                                Sub-event(l,c1)))
```

That is, there is a complex event that has a subevent corresponding to each individual's looking action. Each of these actions has the standard case structure. We can refer to the entire complex event by referring to c1, while preserving the desirable structure of the individual component actions. Note that it is relatively easy now to say that one of these looking actions is derisive, say, simply by creating a description of an individual event having this property, and assertion that it is a subevent of c1.

One appealing aspect of this proposal is that it captures some of aspects of the underlying events that one would want independently. That is, that events like c1 are composed of individual subevents is a fact that is useful for any number of purposes. Therefore, relying on such an ontology for a solution to the situation-as-entity problem is not simply gratuitous. Also, the same particular category, "Complex-

event", would be used to represent sentences involving many other quantifiers, such as "many", "most" or "almost all", should a suitable analysis of these quantifiers be given.

One perhaps less appealing aspect of the proposal is that it at least opens the door to having ontological categories duplicating various logical connectives. For example, consider the following sentence:

(50) John didn't go to New York.

The representation for (50) might be the following:

(51) Exists n,e (AIO(n,Non-event) &
negated-event(e,n) &
AIO(e,Going) &
Actor(john,e) &
Destination(newyork,e))

Here n denotes the non-event of John going to New York.

Having situations that are "non-events" may seem ontologically suspect (cf. Hobbs (1985) and Hirst (1989). However, that such situations are plausible is suggested by the fact that (50) could be followed by

(52) This caused the firm to lose an important customer.

That is, non-events seem to be as referable and as causally culpable as "real" events.

In contrast, note that there does not appear to be a need to have disjunctive situations. For example, consider the following sentence:

(53) Either John went to New York or Bill went to Pittsburgh.

Presumably, if (53) is followed with (52), it is not some disjunctive situation per se that caused the loss, but one of the two disjuncts. That is, we would have to interpret these events as either John's going to New York or Bill's going to Pittsburgh having caused the firm to lose an important customer. Therefore, we are not compelled to enter such a category of situations into our ontology, at least by our current arguments.

Note that a somewhat different reading is available if (53) is followed by

(54) This infuriated Mary.

There is an interpretation of (54) in which Mary's infuriation depends only on her having learned the disjunction, and not on her learning of one or the other event. I take this as evidence of the need for propositional rather than situational objects, which are discussed further below.

Such extended ontologies are not new, but there appears to have been confusion over what they are ontologies of. For example, Hendrix (1975) has categories like "Negations", "Implications", and "Disjunctions" and has nodes (actually, "supernodes" denoting spaces in his partitioned semantic network notation) that are predicated to be individuals of this category. However, these categories, unlike those associated with more basic sentences, are explicitly categories of propositions. Thus, two very different notions seem to be conflated here. "John owns a car" gives rise to a node that is an individual "Owning" situation, but "John doesn't own a car" and "Everyone owns a car" yield nodes that are individual propositions; they are not situations at all. In effect, Hendrix has changed from a situation-based representation to a propositional one in midstream. Moreover, the ontology of situations is not extended to cover those situations corresponding to the more complex logical forms. While Hendrix is clear that his categories are categories of propositions, his lack of comment on the transition may indicate that the difference is not

much appreciated. In this instance, Hendrix appears to build upon prior confusion, such as that in Woods (1975, p. 57), which construes individual nodes in case-based representations as standing for both assertions of facts and instances of events.

Note also that propositional networks, i.e., networks in which the emphasis is on representing as nodes the propositions underlying an utterance, can easily provide representations for the content of logically complex sentences. But in such systems the representations is of course propositional rather than situational, and what distinctions there might be between different kinds of propositions has a rather different role. For example, Schubert et al. (1979) and Shapiro (1979) provide representations for utterances containing logical operators, and in Shapiro in particular it is clear that these involve nodes denoting the logical propositions. Thus in SNePS (Shapiro, 1979), all sentences involving logical operators are classified as "deduction rules" and yield corresponding "rule nodes" in the notation. So "John loves Mary" would correspond to an (ordinary) assertion node, while "John does not love Mary" would correspond to a rule node. But nothing appears to hang on this distinction. Rule nodes just correspond to non-atomic logical sentences (i.e., "John does not love Mary" is no more a "rule" than "John loves Mary" is). Of course, an inference mechanism would make different inferences based on the nature of an assertion, but only as one would expect from the logical interpretation of these nodes.

In sum, the ontological solution seems to be a plausible remedy for the problems of reifying events corresponding to non-atomic sentences, while preserving an aspectualized representation. Having a richer ontology raises the issue of which logical forms correspond to situations, but it seems that this can be satisfactorily handled on a case-by-case basis. However, several potential problems arise from this approach. These are quite general issues, having to do with reifying states, with reifying propositions, and with when two events should be considered the same event. I now look at each problem in turn.

5.1. Reifying states

We have just seen how a modest extension of the kinds of situations we are willing to entertain solves the problem of representing the designatum of certain sentences. However, most of the examples we have examined so far have either been events or notions derivative of events, specifically, non-events and complex events. Probably the most significant class of omissions is that of stative situations, or states.

As the critique of Moore's proposal above suggests, it seems quite reasonable to consider states on par with events as a subclass of situations. If we follow the ontological solution to the reification of situations, we should analyze sentences denoting states as instances of state categories. For example, consider how we should represent the content of the following sentence:

(55) Jan owns a book.

Using a category-based representation, we would posit a category denoting the concept of being the owner of some possession, and represent (55) as the following:

(56) Exists o (AIO(o,Owning) & Owner(jan,o) & Object(book1,o))

There is a serious issue that such representations raise, however. This is the question of just which entities constitute states. There are several ways in which this question manifests itself. One is that virtually any relation seems to be a plausible candidate for the state of that relation holding. Hence there is a potential for infinite regress of states. Another is that all the domain predicates denoting states are no longer predicates in the proposed logical form. This is counterintuitive.

Let us consider the first problem. Note that, in (56), we propose a relation "Owner" holding between the state of ownership and an individual person. However, one might further propose that the content of this aspectual predication, Jan being the owner of an owning state, is also a feasible state; at least, we have not

yet articulated a principle to rule out this possibility. Hence, we might want to further reify this state, for example, by replacing the aspectual above with the following:

(57) Exists a (AIO(a,Being-owner) & Owner-of-being-owner(jan,a) & Owning-of-being-owner(o,a)

Here "Being-owner" denotes the state of being the owner of some state of ownership. We can continue reifying such proposals as long as we like, proposing state objects that are less and less intuitive. (This issue is discussed in Shapiro (1979) and Norvig (1987)).

Of course, we need not start with the representation of a state for such a proposal to arise; we could just as well have proposed a state like being the agent of an action, etc. It is simply representing states as objects, and a liberal notion of what may be a state, that allows the problem to arise.

The point here is not to recommend representations like (57), but merely to recognize that they are notational possibilities we cannot in principle rule out. Indeed, perhaps the best way to deal with such potential representations is not to attempt to rule them out in principle, but rather, propose that they are simply empirically unmotivated. That is, having a term "Owning" but not a term "Being-owner" is a claim about the particular ontology employed by a conceptual system; the choice of state terminology amounts to an empirical claim that English speakers have the first concept (i.e., being the owner of a state of ownership) but not the second (being the person in a state of being the owner of an ownership state).

We might even want to propose that representations like (57) are appropriate should one conceptualize a situation in a peculiar fashion. That is, one *could* conceivably think about the state of being the owner of an owning event (as opposed to simply being the owner of an owning event); in such a case, (57) would be the appropriate representation. However, this state is difficult to express in natural language, and seems to occur rarely, if at all, because it is not particularly useful for anything; thus, the ordinary interpretations of most natural language utterances does not entail this particular conceptualization.

The second problem with representations such as (56) is that they have a counterintuitive consequence. As an illustration, consider how we might represent a simple utterance such as a proper name. For example, consider how we should represent the utterance "Jan", as it occurs as part of some larger utterance. Assuming we believe that this is just the first name of a person, we might include the following in our representation:

(58) Exists jan (AIO(jan,Person) & first-name(jan,"Jan"))

However, as per our previous arguments, if the expression "Jan" has the same content as expressions like the following

(59) The person named Jan
(60) That person is named Jan.

and differs only in the stance of the speaker, then the logical form of the content of these utterances should be the same. Moreover, (60) is most clearly a state, and therefore has a logical form we would render as follows:

(61) Exists jan,s (AIO(jan,Person) & AIO(s,First-name-state)
& First-name-state-holder(jan,s)
& First-name-state-name("jan",s))

That is, s is the state of some person being named "Jan". Thus (60) and the simple utterance "Jan" must also have this structure. Moreover, we should eschew predicates like "first-name" in (58) in favor of categories like "First-name-state" for exactly the same reason we eschewed predicates like "Give" in favor of categories like "Giving".

Following this line of reasoning to its logical extreme, all our beloved, prototypical predicates, e.g., "Tall", "Sweet", "Red" are no longer predicates in the analysis, but instead are replaced by the likes of "Tall-state", "Sweet-state" and "Red-state", plus some associated aspectuals. There is nothing immoral about doing so, but the consequences should be fully appreciated. In particular, facts involving such concepts are a bit more awkward to write down, and one is tempted to revert to a shorthand in which predicates like "Tall" (and indeed, "Give") reappear as a notational convenience, to be replaced in the actual representation by the more fundamental "Tall-state" and "Giving".

While the resulting analysis is somewhat awkward to work with, I note that the problems that motivated us to this solution in the case of verbs expressing events also appear in the adjectival cases. First, we might want to refer to situations involving such states just as we would to those involving events. Second, such an approach levels linguistic distinctions that probably do not have conceptual import. For example, we normally express height and weight in English with quite different grammatical forms:

(62) John is six feet tall.
(63) John weighs 190 lbs.

(62) and (63) have parallel paraphrases in "The height of John is six feet" and "The weight of John is 190 lbs", and we probably do not wish to attribute much cognitive significance to the fact that we have no verb for height parallel to "weigh", or that the adjective "heavy" cannot be used analogously to "tall" for the expression of weight. Of course, this is just an argument for having a canonical representation for such utterances, which the ontological approach easily admits. In particular, we would represent (62) and (63) as situations that are instances of "Height-state" and "Weight-state" categories, respectively, with analogous aspectuals.

Also, with adjectives like "tall" or "taller", we have the issue of optional complements versus adjuncts. Thus, while "tall" is often thought of as a one-place predicate, many analysts (e.g., Bierwisch 1987) have noted that the logical structure of the predicate makes recourse to a group whose height establishes a norm with which the predicate contrasts its subject. That is, "tall" is really a two-place predicate whose second argument is some contrast group. Indeed, this argument may be specified by a prepositional phrase:

(64) John is tall for a 7 year old.

When such information is omitted, it is presumably inferred pragmatically. Similarly, comparatives like "taller" can often be used without specifying a complement, as in

(65) I would like America to be a kinder, gentler nation.

The comparatives may also allow an additional argument, as in the following:

(66) John is taller than Bill by two inches.

Thus, while it is possible to describe "tall" as a two-place predicate (one of whose arguments in rarely expressed) and "taller" as a three-place predicate (two of whose arguments are typically expressed but with complex omissibility criteria), doing so is not appealing. Using arguments analogous to those about event verbs, representing the content of these sentences as objects, with aspectuals to be asserted as needed, is a compelling alternative.*

*It is interesting that one cannot say

*John is tall by two inches.

even if we knew exactly the height norm of the contrast group. I speculate that the reason for this is that, unlike "taller", "tall" does not have in its logical structure an aspectual specifying the quantity corresponding to the difference in height. Similarly, adverbs like "much" might apply to quantities, and hence to "taller", but not to "tall". A more thorough analysis of such issues cannot be presented here.

Of course, we have still not addressed the issue of exactly what constitutes an event. For example, one can imagine that a category like Non-event qualifies for statehood; alternatively, one can imagine a scheme in which this is not a state, but is simply its own kind of situation (perhaps dominated by a category like Non-situation). While some stand eventually needs to be taken on such issues, the details of categorization do not appear to have any substantive bearing on the other issues at hand, and hence are not dealt with here.

5.2. Generic Facts and "Frames"

At this point, it is useful to look at how some general facts about events might be represented using the ontological approach. Suppose we want to represent some facts about robberies. Let us assume that robberies have agents who rob victims of some goods, using some weapon. Suppose that we also want to represent the fact that possessing the weapon is necessary for performing the action.

To represent

(67) Jan robbed Lynn of $20 using a gun.

we might state the following:

```
(68) Exists r (AIO(r,Robbery)
                & Robber(jan,r)
                & Victim(lynn,r)
                & Loot($20,r)
                & Enforcer(gun1,r))
```

Such a representation is easy to depict as an network with the relations shown as links and the constants (including the skolemized version of the variable) as nodes. It is equally obvious how to depict the relations as slots and the other entities as frames. Also, we can easily represent the event of Jan possessing the gun, and predicate that this state is a precondition for event r above. However, many frame- and semantic-network systems either lack the means for representing more general facts, or must resort to awkward (and generally too limited) notations. For example, Conceptual Dependency (Schank 1973) and Simmons' networks (Simmons 1973) provide nice analyses of individual sentences, but no obvious formalism for general facts.

However, a simple logical notation suffices. Here is the general structure of robbery, including the constraints on role-fillers and the fact about having the gun being a precondition:

```
(69) Forall r (AIO(r,Robbery) ->
        Exists a,o,v,w,h,p
            (AIO(a,Person) & Robber(a,r)
            & AIO(o,Phys-obj) & Loot(o,r)
            & AIO(v,Person) & Victim(v,r)
            & AIO(w,Weapon) & Enforcer(w,r)
            & AIO(h,Possessing) & Possesser(a,h) & Possession(w,h)
            & AIO(p,Precondition) & Pre-action(r,p) & Pre-state(h,p)))
```

One can view the handling of quantifiers in partitioned semantic networks (Hendrix 1975) as advocating such a representation, and Hayes (1985) notes that such logical representations are generally adequate for representing frames. In general, the scoping of the quantifiers in (69) is the default for most semantic network and frame systems that do not specify them explicitly (e.g., Bobrow and Winograd (1977), Lenat and Guha (1988), Brachman (1979)). That is, the interpretation we are to give to there being a "name" slot in a "person" frame is that each person has some name. The advantage of having explicit quantifiers is that

many concepts do not conform to this quantificational structure. For example, if we believe that an anti-Semite is someone who hates Jews, then those non-quantificational notations have difficulty expressing this concept: The standard frame-like notation would mean that every anti-Semite hates some Jew, which may be true, but is not the fact to be expressed. However, with a general quantificational capability at hand, such concepts are not problematic.

Note that we have not included many other facts about robberies. For example, we have not mentioned the essential fact that a robbery is an action involving the use of force or threat to procure goods. Making these assertions requires the inclusion of standard hierarchical information, for example, that a robbery is a kind of action. There are any number of ways of adding this information, but since doing so interacts with the issue of when two events are the same, we shall discuss both issues together below.

5.3. A Note on Aspectuals

The reader may have noted that some of the aspectuals we have posited thus far are quite similar to the motivating English words, while others appear to be rather different. For example, while the aspectual "Agent" relates an individual to an action, as the English word suggests, the aspectual "Owner" relates an individual to a state, not to an object owned, as does the English word. That is, we can say "the owner of that car", but do not ordinarily say "the owner of that owning".

Now, it is not the case that these English words are supposed to be directly related to similarly named aspectuals. Indeed, the words "owner" and "agent" should refer to concepts which are further defined in relation to the categories "Owing" and "Action" and their associated aspectuals. (Doing so is one way to give a "frame semantics" to certain words, as advocated by Fillmore (1982).) For example, we can say that the *category* Agent (as opposed to the aspectual of the same name) applies to individuals in the Agent aspectual relation to individual Actions, and that the *category* Owner applies to individuals in the Owner aspectual relation to individual Ownings. But we still have not explained why we talk of actors of actions and owners of object, but not owners of ownings.

However, I suspect that this apparent asymmetry is actually rather superficial. Consider for example how we might use the preposition "of" to express any number of relations between and among objects participating in situations. Thus, we can speak of "the victim of a robbery", "the victim of a robber", "the robber of a victim", "the robber of the jewelry", "the loot of the victim", and perhaps "the robber of that robbery". One analysis of this phenomenon is to construe words like "robber" as meaning "an individual in a Robber relation to a robbery event". We must then also construe "of" generously enough to include the relationship between such individuals to other individuals in aspectual relations to situations (e.g., "victim of the robber"), as well as the relationship of such individuals to situations themselves (e.g., "victim of that robbery"). The peculiarity of phrases like "the owner of that ownership" is then attributed to the rarity of the direct expression of the state of owning something per se.

Note that I am positing no relations in the underlying logical form that hold directly between the individuals that participate in aspectual relations of the same situation. For example, there is no "Owner-owned" predicate that might hold between an owner and a possession; having such a predicate would be equivalent to adopting the non-aspectualized predicate-based representation that we have eschewed. (I.e., it is the same as having a predicate "Owns" that holds been owner and possession.) Similarly, a "Robber-victim" predicate, while not identical to re-introducing a predicate like "Rob", would be a step in this direction, and a step away from an aspectualized format. Arguing as we did in the previous section, we cannot rule out having a "Robber-victim" state, which is some relation to a Robbery event, but we can take the position that such states are neither necessary nor appropriate for representing the way events like robberies are normally conceptualized.

5.4. Propositions and Situations

Thus far I have emphasized the importance of situational objects. I have suggested that such objects have received less attention in semantic network research than they are due; occasionally, they have even been confused with propositions. Propositions, on the other hand, have been given rather prominent treatment. What role remains for them?

Adding a full ontology of situations does not seem to reduce the need for propositional objects. There are at least two arguments for their existence. One is the need for propositional anaphora; the other is the familiar arguments about referential opacity. However, when situational and propositional objects are considered together, the demands on propositional objects change considerably.

Let us first look at situations corresponding to verbs of propositional attitude. For example, suppose we want to represent sentences like the following:

(70) Lynn knows that Jan went to New York.

Presumably, we will represent a "knowing" similarly to any other state, namely, as an object with aspectuals designating the knower and the known. However, what kind of object can be known? While it may be tempting to believe this to be a situation, this cannot be so. A situation is just the wrong kind of entity to be known or believed, just as a person or physical object cannot be known or believed (in the pertinent sense). More formally, if we tried using situations for this purpose, exactly what is known or believed about the situation becomes difficult to determine. For example, suppose we represented (70) as involving the following:

(71) AIO(k1,Knowing) & Knower(lynn,k1) & Known(g1)
& AIO(g1,Going) & Goer(jan,g1) & Destination(newyork,g1)

Then the standard issues of referential opacity would appear. In particular, there are apt to be other predications about the situation referred to by g1, and we would normally not want to attribute all of them to the knower. For example, if we knew about Jan's going to New York that Jan left from San Francisco, but we don't know whether Lynn knows this particular fact, then it is awkward at best to state this fact without also falsely implying that Lynn were aware of it. That is, there might be another event term, g2, denoting Jan's going from San Francisco to New York, but which denotes the same event as does g1 above. I.e., g1=g2. Since the facts about g1 are not in any special context (they are simply facts about an event), an agent to which we attribute all these believes could infer, correctly, that the origin of g1 is San Francisco. This inference is correct because the origin of that event *is* San Francisco. But then (71) would no longer state what it is supposed to state.

Intuitively, what we want is some way to delineate just those propositions about g1 that appear in (71). One possibility is to do what Maida and Shapiro (1985) propose, which is to interpret terms like "g1" intensionally, and not to substitute equals for equals as a basic reasoning rule. However, we have reasons to be discussed below for rejecting this notion of intension altogether. But in any case, even Maida and Shapiro assume that the object propositional attitudes is a proposition. Thus, we introduce proper propositional objects. One way to do so is simply to put the proposition "in-line". Then, in place of (71) we would have the following:

(72) AIO(k1,Knowing)
& Knower(lynn,k1)
& Known(AIO(g1,Going) & Goer(jan,g1) & Destination(newyork,g1))

Since the known here is a proposition, and is in a context involving propositional attitude, anything else we may come to believe about g1 would not affect the meaning of (72).

This argument demonstrates the utility of propositions, but not of propositional objects. However, objects corresponding propositions can be justified on a basis similar to that we have been using for situations. In particular, pronouns can refer back to the propositional content of an utterance as well as the situation such a proposition describes. For example, consider following

(73) Jan went to New York.

with

(74) This took five hours.

versus

(75) Lynn knew this.

In the first case, "this" presumably refers to the event which has a duration, and not the proposition, which doesn't. However, in the second case, "this" refers to the proposition, not the event. Therefore, one would have needed to posited a proposition associated with (73), as well as a situation.

Moreover, one needs a way to represent unknown propositions. That is, in a sentence like "Jan told Lynn something, but Lynn couldn't remember it" we would like to represent what Jan told Lynn as a proposition whose content is unavailable to us. Perhaps later on, we would want to refer back to this proposition, and specify what its content is. This would also be the preferred treatment of (75) above: We might want to initially state that Lynn knew some (contextually uniquely determinable) proposition; only when the referent has been determined would this proposition be identified as the contents of (73).

Thus, it seems that we need propositional objects as well as situational ones. Let us introduce the operator "Prop" for this purpose. For example, using "Prop" we can offer the following notation for (70):

(76) AIO(k1,Knowing) & Knower(lynn,k1) & Known(p1)
& Prop(p1,AIO(g1,Going) & Goer(jan,g1) & Destination(newyork,g1))

Here p1 designates the proposition that Jan went to New York.

If we knew that Lynn knew something, but we didn't know what, we would say the following:

(77) AIO(k1,Knowing) & Knower(lynn,k1) & Known(p1))

Later on, we can use "Prop" to unproblematically assert the content of p1.

"Prop" is syntactically identical to "Fact" or "**". However, "Prop" is to be interpreted as associating an individual with a proposition, rather than with a situation, which, as was suggested in our critique of Schubert and Hwang's proposal, is probably a better interpretation of proposition-based-situation notations.

It seems that considering both situations and propositions together eases of the representation burden that is sometimes overextended to each one. Note that as a reification of propositions, rather than situations, proposition-based-situation proposals are no longer problematic. Unlike situations, propositions are completely bounded in extent, and are thus identical given the same content. That is, there is only one proposition that Jan went to New York, and that Jan went to New York is its entire contents; however, the event of Jan's going to New York might have any number of other components.

Also, the problem of what predicates should apply to situations in a proposition-based-situation notation does not arise if we consider these items propositions. For example, situations can be implicated in causality, and hence need to be the arguments of predicates like "cause". Propositions, on the other hand, don't

cause much to happen in the world; therefore, they can be restricted to a few types of situations, namely, those situations of propositional attitude (and, of course, the operator "Prop"). A case in point is (53) and (54) above:

(53) Either John went to New York or Bill went to Pittsburgh.
(54) This infuriated Mary.

Here the referent of "this" could be interpreted as the proposition expressed in (53) (or perhaps, Mary's learning of this proposition), rather than a situation described in (53). Also, we can avoid troublesome potential circularities by simply recognizing that predications involving "Prop" are not predications within the domain of discourse, and hence, are not amenable to further predication of "Prop".

5.5. Intensional Representations and the Equivalence of Situations

The preceding discussion took an extensional view of situational objects. This implicitly raises the general issue of whether intensions need to be represented at all. In intensional semantic networks, e.g., Maida and Shapiro (1985), much is made of the view that no two distinct nodes are equal, and that referential opacity is the norm. However, with propositional objects, it seems that all needs for intensions in the representation can be eliminated. That is, it is perfectly acceptable to assume that situational and other individuals refer to objects in the world, and that nothing in our system corresponds to an intension.

One motivation for intensional representations (e.g., Woods (1975) and Maida and Shapiro (1985)) is that without them, it is not possible to represent sentences like "Jan knows that the Morning Star is the Evening Star". This is because such a representation would only have one node representing the extension, about which it is predicated that the object was both the Morning Star and the Evening Star. But in fact, with propositions in our notation, this is not the case. Here is one possible way to represent exactly this sentence without intensions:

```
(78) AIO(k1,Knowing) & Knower(jan,k1) & Known(p1)
     & Prop(p1, AIO(m1,Star) & Named(m1,"Morningstar")
              & AIO(e1,Star) & Named(e1,"Eveningstar")
              & =(e1,m1))
```

That is, Jan knows that something called the Morning Star and something called the Evening Star are the same thing. (I should have used a stative form instead of the predicate "Named" (and indeed, instead of the predicate "=") to be consistent with previous analyses, but I did not do so for the sake of clarity.)

Propositional contexts are considered referentially opaque, but elsewhere we can freely substitute equals for equals and arrive at truth-conditionally equivalent formulas.

One might argue about whether the right facts are included in the proposition proposed in (78). Actually, this famous example is rather defective, since what is meant by the intension of a proper name, especially one that is an interpretable phrase, is problematic, or at least, subject to a number of distinct interpretations. There are at several ways in which we might wish to modify (78), but none of them affect the force of the argument. For example, we might include "more meaning" in the propositional content, e.g., facts like The Evening Star is the first star seen in the evening. While I would argue against such an account, this proposal simply amounts to having other conjuncts in the propositional content, and does not affect the utility of the proposal.

Another set of modifications involves the degree to which we recognize this utterance to have achieved successful reference. The representation in (78) does not show how an agent might have understood this utterance as referring to objects with which it is already familiar. For example, it might be the case that the agent hearing (78) interprets both "The Evening Star" and "The Morning Star" as referring to the same

object, the planet Venus. However, we could provide this interpretation by adding to (78) "=(e1,venus)" and "=(m1,venus)" (not as part of the proposition, of course, but as other top-level conjuncts), where "venus" is a node having many other facts predicated about it. Once again, the representation has all the desired properties.

Alternatively, we might believe that some linguistic expressions refer more directly than this analysis would indicate. For example, in a given discourse, whenever the word "Jan" is used referentially, we might translate each use directly to the same constant, say "jan", rather than produce a new constant for each occurrence, each of which, when it is determined to be the same as some previous "jan", would at that point be declared equal to such a node, and perhaps merged with it. In the domain at hand, a corresponding example might be an interpretation of the sentence

(79) The Evening Star is Venus.

in which "Venus" is being used referentially, while "the Evening Star" is interpreted as a name. I.e., a paraphrase of (79) would be something like "The so-called 'The Evening Star' is actually Venus". Moreover, if (79) were the object of Jan's belief, say, then the propositional object itself would contain a mention of "venus", i.e., the same constant used by the agent to designate the extension is predicated to be part of someone else's belief. Thus, we would have the following:

(80) AIO(k1,Knowing) & Knower(jan,k1) & Known(p1)
& Prop(p1, AIO(e1,Star) & Named(e1,"Eveningstar") & =(e1,venus))

The complication here is to figure out what it means to postulate sharing an extension with someone else. In particular, the question arises as to what (80) implies about what Jan knowns about "venus".

The answer to this question sanctioned by the representation alone is "nothing much". All we have said is that Jan knows that the star named the Evening Star is the same as some object, but we have not said what Jan knows about this object. The broader answer to this question, though, is whatever is sanctioned by appropriate inferential processes. For example, if almost everyone knows that "venus" is called "Venus", or that it is the second planet from the sun, then it is reasonable to assume that Jan knows this too, unless this assumption is contraindicated.

The issue here is really a very general one having little to do with the particulars of the proposed representation. The issue arises any time a term is used both within and without a referential opaque context, which happens even in intensional networks like that of Maida and Shapiro (1985). The broader issue is the relation between mutual belief and successful reference. There is of course much to say about this issue (e.g., see Fauconnier (1985) and Sperber and Wilson (1986)). I note only that any number of proposals are compatible with the suggestions made above, none of which require objects representing intensions.

We are able to do without intensions here because we are willing to provide "redundant" information in the proposition. Thus, rather than have an intension for the Evening Star, we simply specify the propositional content of "a star named 'The Evening Star' ", and associate this content with a term. We may already know that "venus" is also known as "The Evening Star", so a very similar fact is already in the knowledge base. However, this redundancy seems to correspond to a rather intuitive interpretation of the information the sentence is actually conveying.

If intensions are not needed to deal with referentially opaque contexts, perhaps they are still required for "roles". For example, a sentence like

(81) The president is elected [every four years].

is not true of the person occupying the president role, but rather, seems to be true of the president role itself. That such roles are intensions is explicit in KL-ONE (Brachman, 1978). However, once again,

intensions appear to be unnecessary. This time, the solution is ontological. If we assume that we have categories like "President", then utterances such as (81) are treated by quantifying over individuals of such categories. Thus, it is simply true of all individual "President"s that they are elected. In this sense "the president" is treated analogously to "the dog" in "The dog has a tail". Of course, any individual president might be represented by an (extensional) object about which many other things are true, but such facts will not be true of individuals of "President" per se.

Another justification of intensions has to do with enabling agents to reason about non-existent objects (Woods, 1975). However, this objection to extensions can also be eliminated if extensions are construed in a cognitive correspondence sense. That is, when I say that "venus" denotes the planet Venus, I mean that it denotes some cognitive agent's idea of the referent in the world, rather than any actual object per se. Such objects are part of what Jackendoff (1983) calls the "projected world." Thus, we are not making any commitment to objective truth or reality by considering these objects as extensions. I believe this interpretation comes closest to capturing the intuition that there are objects to which linguistic expressions refer, even if these objects are not actual or real, and that it is preferable to denying that such objects have mental representations, but rather, that there are only many different descriptions which are known to be coreferential.

The same reasoning applies directly to situations. The only caution is about when it is correct to identify two events. It is perhaps useful to distinguish two cases. First, there is the case in which one situation is logically entailed by the other. Consider for example the representation of hierarchical information. As suggested above, suppose we want to assert that robberies are actions, with the robber the actor and the loot the object. One way to represent this information is to simply predicate these additional facts about the variable r in (69) that ranges over robberies. That is, we could include the following predicates within the scope of the variables of (69):

(82) AIO(r,Action) & Actor(a,r) & Object(o,r)

An alternative is to specify a new situation, and declare it to be co-referential with r:

(83) Exists action (AIO(action,Action) & Actor(a,action) & Object(o,action))
& =(action,r)

(83) is supposed to be within the scope of the universal quantifier of (69), so it means that, for every robbery event, there is an action involving the robber and the loot of that robbery, and in fact, this action is the same event as the robbery.

(Note that in any case, we are postulating very abstract categories like Action. Categories like State, Event, and Situation, etc., would also be included in the knowledge base. The knowledge base would also specify that each individual State or Event is also an individual Situation, etc., however we decide to express such information.)

These seem harmless enough. On the other hand, consider the case in which one of the two events does not necessarily entail that other. For example, suppose that I have replaced a pipe under my sink, and that this replacement fixed a problem with my sink. In this case, we could say that one event, described as replacing a pipe, is coreferential with another event, that of fixing my sink. Suppose we attempt to represent this situation with a single entity, e1. Then we would say something like the following:

(84) AIO(e1,Replacing) & Replacer(rw,e1) & Replaced(oldpipe,e1) & Replacement(newpipe,e1)
& AIO(e1,Fixing) & Fixer(rw,e1) & Fixed(sink,e1)

Let us suppose further that both the replacer and the fixer are agents, and that both the thing replaced and the thing fixed are objects. That is, we can infer (85) from the first set of conjuncts of (84) and (86) from the second:

(85) AIO(e1,Action) & Agent(rw,e1) & Object(oldpipe,e1)
(86) AIO(e1,Action) & Agent(rw,e1) & Object(sink,e1)

But, if (85) and (86) are both true, we have lost some crucial information; we no longer know which aspectuals go with which event category. In particular, if we make the usual assumption that actions have unique objects, one can infer that I replaced my sink with a new pipe, which is simply false. (A version of this problem appears in Parsons (1985)).

It is probably undesirable to abandon the assumption of actions having unique objects, since then actions may have any number of objects, only one of which is qualified to be grammaticalized as a syntactic object. The better solution, it would seem, is to deny the identity of the two events. We would say instead that there was a fixing event, f1, say, and a replacing event, r1, and that the latter "comprised" the former, or that some other such intimate but non-identifying relation holds between them.

Determining the correct vocabulary of such relations is an important open problem. However, it does not appear to be unique to situations. There are at least two other related cases. One is the relation between objects and the substances that comprise them. Some approaches equate the two. For example, Lenat and Guha (1988) define a lake as a quantity of water. However, this is certainly incorrect, as the particular water comprising the lake changes while the lake object remains constant. Another case is the relation between roles and their fillers. If we allow categories like "Passenger" along with individuals of such category, it is tempting to equate the role object with its filler. But again, problems will arise. For example, the yearly number of passengers is greater than the number of individual people who fly, since some individual may fly multiple times, and hence, count as several passengers. In both of these cases, as in the case of co-extensive but non-identical situations, the solution seems to require having a relation between objects that does not allow for substitutability, but nevertheless declares them to be co-extensive.

Finally, I note in passing that while Maida and Shapiro (1985) emphasize that their network is intensional and propositional, i.e., that it has nodes for propositions, it doesn't make sense to consider the propositional nodes themselves as intensional. That is, there is only one proposition corresponding to "John loves Mary", and if two nodes were created denoting this content, they would be equal, and, moreover, mutually substitutable in all contexts. The same could not be said for the other nodes of such a system.

6. Summary

I began by acknowledging the virtues of predicate- and category-based representations, in particular, their amenability to aspectualization, but accepting Schubert and Hwang's point about such representations being limited to reifying situations described only by atomic sentences in the logic. However, we found that their proposition-based-situation proposal, while overcoming this difficulty, results in an apparently unaspectualizable representation, and hence reintroduces a number of problems, some of which predicate- and category-based representations address, plus some additional problems of its own. I abandoned hope of resolving these difficulties, and instead, sought to extend the category-based solution.

The extension is first an ontological one, in that it introduces situations corresponding to the logical forms for which category-based solutions would not otherwise apply. The problems Schubert and Hwang illuminate can thereby be resolved while maintaining category-based advantages.

The second aspect of the extension is to allow propositional objects. These are needed primarily to deal with problems of referential opacity and for propositional anaphora. Having propositions as objects in the system eliminates the need for any kind of intension altogether.

While the proposal is primarily a way of maintaining aspectualization, this necessary virtue yields a rather cumbersome representation. In particular, what used to be a simple predication now requires a variable or a constant and a number of predications; also, every utterance has both a propositional and situational

object associated with it. However, this inelegance appears to be the price one has to pay for the features crucial for an adequate representation.

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