Passing Markers: A Theory of Contextual Influence in Language Comprehension*

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Most Artificial Intelligence theories of language either assume a syntactic component which serves as "front end" for the rest of the system, or else reject all attempts at distinguishing modules within the comprehension system. In this paper we will present an alternative which, while keeping modularity, will account for several puzzles for typical "syntax first" theories. The major addition to this theory is a "marker passing" (or "spreading activation") component, which operates in parallel to the normal syntactic component.

1. INTRODUCTION

The vast majority of Artificial Intelligence language comprehension systems (Bobrow & Webber, 1980; Charniak, 1981; Erman, Hayes-Roth, Lesser, & Reddy, 1980; Friedman & Warren, 1978; Hayes, 1977; Marcus, 1980; Rieger & Small, 1979; Riesbeck & Schank, 1976; Wilks, 1975; Winograd, 1972; Woods, 1968) follow the general model shown in Figure 1. An initial component uses syntactic knowledge to get a first cut at the functional structure of the sentence (e.g., in "Fred was killed by John" we need to distinguish the killer from the killed). The syntactic process is guided by a semantic unit which also is responsible for turning the input into the semantic representation. For most of these models, the information passed between syntax and semantics is some form of syntactic tree. While some of these theories do not admit to a separation of syntax and semantics, they too follow this

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model, only now the information passed to the semantics is some form of partial semantic representation. Otherwise the model usually holds true.

In this paper I will first present several puzzles which arise given the above model. They will deal with:

- The determination of "context" in story comprehension, e.g., "Jack picked up a menu" has a "restaurant" context.
- The role of context in word sense disambiguation, e.g., "Three men were playing poker. One man called." selects a rare use of "call."
- The relation between syntax and semantics. One routine, coroutines, separate but parallel?

I will then put forward a theory which accounts for these problems in a natural way. The basic outline of this theory is shown in Figure 2.

This is not so much a new theory as a refurbishing of an old one—the spreading activation model. However, while spreading activation has had a long and distinguished run in psychology (Anderson, 1976; Collins & Loftus, 1975; Collins & Quillian, 1969), and to a lesser degree in Artificial Intelligence (AI) (Quillian, 1966), since the early 70's spreading activation has mostly disappeared from the AI literature.¹ For whatever reason, evidence which retained the interest of psychologists has had little impact on AI researchers, including the current author.

Thus, this paper will tend to ignore the large psychological literature, and instead relate spreading activation (or marker passing, as it is commonly referred to in AI circles) to common AI problems. In particular, I will look at the problems listed above: context determination, word sense disambiguation, and the semantic guidance of syntax. The sole exception to the exclusion of psychological evidence will be some experiments by Swinney (1979). I make this exception because his data so obviously contradict most standard AI theories of word sense disambiguation, and, by extension, the relation between word sense disambiguation and syntax.

While I have not programmed this theory, and have no illusions about the simplicity of the task, I nevertheless see it as an AI theory. That is, I expect to see it programmed. At the same time, given the popularity of

¹Of current AI models, the one closest to mine is the IPP model of Lebowitz (1980) in the sense that it too goes against the idea that syntactic processing typically precedes other processing. However, IPP is anti-modular, which gives it a very different flavor from the one presented here. It would take a better scholar than I to get beyond the superficial differences to find it there are deeper similarities.
Figure 2. The Proposed Theory
spreading activation within psychology, the model presented here may say something about people as well.¹

2. THREE PUZZLES

2.1. Syntax and Semantics

Of all the issues in language comprehension, the relation between syntax and semantics is one of the most puzzling. While linguists have been poor salesmen, insisting on selling grammatically judgments when most people are interesting in buying semantic relevance, most, if not all, of the normal rules that linguists come up with are of direct relevance in semantic interpretation. To take a classical case, the rule of equi np deletion accounts for the relation between

Jack wants to go to the store.
Jack wants Bill to go to the store.

by stating that when the internal clause following “want” (or similar verbs) is missing its subject then the subject is interpreted as the subject of the higher clause. This rule, and syntactic rules in general, are crucial for the correct determination of the “functional structure” of a sentence, i.e., who plays what semantic roles in the sentence. As such, I have argued elsewhere (1981a,b) that it seems plausible to assume that the rest of semantic processing only occurs after syntax has finished establishing the functional structure. This need not be at the very end of a sentence; the boundaries of major constituents would do. In such a model, semantics can be thought of as a subroutine, being called by syntax from time to time.

There are two potential problems with such a position. First, people understand ungrammatical sentences, whereas typical syntactic parsers reject such sentences out of hand. If we depend on a syntactic parser to establish the functional relations, how is it that we can understand ungrammatical sentences? This argument can, I believe, be overcome by simply assuming that the syntactic parser can, by the nature of its architecture, parse ungrammatical sentences. For one such parser the reader can consult Charniak (1981a).

There is, however, a more important objection. Not only can people handle ungrammatical sentences, they can understand completely agrammatical strings of words. For example:

Fire match arson hotel

¹Most AI theories, if taken literally, are much too strong as psychological theories. Thus, we must distinguish between some weaker “core” of the theory which bears the psychological burden. In this case, the core is that portion shown in Figure 2.
This is simply a string of nouns in no particular order. How is it understood? Let me stress that the typical alternatives to the "syntax first" position do no better when confronted with such examples. For example, one alternative is to use a parallel arrangement (called a "blackboard" model) as in HEARSAY (Erman, et al., 1980). In this scheme the syntax and semantic components work in parallel, leaving their conclusions on a common "blackboard". The idea is that, even if the syntactic component fails, the semantic component will still succeed, at least if the sentence is comprehensible.

That there are troubles with this model is suggested by the fact that HEARSAY itself did not really use it. While technically the two systems worked in parallel, in actual design the semantics would only work on the output of the syntactic component, making the model isomorphic to the semantic subroutine model proposed earlier. Nor is it hard to see why this should be the case. As we have already noted, syntax is the most obvious way to get a first cut at the logical structure of the sentence. In a real blackboard model, the semantics would be forced to do without the logical structure established by the syntactic component. This would mean that it would have to re-establish the same information by other means. If it could do this, then why bother with syntax at all?

We can save the "syntax first" position by simply assuming that syntax has some escape clause allowing it to pass the string along to semantics should the string prove recalcitrant to normal syntactic methods. In the next section we will see that there are even problems with this very weak theory. For now, however, let us just note that the basic puzzle is still left open: semantics requires functional relations, functional relations require syntax, but semantics can be done without syntax.

### 2.2. Contextual Determination of Word Senses

In the presence of the right context, people are not consciously aware of ambiguous words. Introspection tells us that we never even considered most (any?) of the alternatives. Rather, things seem to be organized so that the right meaning is considered first. Furthermore, this introspection is supported by examples like:

The astronomer married a star.

Most people have trouble finding the "movie star" reading of "star", despite the fact that the "astronomical object" reading makes it difficult to imagine the ceremony. Such examples have been taken as evidence for a theory in which the order people consider word senses is modified by contextual clues (or even that only some word senses are "available" for consideration). According to this theory, our troubles with such examples stem from the fact that the first sense tried does not fit the actual requirements of the sentence, and hence has to be rejected.
However, some recent results by Swinney (1979) seem to argue against such a position. In Swinney’s experiments, the subject is given an auditory text such as:

Rumor had it that, for years, the government building had been plagued with problems. The man was not surprised when he found several (spiders, roaches and other) bugs in the corner of his room.

The text in parentheses gives contextual clues for one meaning of “bugs”. This material could be deleted, or replaced with other words which would select a second word sense, such as “spying device”. Immediately following the word “bugs”, and before the next word in the sentence, a string of letters is visually presented. The subject is asked to determine if such a string is an English word or not, and the time to do this task is recorded.

The basic effect on which these tests depend is this: if the string is a word, and furthermore, is a word semantically related to the one just heard, then the reaction time is shortened. So, if the subject is shown “ant”, he would react faster than if shown “sew”, a word with no relation. The question then becomes, suppose the subject is shown a word which is related to one of the senses of “bug”, but not the sense selected by context? For the above example, “spy” would be such a word. Swinney’s results indicate that the reaction time is again shortened. The interpretation should be clear. Presumably the speed up in identifying “ant” is due to our having accessed a semantically related word sense, namely the sense of “bug” having to do with insects. If we get the same effect with “spy”, then that seems to argue that we have again accessed a semantically related word sense, this time “bugging device”, despite the fact that context was sufficient to suggest the other reading of “bug”. Thus, it would seem that context does not, in effect, preselect which word senses we consider.

But if this is the case, why should people have trouble with the “astronomer/star” example? It made sense when we assumed that context preselected the word sense incorrectly. But we have just argued that context does not preselect. Thus, it would seem that semantics has all the senses available to do it, and has all of the information needed to make the right choice (in particular, it knows that “star” is the direct object of “marry” and that “marry” requires a person as direct object). Yet semantics still makes the wrong choice. In the standard model of Figure 1 there is no reason why this should happen. Why then do people go wrong?

Even more puzzling, other of Swinney’s results seem to indicate that syntactic word categories have no effect on which word senses we look at (Prather & Swinney, 1977). So, if the sentence uses “watch” as a noun, we still get reaction time speed ups with words related to the verb sense of “watch”. Again, with the standard model, this makes no sense. If we only
try to decide on the word sense after syntax, the system would know the part of speech and, therefore, would only need to consider the sense related to the correct part of speech. That this does not happen suggests that we start trying to decide on the word sense prior to the completion of syntax, in contradiction to Figure 1.

2.3. Finding Explanatory Actions

At Brown we have written a program which is able, in some cases, to infer explanatory actions in "stories" (Wong, 1981). So, if we tell it that

Jack picked up a menu.

it has a specially indexed data base which allows it to find situations in which this would be a reasonable activity. In particular, it finds that it would be particularly appropriate if Jack intended to read the menu, thus this action is postulated as a "explanation" of the reported event. The program would then be applied recursively to the reading activing, with the final result that it assumes that Jack is eating out and trying to decide what to eat. Note that this assumes that we have bidirectional pointers from an action to higher level actions in which it may play a role. We will also assume that we have such pointers from objects to actions in which they typically play a role, and from objects to their superclasses (this latter is the ubiquitous "isa" pointer). One important feature of this program is that it depends crucially on having a reasonably complete knowledge of the functional structure of the sentence. So, in the above example, the only way it finds "reading" is because it knows that some person picks up some reading material. If we had told it

The wind picked up the newspaper.

nothing of the sort would have been postulated. Hence, it depends on knowing that the agent is a person, and not a breeze. As we have already noted, it is syntax which is primarily responsible for establishing functional structure.

Since it would seem odd to postulate reading in the "wind" example, this theory seems reasonable. That is, without the functional structure we would have postulated an absurd action. Furthermore, in other cases it is only the functional structure which allows us to suggest the correct action at all. For example:

The man sawed the woman in half.

This suggests a magic trick. But the words without functional structure are not sufficient. We do not get this reading with:

The man and the woman sawed something in half.
This suggests that it is important in our understanding of "The man sawed the woman in half" that it is a person who is the direct object (or patient).

But then how do we explain examples like the earlier "fire match arson hotel"? Here we get some "explanation" in which someone commits arson by setting a hotel on fire with a match. No functional relations are given here, and hence they cannot be required. So, do we use functional relations in the process or not? Also, if we do not, what happens to our standard theory?

3. THE THEORY

As stated in the introduction, I believe that some variation of a marker passing, or spreading activation theory, can account for the problems just outlined. We will consider them in reverse order.

3.1. Finding Explanatory Actions

The problem is that we appear to have two kinds of phenomena. One requires the use of functional relations in finding explanatory actions, the other does not. Solution: postulate two separate capabilities. One works on the cases which require functional relations; the other works on the ones which do not.

The theory is easy enough, the hard part is its acceptance. The remainder of this section will be devoted to convincing the reader that there is independent justification for such a solution. To do this we must approach the question from a new direction.

3.1.1. Searching for Connections. In an example like:

Jack picked up a menu.

our current program depends crucially on the fact that at each point where it must hypothesize an explanatory action, there is one which is clearly superior to all of the rest. That is, it can choose the best path on the basis of local information. It need not search several possible paths in order to find the best. While this seems reasonable for the above example, there are certainly cases where one must investigate multiple paths.

Jack got a rope. He was going to immobilize Bill.

There are many reasons for getting a rope: jump rope, hang oneself, hang up clothes, or tow a car, to name just a few. Similarly, immobilizing someone may be accomplished in any number of ways: hit him over the head, and chain him to the floor will serve as alternatives. To understand that Jack will use the rope to immobilize Bill requires that our program search through this maze of possibilities.
It is important to realize that the number of possibilities to be checked is very large. One of my favorite examples in this regard is:

Jack was going to commit suicide. He got a rope.

I have always taken it as axiomatic that the number of uses for rope, and the number of ways to commit suicide, would make a serial enumeration of all possibilities out of the question. However, a common response has been that there are only a small number of standard ways to commit suicide, and hanging is one of them. So perhaps enumeration is not so bad.

It may well be true that we have only a small number of standard ways, but our ability to understand such examples is not limited to the standard possibilities. Consider the following continuations to “Jack was going to commit suicide”:

He found a bomb.
He found a hang-glider.
He found some pills.
He found a tall building.
He found a tiger.
He found a razor blade.
He found a tarantula.
He found a chain saw.
He found a blazing building.
He found a plastic bag.
He found an abandoned refrigerator.

Some of these are definitely odd, but people seem to be very consistent in their interpretations. Admittedly, not any object will work. For example, “He found a light bulb” would leave most of us puzzled. The basic constraint seems to be that if the object has a standard way in which it can participate in someone’s death, it can be considered for suicide. But the number of such objects, and perhaps even the number of types of death, is large indeed.

A lot of work has been expanded on finding ways to accomplish such searches in some “intelligent” way so as to reduce its expense. The fact of the matter is that after 10 or more years of work on this question, no such method has been found. The only suggestion which has offered even a glimmer of hope is simply do the search and depend on parallelism to bring the time down to reasonable levels. In other words, give up looking for “smarts” and depend on “muscle”. I have resisted this suggestion for years, but no longer.

3.1.2. Marker Passing. Roughly speaking, proposals for doing such searches have been of two types, which I will call “dumb marker passing” and “smart marker passing”. Dumb marker passing is fairly old, and is another name for the standard spreading activation model already men-
tioned. Smart marker passing is relatively new, and was first proposed by Fahlman (1979).

Fahlman’s scheme is “marker passing” since one can think of it as passing markers along a semantic network. In Fahlman’s program, if you wanted to know if Clyde the elephant is gray, you first pass markers from the node representing Clyde, to those nodes which are up the isa hierarchy from Clyde. Doing this repeatedly until we mark no new nodes causes Clyde, plus all of his superclasses, to be thus marked. We then pass a second type of marker to any node which is connected to a currently marked node by a “color” link. The resulting node will be Clyde’s color.

This example illustrates two properties of Fahlman’s theory. First, marker passing should work quite well for finding connections in stories. We start markers from each action, and wait until we find something which gets markers from both ends. Second, Fahlman actually proposes to do deduction using his scheme. That is, his scheme will not simply say there is a connection between Clyde and the color grey, it will actually deduce that Clyde’s color is grey.

Nevertheless, I do not intend to use a marker passing scheme for deduction. The trouble is that parallel deduction is very complicated. While the basics are easy to understand, what happens when one allows “exceptions” to rules (birds fly, but penguins are an exception) is quite difficult, and few people understand the scheme in its full glory. Furthermore, I have doubts that Fahlman’s scheme will do the sorts things I need, but I will not try to support this contention here.\(^3\)

Instead of Fahlman’s complicated scheme, the theory I am proposing relies only on dumb marker passing. Given a predicate, such as “rope”, we can pass markers to predicates which represent:

- Objects and actions in which rope plays a part (and vice versa, that is, we can go from noose to rope, as well as from rope to noose)
- Concepts higher on the isa hierarchy (tying-thing, or something of this nature might appear over rope, string, chain, ribbon, etc.). I will assume one may not go down the isa hierarchy.
- Actions which involve a given action, or which are alternate ways of accomplishing a given action (this does not apply to rope, but would connect kill to hanging).

Even dumb marker passing is very expensive in a serial machine, hence we will assume that people do it in parallel, and that one day our machines will too.

\(^3\)There is also some evidence from psychology supporting the use of dumb marker passing over smarter versions (Anderson, 1976).
It is important to keep in mind, however, that because this scheme does not do inference, it cannot keep track of who is doing the action, or to whom. So, if we read

*Bill wanted to commit suicide. A rope fell down on Fred.*

our marker passing scheme would work exactly the same way:

suicide—kill—hang—noose—rope

Thus, we need a second program which *does* do deduction, and hence would have the information needed to decide that things do not really match up in this last example. I will call this second program the *path checker* (Wong (1981) calls this program *pragmatics*, but given the theoretical baggage associated with this term, I have chosen a more neutral term.). The path checker would be much smarter than the marker passer, but it would not be a parallel scheme, and thus would not incur Fahlman’s problems. On the other hand, because it would only look at the suggestions put forward by the dumb marker passer, it would not have to do the exhaustive search which promises to be so costly in a serial machine.

**3.1.3. Back to Our Original Problem.** The reader who has steadfastly kept our original problem in mind should now see that I have accomplished what I set out to do. We saw that some examples of action recognition went forward without benefit of functional relations, while others depended on them. To account for this I proposed that there are two separate processes. We now have them—the marker passer and the path checker.

Furthermore, the decision I made not to have the marker passer do deduction now takes on an added significance. In order to deduce new facts from old we have to have the functional structure of the old facts. That is, if we wish to deduce that the fly is dead after reading that “The frog ate the fly” then we must know that the fly is the thing eaten (the patient) and not the eater (the agent). But, as we have already noted, in many cases we can find explanatory actions without any recourse to functional structure (our “match fire arson” example). Thus, any scheme such as Fahlman’s, which combines marker passing with deduction, would, at the very least, be more powerful than need be for such examples, and possibly (unless designed very carefully) not be able to handle such examples at all.

**3.2. Word Sense Disambiguation**

We now have a proposal which will account for our puzzle concerning the hypothesis of explanatory actions. Next let us consider the second of our puzzles—how is it that the experimental evidence suggests that we access all
senses of the word at the same time, while examples like “The astronomer married a star” indicate that we are thrown off if context suggests the wrong sense.

Essentially we need simply follow some ideas put forward by Hayes (1977) and others on how to perform contextual word sense disambiguation. Using the terminology of the present paper, Hayes' program disambiguates a word with multiple senses by using a marker passing scheme. It starts marker passing with the predicates associated with each word sense and the correct word sense would be the one which first found a node which already contained a marker put there by the context.

This fits easily into the marker passing scheme suggested in the last section. The only change required is that we put in all word senses associated with a given word when we do intersections, rather than just the “correct” ones. So let us adopt this idea.

With this in mind, Swinney’s results make much more sense. First, this theory matches his results in so far as all senses of a word are activated. Second, we can now account for the “astronomer/star” examples. In order to see this, let us now ask exactly when this marker passing will be done. Since the process does not require functional relations, there is no reason why it should be dependent on the output of syntax. Thus, the logical place to put it would be in parallel with syntax. But if this is the case, then it is clear why we get confused with the “astronomer/star” example. Our marker passer decides on “celestial body” before syntax can give us the functional structure which would suggest that “well-known personality” would be a better reading because the direct object of “marry” should be a person.

Furthermore, note that this theory predicts (correctly according to Swinney) that we access all senses of a word, independently of grammatical type. Since marker passing works in parallel with syntax, it must start before we have any idea of the word’s part of speech.

The theory up to this point is illustrated in Figure 3.

3.3. The Relation Between Syntax and Semantics

We now turn our attention to the first of the puzzles we brought up at the start of this paper—how can we get semantic information without the use of syntax when it is syntax which gives us the functional relations needed for semantics? We can now see that the puzzle stems from the plausible, but erroneous, assumption that semantics requires functional relations to operate. Dumb marker passing does not require functional relations and is, thus, independent of syntax. As soon as we recognize this fact, the puzzle goes away.
Figure 3. The Proposed Theory—Pass 1
There is, however, a bit more to say on this subject. To say it, however, requires a detour into a new topic.

3.3.1. The Case/Slot Identity Theory. The case/slot identity theory states that the cases of case grammar and the slots of frames are one and the same. We will assume the version of this idea presented in Charniak (1981). The interested reader should consult that paper for details. For our current purposes, we need only a few facts. First, as we commented earlier, given a predicate which describes some activity, we must have pointers to the sub actions of that activity, the restrictions on the objects which take part in that activity, etc. This collection of pointers is, to a first approximation, a "frame". The collection of objects which take part in the frame are called the slots of the frame. The objects (slots) will be given names so that we may refer to them within the frame. So, for example, in our discussion of hanging, we noted that we would have to talk about the noose used in the activity. The noose would then be a slot in the hanging frame.

Now many frame representations (Brachman, 1979; Charniak, 1981; Hayes, 1977) have the property that slots in a superior frame are "inherited" by lower frames. That is, if an elephant is a mammal, and if mammals have a head slot, then it will not be necessary to explicitly include a head slot in elephant since it inherits the slot from mammal. Thus, using a notation from Charniak (1981) we would write the frames as:

```
(frame: mammal
  isa: (animal ?mammal)
  slots: (head-of (head ?head-of)))
```

```(frame: elephant
  isa: (mammal ?elephant)
  slots: (trunk-of (trunk ?trunk-of)))
```

```
(frame: head
  isa: (solid ?head)
  slots: (eyes-of . . .))
```

Here the elephant frame need not have a "head-of" slot because it inherits this slot from mammal. It does have an explicit slot for trunk, since this is not inherited.

Returning now to case theory, we will use the term action to denote an event which was deliberately caused by some agent. As such, the action frame will have a slot for agent:

```
(frame: action
  isa: (event ?action)
  slots: (agent (animate-heing ?agent)))
```

If we take the case/slot identity theory seriously, then this agent slot is, in fact, the agent case. Other slots will appear in more specific frames for tran-
sitive actions, for movements, etc. Thus, in our version of the case/slot identity theory, a case corresponds to a single slot in a high level frame—a slot which is then inherited by lower frames.

At the same time, if we are to take the case part of the case/slot identity theory seriously, then the fact that some noun phrase or prepositional phrase fills this case/slot should tell us things about the surface form of the phrase. How this works is not of concern to use here; we will simply assume it to be true.

3.3.2. From Marker Passing to Cases. Let us return now to the interaction of syntax and semantics. So far, we have simply noted that the marker passing scheme is independent of functional form (indeed, independent of syntactic category) so it is independent of syntax. What about the reverse? Is syntax independent of the marker passer?

The only connection between the two shown in Figure 3 is that the marker passer feeds word sense suggestions to semantics so that, at the very least, these can be incorporated into the semantic representation. However, given the case/slot identity theory, the marker passer will produce more. Consider the various intersections we will find in the course of processing a sentence like:

The boy raked the leaves.

Figure 4 shows a portion of our knowledge about yard raking. In particular, it shows that the word "leaves" will eventually be hooked up with the word "rake" with the path indicating that "leaves" should be considered the patient in the yard-raking frame. This is similar for "boy", except here the connection with rake is slightly indirect, since the specification that agents are animate beings is specified in action, rather than in yard raking directly.

The point is that our marker passer will (unless we go out of our way to prevent it) find all possible semantically reasonable case assignments in the sentence. If it is indeed true that knowing the case of a noun phrase is useful in the processing of the sentence, then this information would be useful to the syntactic processor, and hence it would seem reasonable to assume that the syntactic processor uses this information. If this is correct, then Figure 3 should be modified to indicate that the marker passer also passes case suggestions to syntax. This gives us the version of the theory shown in Figure 2.

However, remember that the marker passer will suggest all semantically possible case relations. In Figure 4, I deliberately only included the correct ones. There will be numerous incorrect ones. Movement actions take physical objects as their patients, and since the boy is a physical object, he too could be the patient of rake. However, I suspect that this sort of problem will not be too bad, since it seems reasonable to consider the alter-
Figure 4. Paths to Case Relations

Nate paths starting with the shortest. As we shall see, however, the shortest is not necessarily the correct path.

Naturally, for situations where the semantics do not strongly predict case relations the results of the marker passing will be much less useful, or even useless. The classic case is the so called "reversible passive" as in:

The boy was hit by the girl.

Here the semantics do not suggest who did the hitting and who got hit. Both "girl" and "boy" will be suggested as agents of the action "hit". Furthermore, "boy" will have a shorter path to "hit" as the agent than as the patient, hence the comment in the last paragraph that shortest is not always best.

4. CONSTRAINTS ON MARKER PASSING

The ideas presented here have not been implemented. While the behavior of many AI programs can be predicted well by someone who has a good understanding of the basic theory, this is not true of marker passing. The problem is that while a marker passing algorithm is basically quite simple, the ensu-
ing behavior can be quite unintuitive. A major issue here is that of false positives.

As described so far, the marker scheme has few built-in limits. What is to prevent the markers from spilling over the bounds of rational associations and reaching the shores of the ridiculous? In such cases we would have our marker passer reporting many many intersections, but almost all would be false positives. At best these would be rejected by the path checker and simply waste a lot of time. At worst they might lead the entire mechanism astray. Some bounds must be built in.

4.1. False Positives in Case Relations

We have touched upon this problem on two occasions in this paper. The most explicit of these was in the last section when we noted that our marker passer would find all sorts of semantically plausible, yet incorrect, assignments of objects to cases. Actually, the situation is much worse than we described. As currently described, not only will we find potential case relations within the sentence, but without as well. So, consider a story like:

Jack picked up a menu.
The waiter came over to the table.

When we start the second sentence, there will be nothing to prevent us from finding a connection in which “waiter” is seen as the agent of “pick up” even though they appear in different sentences. For that matter, if the first sentence suggests actions like “eating at a restaurant”, the agent slot of this action would be also proposed as a semantically reasonable case for “waiter” to fill.

One possible solution would be to use “new” markers for each sentence, so we could distinguish such situations. This might work, but it would fail abysmally for long sentences with many subclauses. However, it seems likely that in such cases syntax eventually decides that it has an entire clause, and transfers it over to semantics, and ultimately to the path checker. If this is possible, then the new marker technique might work. At any rate, it seems the most promising option.

Alternatively, we could give up on the idea of having marker passing produce suggested case relations. This is possible, but as we noted earlier, the marker passer will find them in any case. If we want it not to find them, then we will have to add some kind of restriction to stop it.

4.2. False Positives and the Isa Hierarchy

The other time we touched upon limiting marker flow was when we noted, in an off-hand way, that we would not allow markers to flow down isa
links. The reason for this limit is simple. If we are allowed to travel all the way up the hierarchy, and then all the way down again, we have implemented a very inefficient universal marking algorithm.

There are other problems associated as well with marking the isa hierarchy. As currently proposed, we are guaranteed to always get one false positive intersection for every marking pass—namely when the marker reaches the top of the hierarchy and finds a meaningless intersection with every other search which reached the top as well. Typically, this will be at the concept *everything*, although it may be at a lower level like *action*. We will call these "isa intersections". As isa intersection is an intersection where the two links which lead to it are both isa links. If we only had one isa intersection per marker pass we could accept it, but it takes no great imagination to envision such false isa intersections occurring all over the place.

At one time I thought that all isa intersections were false positives and hence, the marker passer could simply ignore them. I still believe that this is true for inferring contextual actions. After all, in such cases we are looking for a chain of planning steps such as that which connects suicide with obtaining a rope. Finding that two of our actions are both instances of some general category hardly fills this goal. 

However, it seems that the rule "all isa intersections are false positives" is incorrect for word sense disambiguation. Consider:

Jane liked the German shepherd, but I preferred the boxer.

Here the disambiguation of "boxer" seems to rest solely on the isa intersection of "boxer" with "German shepherd" at the node for dog. Some other rule must be found.

One possible way to eliminate marker spillage is to limit the number of markers. This can be done in several ways. Perhaps the most common is to assume that markers are not "all or none" things, but rather have a certain "force" behind them (Collins & Loftus, 1975). When we pass marker from a node to its $N$ neighbors, then the force of the marker at the neighbors is divided by $N$. Naturally, should the force behind the marker go below some threshold, the marker no longer propagates. This may work, but it is by no means clear that it will. For one thing, we have postulated that we have enough markers to see that "The boy raked the leaves" has an intersection of "boy" and "rake" at this point where the boy is seen as filling the agent slot of actions. This is very deep indeed. (But again, we have already suggested that the case proposing mechanism may have to go, so that we would

*Do not confuse this with the superficially similar case of two actions both being involved in some higher action, like, for example, gardening. This would be useful to recognize, since either one by itself might not be enough to allow us to postulate there is gardening afoot. The difference is that here we would say that we have seen two distinct steps in a generalized gardening plan, not two actions each of which "isa" gardening.
no longer be required to mark this deeply.) Also, according to this theory, what gets marked will change with every modification of our knowledge base. Perhaps such changes will be at the level of idiosyncratic differences between people, but things seldom work out this well.

Two points should be clear from this section. First, there is a host of problems which must be investigated. And second, the false positive problem is the most serious obstacle which this theory must face.

5. CONCLUSION

I deliberately started this paper with a rather long section describing various puzzles in the area of language comprehension. I did this because it seemed to me that only someone who had lived with the puzzles, even for just a few pages, could properly appreciate the benefits of the theory I wish to espouse. But, especially for those who have already absorbed the basic ideas, the theory can be justified in a rather simple fashion.

Given a string of disconnected words (hence, completely lacking functional structure) people can disambiguate word senses, establish case relations, and propose explanatory actions. The process responsible here must, on one hand, be independent of syntax (the examples use no syntax) and, on the other, not need functional relations (because none are present). Dumb marker passing can do all of these tasks, and can do them without functional relations. I can think of no other process which can do any of them under these constraints.

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