Structure and Ostension in the Interpretation of Discourse Deixis

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Abstract

This paper examines demonstrative pronouns used as *deictics* to refer to the interpretation of one or more clauses. Although this usage is frowned upon in style manuals (for example Strunk and White (1959) state that "*This.* The pronoun *this*, referring to the complete sense of a preceding sentence or clause, cannot always carry the load and so may produce an imprecise statement."), it is nevertheless very common in written text. Handling this usage poses a problem for Natural Language Understanding systems. The solution I propose is based on distinguishing between what can be *pointed to* and what can be *referred to* by virtue of pointing. I argue that a restricted set of *discourse segments* yield what such demonstrative pronouns can point to and a restricted set of what Nunberg (1979) has called *referring functions* yield what they can refer to by virtue of that pointing.

1 Introduction

1.1 The Phenomenon

This paper sets out to explicate a use of demonstrative pronouns illustrated in the following examples:

Example 1

> It's always been presumed that when the glaciers receded, the area got very hot. The Folsum men couldn't adapt, and they died out. *That*'s what is supposed to have happened. It's the textbook dogma. But it's wrong.

Example 2

> Using microscopes and lasers and ultrasound, he removes tumors that are intertwined with children's brain stems and spinal cords. There is only the most minute visual difference between the tumors and normal tissue. Operations can last 12 hours or more. The tiniest slip can kill, paralyze or leave a child mentally retarded. *This* is the easy part of his job. (*New York Times*, 11 August 1990)

In these examples, a demonstrative pronoun is used to refer to something other than the referent

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of a previous noun phrase. It is not, however, referring to a previous *section of text* – what Lyons (1977, p.668) has called *pure textual deixis* – as in,

Example 3

A: The combination is 7-4-1-5.

B: I'm sorry I didn't hear you. Could you repeat *that*?

In example 1, the referent of *that* must be something that can happen. In example 2, it must be something that can be part of a job. Sections of text, i.e., strings of words, can be neither. On the other hand, sections of text can have such events or actions associated with them. My goal in this paper is thus straightforward, i.e. to show how sections of text can provide referents for demonstrative pronouns.

The paper proceeds as follows: First I discuss terminology and assumptions. I then try to show (Section 2.1) that it is not any *arbitrary sequence of clauses* in a text that can provide referents for demonstrative pronouns, but rather, only those that correspond to what have been called *discourse segments* in many current discourse theories. I then try to show that, at any point in the text, only certain discourse segments can yield referents for demonstrative pronouns – in particular, only those segments whose *contribution to the discourse model* is currently *in focus*.

To make this sense of focus precise, I present in Section 2.3 a simple incremental tree construction algorithm which is meant to serve as a *formal analogue* for text processing. This algorithm specifies precisely (1) the positions at which new nodes can be inserted into a tree and (2) the particular insertion operations that can be used. I then associate with these positions (the current *right frontier* of the tree) the set of discourse segments whose contribution to the discourse model is in focus. I claim that it is just these discourse segments that can yield referents for demonstrative pronouns. In support of this claim, I provide empirical evidence (Section 3) that segments corresponding to nodes no longer on the *right frontier* can no longer provide such referents.

Thirdly, I argue against the view that it is the structure of the *world* rather than how a speaker chooses to describe it that is the primary constraint on what deictic pronouns can refer to in discourse. I conclude in Section 4 with a descripiton of the indirect process by which I believe discourse segments yield referents for demonstrative pronouns through their contribution to the discourse model. This process draws on Nunberg's exploration into polysemy and demonstrative reference (Nunberg, 1979) and current theories of what has been called *natural language metaphysics* (Bach, 1989).

1.2 A Name for the Phenomenon

Phenomena need names. Lyons, recognizing the difference between *pure textual deixis* (see above) and the phenomenon under discussion here, called this phenomenon *impure textual deixis*. It was "deixis" because

> The term 'deixis' (which comes from a Greek word meaning "pointing" or "indicating") is now used in linguistics to refer to the function of personal and demonstrative pronouns, of tense and of a variety of other grammatical and lexical features which relate utterances to the spatio-temporal co-ordinates of the act of utterance. (Lyons, 1977, p.636)

It was "textual" because it had to do with the utterance itself, and "impure" because what was being indicated was not the utterance as a thing but what it expressed.

I think a better name is called for. The terms *reference to events* and *reference to propositions* used by Bäuerle (1989) reflect the semantic *sort* of the thing referred to. My problem with these terms are that (1) events and propositions are only two of the many sorts of things that demonstrative pronouns can refer to in discourse and (2) the separate names may be seen as implying that there are separate processes involved in reference to events and in reference to propositions. I do not believe this. I try to show here that only a single process need be involved. Another possible name is *discourse deixis*, previously used by Lakoff (1974). This is the name I favour: it labels the phenomenon as an instance of deixis, and grounds the *source* of its referents in the discourse.

As for a name for the referring phrases, when Lyons begins his discussion of *this* and *that*, he uses the locution *the English demonstratives 'this' and 'that', used as deictics* (Lyons, 1977, p. 655) acknowledging the fact that demonstrative pronouns are used for other functions as well. Shortly thereafter, he contracts this locution to *deictic pronoun* –

> In so far as the very fact of pointing to something commits the person who is pointing to a belief in the existence of what he is pointing at, the use of a deictic pronoun carries with it the implication or presupposition of existence. (Lyons, 1977, p. 656)

One reason for promoting this phrase is that it turns out that in several languages, including Italian and even English, zero-pronouns (Ø) can be used in the same way as demonstrative pronouns. (See Di Eugenio (1989) for a discussion of discourse deixis in Italian.) In English, this occurs in instructions, where it is common to find ellipsed direct-objects (Sadock, 1974). However, the referent of this ellipsis need not be a physical object. Consider example 4 drawn from a Frigidaire assembly and repair manual:

Example 4

> Check the door seal by closing the door on a 1" wide strip of paper. A slight drag should be felt when the paper is pulled from between the gasket and the cabinet. Repeat Ø around all four sides of the door.

Here the zero-pronoun refers to the process described in the preceding section of text.[1] This reference would ordinarily be achieved explicitly using a demonstrative – "Repeat this (or this process) around all four sides of the door." Thus the term *deictic pronoun* can serve to denote any pronoun (zero-pronoun, demonstrative pronoun, or even personal pronoun) that serves this same function.

1.3 Terminology and Other Assumptions

I assume that in processing a text, a listener is constructing a *model* that supports it and that evolves with the text. Lyons (1977, p.670) has called this model the *universe-of-discourse*. I and others have called it a *discourse model*. A discourse model is clearly a mental construct, but as long as the participants in a discourse believe they understand one another, they will assume that their models are consistent. Discourse models may correspond to particulars of the real world, if the real world is the subject of the discourse, but they need not. (This is not to say that people do not use their beliefs about the real world and how it works, in interpreting texts and constructing discourse models. It just says that the particulars of the two need not be the same. The only thing essential for successful discourse is that the participants believe their models are consistent with one anothers'.)

A discourse model contains *entities* to which are ascribed the properties and relationships predicated of them in the text. (Bill Woods once referred to them as "conceptual coathooks".) More sober names that have been used include *discourse referents* (Kartunnen, 1976), *reference markers* (Kamp, 1981), and *file cards* (Heim, 1983). I have called them *discourse entities* (Webber 1979, 1982), and will continue to do so in this paper. Discourse entities ground *referring phrases*. They may or may not correspond to particular entities in the real world.

As in many recent theories of discourse, including *Discourse Representation Theory* (*DRT*) (Bäuerle,1989; Kamp, 1981; Roberts, 1989), Grosz and Sidner's theory of discourse (1986) and that of Polanyi (1986), I assume that a discourse model is *structured* into regions in a way that reflects the recent structure of the evolving text. Utterances seen as part of the same segment of

[1] Dick Oehrle has bointed out that these instructions literally specify five tests: it is only three additional repetitions that are needed. But how much in life would get done if people insisted on following instructions literally?

text (for any of the reasons noted in Section 2.1) will be taken by the listener to contribute to the same region of the model.[2] Likewise, clauses in the text that are understood as contributing to the same region of the model will be seen as part of the same segment of text. Regions of the model may be embedded in other regions, reflecting substructures in the text. In DRT, these regions correspond to contexts. As in recent work in DRT (Asher, 1987; Bäuerle, 1989), I assume that each context has a discourse entity that "stands proxy" for its propositional content. This discourse entity will come into play in Section 4, when I explain how discourse segments can indirectly yield referents for deictic pronouns through their associated regions in the discourse model.

Like Nunberg (1979) and others, I assume an approach to ostensive acts (such as in the use of deictic pronouns) that distinguishes what is pointed to (the *demonstratum*) and what is referred to (the *referent*). These two entities may be the same, but they do not have to be. What is of interest is the link between them, which Nunberg (1979) has called a *referring function*. Referring functions apply to demonstrata to produce referents. In the approach that I present in Section 4, referring functions apply to discourse entity "proxies" for regions of the discourse model corresponding to discourse segments, thereby yielding referents for deictic pronouns. The range of possible referents follows directly from the range of *referring functions* possible in the given circumstance. In example 5, at least four are possible:

Example 5

Hey, management has reconsidered its position. They've promoted Fred to second vice president.
(a.) *That's* a lie.
(b). *That's* false.
(c.) *That's* a funny way to describe the situation.
(d.) When did *that* happen?

In (a), the referenced interpretation is the specific speech act (only speech acts can be lies); in (b), the proposition conveyed by the segment; in (c) the description expressed by the segment; and in (d), the particular event denoted by the segment. Because in the rich ontology advocated by Bach (1990) and others, all of these are sorts of individuals, I take it that the act of *ostension* performed by deictic pronouns in discourse can add new individuals (discourse entities) into the model that were not present prior to the ostensive act. As such, ostension can have the same effect as what has been called *accommodation* (Lewis, 1979).

That is, in the simplest case, a referring phrase will be taken to refer to an entity already in the discourse model. However, it can also cause the listener to add a new entity to the model to which he or she can ascribe the indicated properties or can set in the indicated relations. The addition of a new entity in response to an indefinite noun phrase is a common case. Where new entities are added in response to definite noun phrases, the process has been called *accommodation* because the use of a singular definite is felt to presuppose that there is *already* an unique entity in the context with the given description that will allow a truth value to be assigned to the utterance. For example:

Example 6

I walked up to the first house on my list. I noticed that *the side door* was wide open.

Houses do not necessarily have side doors. However, in response to "the side door", the listener accommodates a new entity in his/her discourse model corresponding to the mentioned side door of the house in question ("mentioned", because the text is consistent with there being more than one side door). Deictic pronouns can have the same effect as such definite noun phrases.

[2] It is not necessary to suppose that a particular substructure *persists* indefinitely. Later (Section 2.4), I will note how long it is needed in order for the current approach to work.

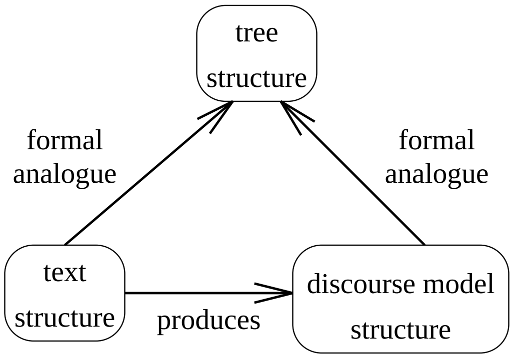

Figure 1: Three Relevant Structures

Finally, I assume that one can identify (at least, *a posteriori*) what a speaker and listener are attending to – what is immediately salient – at any point in the discourse. Items so identified are considered *in focus*, although other terms have been used to distinguish particular theories. Notions of *focus* have been proposed, at least in part, to account for patterns of "efficient" concept verbalization, e.g. when the pronunciation of concept descriptions can be attenuated, when concepts can be specified using explicit pronouns or zero-anaphors, when an unmodified definite noun phrase can be used to refer to a concept, when particular intonation structures and/or marked syntactic constructions like clefts are appropriate, etc. Among the *sorts* of things that are felt to be able to have sort of "focussed" status are discourse entities (Grosz et al., 1983; Sidner, 1982), open propositions (Prince, 1986; Steedman, 1990; Wilson & Sperber, 1979) and "focus spaces" (Grosz & Sidner, 1986; Reichman, 1985).

I will use the notion of *focus* to distinguish those regions of the discoruse model that, at a given point in the discourse, can yield referents for deictic pronouns. The main feature of focus that is relevant here is that it changes in fairly predictable ways, as each new clause is processed.

While I will discuss focus with respect to which discourse segments can yield referents for deictic pronouns, when there is more than one, as in the following minimal pair, I will have nothing to say here about how the choice between them is made.

Example 7

a. Segal, however, had his own problems with women: he had been trying to keep his marriage of seven years from falling apart; when *that* became impossible ...

b. Segal, however, had his own problems with women: he had been trying to keep his marriage of seven years from falling apart; when *that* became inevitable ...

In Example 7a. , it is the region associated with "(Segal's) keeping his marriage of seven years from falling apart" that yields a referent for *that*, while in Example 7b., it is "his marriage of seven years falling apart" that does so.

1.4 For the Record

It is important for the reader to be clear that there are *three* structures under discussion here (see Figure 1): the structure of the text (in terms of discourse segments), the structure of the discourse model (in terms of regions), and a tree structure which, by virtue of its associated insertion procedure, serves as a *formal record* of the *process* by which the discourse model grows and the structure changes, in response to the text and its perceived structure. The value of having such a formal analogue lies in being able to make use of its properties, including how it can legally change over time, to pin things down and avoid hand-waving. (In Section 2.4, I discuss what I believe is the close relationship between these three structures and those proposed by Grosz and Sidner.)

I should also note that this is not the first attempt to provide an account of demonstrative pronouns in discourse (nor do I expect it will be the last). Both Linde (1979) and Sidenr (1982) tried to extend theories of anaphoric pronoun interpretation to account for demonstrative pronouns as well. Both these accounts are in terms of the *focus* status of different objects and actions mentioned in the discourse. More recently, though, Passonneau (1989) analysed 678 instances of *it* and *that* found in conversational interactions, where these pronouns are interpreted as referring to entities introduced into the discourse model by noun phrases and other sentential constituents. She found two independent factors that strongly predicted whether subsequent reference would be via *it* or via *that*: one she called *persistence of grammatical subject*, the other, *persistence of grammatical form*. By the first factor, if both antecedent and pronoun were *subjects* of their respective clauses: if so, the pronoun *it* was strongly favored. By the second factor, if the antecedent noun phrase was other than a pronoun or a canonical noun phrase headed by a noun, then the pronoun *that* was strongly favored. Unlike the current study, Passonneau's analysis was limited to pronouns whose antecedents were constituents within single sentences.

There are also at least two attempts to extend Kamp's (1981) Discourse Representation Theory to handle reference to events and propositions (Asher, forthcoming; Bäuerle, 1988), but as I will try to show, it is more than just events and propositions that deictic pronouns can refer to in discouse, so that a richer interpretive process is called for.

2 Discourse Segments

2.1 Background

I hope that a simple example will convince the reader that not every previous sequence of clauses in a text can yield referents for deictic reference. Consider (8):

Example 8

a. For his part in their joint project, John built a two-armed robot.
b. He had learned about robotics in CSE391.
c. For her part, Mary taught it to play the saxophone.

It is simple to come up with an subsequent utterance in which the referent of *that* derives from just the previous clause (8c), for example:

d. *That* took her six months.

It is also easy to come up with a subsequent utterance in which the referent of *that* derives from the previous three clauses (8a-c), for example:

d'. That earned them both As.

However, it does not seem possible to come up with a subsequent utterance in which the referent of *that* derives from just the previous two clauses (8b and c). This fact seems to follow from the fact that they are not interpreted together as a unit, independent of 8a.

If not every sequence of clauses in a text has an interpretation accessible to deictic reference, which ones do? There is a widely held view that discourses are formed of smaller sequences of related clauses or sentences called *discourse segments*, although as James Allen (1987, pp.398-9) has noted:

> ...there is little consensus on what the segments of a particular discourse should be or how segmentation could be accomplished. One reason for this lack of consensus is that there is no precise definition of what a segment is beyond the intuition that certain sentences naturally group together.

Among the bases that have proposed for grouping utterances into segments are: common conversational role (Fox, 1987; Hinds, 1979), common *discourse purpose* with respect to a speaker's plans (Grosz & Sidner, 1986); common meaning (Hobbs, Stickel, Martin & Edwards, 1988); common perspective in describing a single event (Nakhimovsky, 1988), and common modality (Roberts, 1989). As for what constitutes a minimal discourse segment, theories differ. Hobbs et al. (1988) take it to be a sentence, and Polanyi (1986), a clause. Grosz and Sidner (1986) seem to take a sentence as the minimal segment needed to express a single purpose, but, unlike Hobbs et al. and Polanyi, do not assume that every sentence constitutes a distinct discourse segment.

Characterizing what is involved in recognizing that utterances share a common subject, viewpoint, modality and/or purpose (and doing so in a manner amenable to computer implementation) is both an unsolved problem and an active area of research. To date, particular lexical and syntactic cues have been identified as signalling segmental changes (Cohen,1987; Grosz and Sidner,1986; Nakhimovsky, 1988; Reichman, 1985), as have specific intonational changes at segment boundaries (Hirschberg and Litman, 1987).

That is not the whole story, however. Also needed is a characterization of how listeners bring their beliefs about the world and about speakers' intentions to bear on recognizing common subject, purpose, etc., as this cannot be done on the basis of surface and syntactic cues alone. Here there are fewer research results to date. For this paper, I will have to assume, like Cohen (1987), the existence of an oracle that can decide with which, if any, existing segment the next utterance in a text shares a common subject, viewpoint, etc. If doing so leads the reader to abandon the paper at this point, so be it. My feeling is that existing evidence that discourse segments play a role in text understanding makes it worthwhile to continue, in parallel, efforts at characterizing recognition procedures and efforts like the present one that assume such recognition.

What roles have discourse segments been seen to play in discourse understanding? One early computational reason for appealing to the notion of *discourse segment* was as a *domain of locality* for definite noun phrases (Grosz, 1977, 1981), to account in part for the fact that the same definite noun phrase may refer to different discourse entities at different points in the discourse. The claim is that a definite noun phrase would be interpreted as referring to an entity mentioned in the same segment rather than one mentioned anywhere else, even if the latter were mentioned more recently. For example, consider the following sequence uttered by a single speaker:

Example 9

a. Do you think I can borrow your tent?
b. The one I took on my last hike leaked,
c. and I haven't had time to replace it.
d. I would of course have *the tent* cleaned before returning it to you.

By *the tent* in (9d), the speaker is referring to the one she has requested in (9a), and not the leaky one she has mentioned in (9b,c). This can be explained in terms of discourse segments, by saying that clauses (9b,c) make up a segment embedded in the larger one (9a-d). As a whole, the segment constitutes a request, with (9b,c) functioning as its explanation. Because (9d) is outside the embedded segment, its object noun phrase *the tent* would be interpreted as referring to the one mentioned in the segment that it belongs to (i.e., the outer one).

Another use to which the notion of discourse segment has been put is in the interpretation of tensed clauses in narrative text (Nakhimovsky, 1988; Webber, 1988). For example, the unmarked interpretation of a sequence of simple past tense clauses in English narrative is that the events described happen at the same time or in temporal sequence. But this is not always the case, as in the following example.

Example 10

a. I was over at Mary's house yesterday.
b. She told me about her brother Harold.
c. He went to Alaska with two friends.
d. Together they climbed Mt. McKinley.
e. She asked me whether I was interested in going some time.

Clearly the event described in clauses (10c,d) happened before the event described by (10a,b,e), even though all the clauses use the same simple past tense. Postulating an embedded segment and a temporal focus that can reset at segment boundaries (Webber, 1988) allows one to retain a notion of simple simultaneity or temporal progression in the unmarked case.

2.2 Relations between Discourse Segments

Often (as above) *discourse segments* are taken to be recursive structures, such that either a discourse segment is a minimal segment or it comprises a sequence of embedded discourse segments.[3] As so defined, the recursive structures of interest are *trees*. This does not mean that a discourse corresponds to a *single tree*, just that there may be parts of the discourse that evince an embedding structure, and that this structure has interesting properties.

Now, if a tree structure is to represent the relationship among (certain) segments though, then so must its two basic structuring relations – *parent-of* and *right-sibling-of*. For example, in Robin Cohen's work on the structure of argumentative discourse (Cohen, 1983; 1987), *parent-of* means that the claim made by the child provides evidence for the claim made by the parent. *Right-sibling-of* corresponds to the linear order of claims that provide evidence for the same conclusion. Cohen's goal is to understand how structured arguments are transmitted through a linear sequence of clauses. She presents three common *transmission forms* that enable minimal effort reconstruction of the structure underlying an argument: pre-order, post-order and a mixed pre- and post-order. These tramission forms require minimal effort because of the severe restrictions they place on what an incoming clause can stand in a parent/child or sibling relation to. Cohen shows how "clue words" can be used to provide enough information to enable departures from these expected transmission forms and still produce comprehensible arguments.

In Scha and Polanyi's proposal (1988) for a semi-deterministic, on-line procedure for building a structural description of an unfolding discourse, they take the nodes of discourse structure trees to be any of a variety of types of *discourse constituent units* (DCUs). DCUs differ from one another in two ways: (a) how they derive their semantic attributes from those of their constituents, and (b) the "accessibility" of their constituents to things like anaphoric reference. (The three types of DCU discussed in (Scha and Polanyi, 1988) are subordinations, binary coordinations, and n-ary coordinations, each of which has several subtypes. For example, lists and narratives are types of n-ary coordinations.) For all these node types, *parent-of* means uniformly that one *DCU* is a constituent of another one. However, the meaning of *right-sibling-of* varies, depending on the type of common parent node. For example, *right-sibling-of* in a *narrative* n-ary coordination has a temporal aspect to its meaning, which it doesn't in a *list* n-ary coordination.

Grosz and Sidner (1986) take a more abstract criterion for establishing structural relations in discourse. The *parent-of* relation they call *domination* (DOM), and the *sibling-of* relation, *satisfaction-precedes*. They take these relations to hold between what they call *discourse segment purposes* or DSPs, rather than between discourse segments directly. A segment's DSP specifies how it contributes to achieving the overall discourse purpose. If the DSP of one segment serves to satisfy that

[3]As Passonneau has pointed out (personal correspondence), this ignores the possibility of interpreting a stretch of text as belonging to two adjacent segments in a sequence, serving essentially as a transition between them. Including this possibility complicates what it would mean to have a *sequence* of discourse segments, but would not alter the recursive nature of the definition itself.

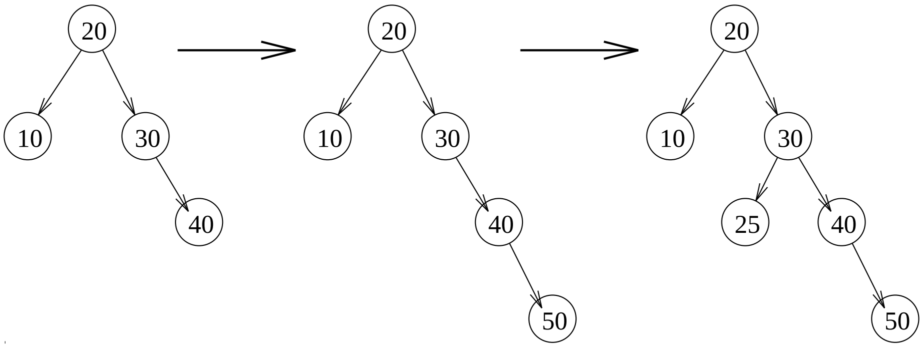

Figure 2: Growing a Binary Search Tree

of another, the latter *dominates* (or stands in a *parent-of* relation to) the former. If one DSP must be satisfied before another (in satisfying some larger purpose), than the former *satisfaction-precedes* the latter (or, alternatively, the latter is the *right-sibling-of* the former). Grosz and Sidner call the resulting hierarchy of DSPs the *Intentional Structure* of a discourse. It is only one of three structures that they associate with a discourse. Another of the three, *Attentional State*, I will discuss in Section 2.4.

2.3 Incremental Tree Construction

Having specified the two tree-structuring relations *parent-of* and *right-sibling-of*, there is still a variety of ways that a tree can be grown incrementally from elements added to it in sequence, depending on the insertion operator(s) used and the nodes that insertion can apply to. Here I will show how the same initial tree and input sequence result in two different final trees, by employing different insertion operations.

First, consider a *binary search tree* (BST), i.e. a tree with a maximum of two branches on each node and the restrictions that (1) the value of any node on a left subtree is *less than* the value of its root and (2) the value of any node on a right subtree is *greater than* the value of its root. Here there are two simple operators *attach as left daughter* and *attach as right daughter*, where the position at which a new node is attached depends on how its value compares with that of existing nodes on a path from root to leaf. These operators can insert new nodes only at the *fringe* of the tree. Thus the root of the tree can never change, nor can the relation between any existing node and the root. Figure 2 illustrates the incremental change in a BST as two new elements, whose values are 50 and 25, are added in sequence.

Now consider another data structure, the *AVL tree*. An AVL tree must satisfy the same constraints as a BST, as well as one additional constraint: an AVL tree must be kept *balanced* around each node. (A tree is considered balanced if the heights of its left and right subtree do not differ by more than 1.) Again, new nodes can only be added at the fringe of the tree, but the insertion operations are more complex, often leading to a restructuring of the tree (via rotation) to keep the tree balanced (see Reingold and Hansen, 1983, or any standard text in data structures, for a more detailed discussion). Figure 3 illustrates the incremental change in the same initial tree – which also qualifies as an AVL tree – as the same two elements, 50 and 25, are added in sequence. Notice that the root node of the AVL has changed by virtue of the insertions, as has the fringe and the right frontier. (The *right frontier* of a tree comprises those nodes along the path from root to tip defined by the sequence of rightmost daughters, starting at the root, as shown in Figure 4.)

No one has claimed that BSTs or AVL trees are relevant to discourse understanding. However, they can provide a basis for understanding other procedures that have been proposed for discourse understanding. For example, Cohen's pre-order transmission form (Cohen, 1983, 1987) uses a single

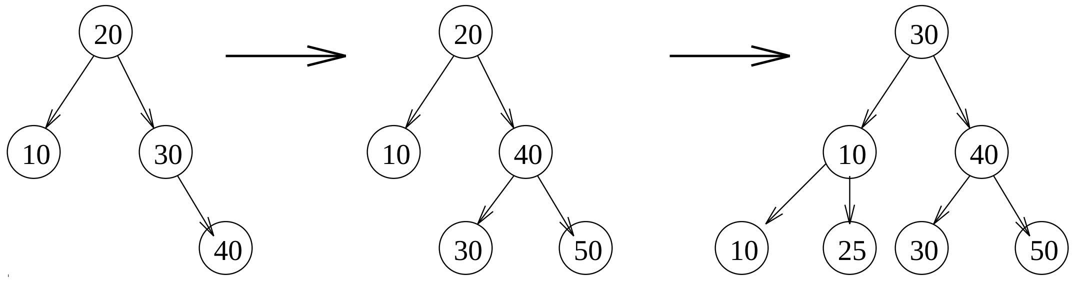

Figure 3: Growing an AVL Tree

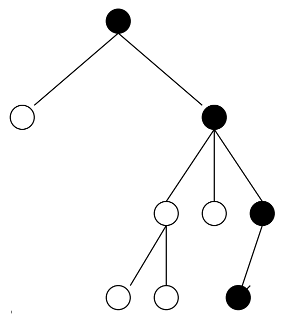

Figure 4: Right frontier

operation – *attach as rightmost daughter*. Her post-order transmission format makes use of a different operation – *attach as parent* – which subordinates a node or set of nodes as daughters of the node corresponding to the new clause. Her hybrid strategy makes use of both operators. At any point, there is an identifiable set of nodes that these operators can apply to. When an operator applies, it may change the tree such that different nodes are available as points of attachment. As noted, Cohen allows for linguistic clues to redirect operators to other nodes in the tree.

What I want to propose is a somewhat different, incremental procedure that makes use of two operations – *attach as rightmost daughter* (or simply, *attach*) and *adjoin*. After describing the operators, where they apply, and how they change the shape of the evolving tree, I will try to explain in discourse terms what the two operators are meant to correspond to. I then offer evidence (Section 3) in support of the claim that it is regions of the discourse model *corresponding to* nodes on the right frontier of a tree created by such a procedure that can yield referents for deictic pronouns.

First, the operations. *Attach* is the simple operation *attach as rightmost daughter* discussed

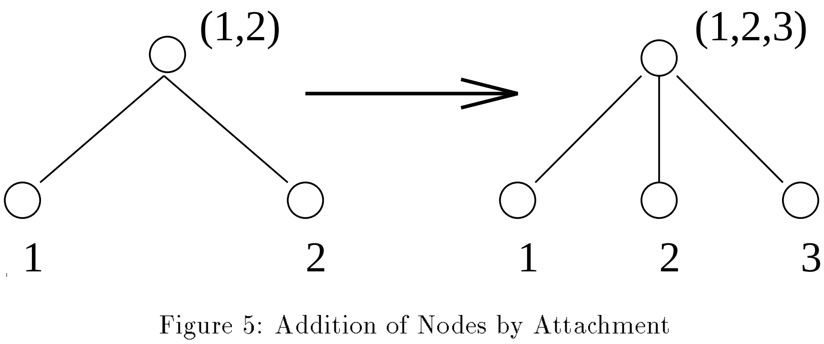

Figure 5: Addition of Nodes by Attachment

previously. (Because nodes here do not have explicit values, I will label leaf nodes in order of their incorporation amd non-terminal nodes, with a list of their children in left-to-right order.) *Adjunction* is a somewhat more complex operation which creates new non-terminal nodes rather than just adding leaves to existing non-terminals. When a new node is *adjoined* to one already in the tree, both become children of the same (new) parent node, with the new one being the right-sibling of the old. As I will show in the next sectin, adjunction applies slightly differently to root, non-terminal and leaf nodes. However, it always adds two nodes to a tree, whereas attachment adds only one.

In the procedure described here, *attachment* and *adjunction* are limited to nodes on the *right frontier* of the evolving tree structure. (In Figure 4, nodes on the *right frontier* are shaded.) If this were really an independent procedure I was describing, I would have to specify how the choice would be made as to (a) *where* on the right frontier to add a new node and (b) *how* to do so (i.e., by *attachment* or *adjunction*). However, because my purpose is just to use the procedure to enable the reader to visualize what happens during text processing to the *right frontier* of this *discourse tree*, I will describe these choices in discourse terms.

2.4 Discourse Segments and Incremental Tree Construction

I will start by assuming a one-to-one mapping between discourse segments and tree nodes, with a clause constituting the minimal segment. When the next clause in a text is taken (for whatever reason mentioned in Section 2.1) to be included in an existing discourse segment, the corresponding tree operation is *attachment* at the node corresponding to that segment. For example, when the third clause is processed in (11), it corresponds to a node being attached to the root of the same tree (Figure 5).

Example 11

1. John eats yoghurt for breakfast,
2. Fred eats Cheerios,
3. and Mary, muffins.

At the level of the discourse model, attachment means that the region of the discourse model comprising the entities, properties and relations conveyed by the new clause is included in the same region of the model as those associated with the rest of the segment. Both the entire region and the new subregion correspond to nodes on the right frontier of the current DST. It is these regions – ones corresponding to nodes on the right frontier of the current DST – that will be taken to be *in focus* (Section 1.3).

Now for the discourse correlate of *adjunction*. When a discourse segment S_i is taken as being directly embedded in another segment S_j, the assumption is that the former contributes *directly* to the meaning or purpose of the latter. Suppose clause C comes along, causing the listener to realize that it is not S_i that contributes directly to S_j, but rather the combination of S_i and C. That is, S_i and C form a segment directly embedded in S_j. This is the discourse correlate of *adjunction* to a non-terminal or leaf node. If C is seen as contributing along with the top-level segment (corresponding to the current root of the tree) to some more encompassing meaning or purpose, this is the discourse correlate of *adjunction to the root*. The general case of adjunction to the root is shown in Figure 6.

Discourse processing that correlates with *adjunction to the root* is actually a common case, as it happens whenever the meaning or purpose of the second clause in a discourse is taken to combine with that of the first clause to form a more encompassing meaning or purpose, such as when the second clause of (11) is processed. This simple common case of adjunction ot the root is shown in Figure 7.

To understand the discourse correlate of *adjunction to a leaf node*, consider the following text at the point at which the reader has finished processing the clause, "John hates snakes".

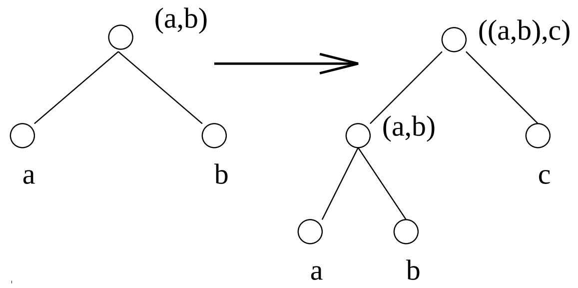

Figure 6: Adjunction to root node

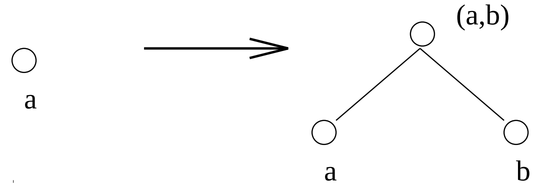

Figure 7: Adjunction to the root of a one-node tree

Example 12
a. John hates snakes.
b. His next-door neighbour had kept snakes,
c. and he had hated his neighbours.

In processing the second clause (12b), the reader may decide that it provides an explanation for the situation described in the first clause and that the two thereby constitute a segment. (This correlates with the *adjunction to the root* operation described above. It is shown in step 1 of Figure 8.) However, in processing the third clause (12c), the reader may recognize that it is the situation described *jointly* by (12b) and (12c) that explains the situation described in (12a). This re-analysis of the relationship between the situations conveyed by (12a) and (12b) correlates with the tree restructuring operation of *adjunction to a leaf* – in particular, to the terminal on the *right frontier*. This second step corresponds to step 2 of Figure 8. Notice how the *right frontier* of the

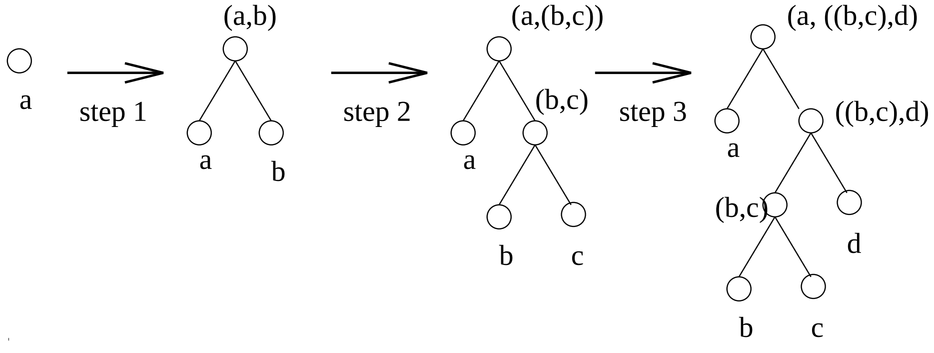

Figure 8: Adjunction operations corresponding to example 12

tree has changed, and thus which regions of the discourse model will be taken to be in focus.

Finally, to get a feel for the discourse correlate of *adjunction to a non-terminal node*, consider the following continuation of (12).

Example 13

a. John hates snakes.
b. His next-door neighbour had kept snakes,
c. and he had hated his neighbours.
d. Later in college, his roommate had kept snakes.

Having decided that it is the situation described in (13 b,c) that provides evidence for (13a), the reader in processing (13d) may decide that it is the *combination* of situations (one described in 13b-c and the other described in 13d) that provides evidence for (13a). This reanalysis of the relationship between situations correlates with the tree restructuring operation of *adjunction to a non-terminal.* This third step corresponds to step 3 of Figure 8. As in step 2, the *right frontier* of the DST has changed, and thus, the regions of the discourse model that are taken to be *in focus.*

Note that because operations only apply to the right frontier of the DST, the rest of the tree becomes irrelevant. In this light, one can easily suppose that the only segments of the discourse and regions of the discourse model that retain their identity are those that corresond to nodes on the right frontier. When they no longer do so, the only thing that needs to persist, for a listener to be said to have understood the discourse, are the entities, propositions and relations predicated of them.

Finally, note that a similar assumption – that integration of the discourse meaning of the next clause only takes place at the *right frontier* of the discourse structure – is made by Polanyi (1986) and Scha and Polanyi (1988). There is also a close relationship between the notion of *right frontier* presented here and Grosz and Sidner's (1986) stack of focus spaces representing *Attentional State.*

In Grosz and Sidner's (1986) model, a listener's attention at any point correlates with the perceived structure of the discourse. In particular, they associate a *focus space* with each discourse segment, as well as its *discourse segment purpose* (DSP). A focus space contains discourse entities, along with the properties and relations predicated of them. Corresponding to the evolving *Intentional Structure* (a tree of DSPs), they propose a *stack* of focus spaces which represents the listener's *Attentional State.* A segment's focus space is pushed on the stack when its DSP is taken to contribute to that of the segment whose focus space is at the top of the stack. Focus spaces will be popped from the stack prior to a push until the top focus space is one whose associated DSP can be taken to *dominate* that associated with the focus space about to be pushed. Another way to put this is that the stack contains the focus spaces of segments whose "purposes" are still open to additional support.

Drawing on Grosz's earlier work (Grosz, 1977, 1981), *Attentional State* serves as a structured domain of locality for the interpretation of definite noun phrases. Resolution algorithms can then prefer to resolve a definite noun phrase against a referent in a focus space closer to the top of the stack than in one further down. Picking up a referent further down may, in fact, indicate that the segments associated with focus spaces higher up the stack can now be taken as "closed", with attention shifting back to a more inclusive segment.

The *right frontier* of the DST discussed here is closely related to Grosz and Sidner's *Attentional State.* First, there is a simple mechanical relationship: Any directed path through a tree from root to leaf node can be mapped directly to a stack, with the element corresponding to the leaf at the top. *Attach* and *adjoin* then correspond exactly to the simple push and the sequence of pops followed by a push that Grosz and Sidner use to manage the stack. (That is, *attaching* a new leaf node corresponds to *pushing* a new element on the stack. *Adjoining* a new node S_k to a node S_i corresponds to *popping* all the stack elements through that corresponding to S_i and *pushing* that corresponding to S_k onto the top of the stack.)

There is also a functional relationship: nodes on the *right frontier* of the DST correlate with regions of the discourse model taken to be in focus – substructures that resemble Grosz and Sidner's focus spaces. In fact, by positing a single tree structure and insertion algorithm to serve as a formal analogue of both on-line recognition of discourse structure and changes in participants' attention on regions of the discourse model, one can eliminate Grosz and Sidner's stack as now redundant, while retaining their insight into the usefulness of distinguishing text structure, Intentional Structure and Attentional State.

3 The Referents of Deictic Pronouns

The point of reviewing notions of discourse structure and incremental tree construction algorithms is to allow me to argue that it is only regions of the discourse model corresponding to nodes on the right frontier of the DST – those regions that are *in focus* – that can yield referents for deictic pronouns. Before doing so, I want to demonstrate that it is the structure of discourse segments (and hence that of the discourse model) that constrains the referents of deictic pronouns rather than the world being described.[4]

Evidence that the primary constraint on possible referents of the deictic pronouns is the presentation of information (not simply what that information is about) comes from the fact that, presented differently, the same information about a situation gives rise to different referents. To see this, consider (14), focussing on the referents of the deictic pronouns in b-d.

Example 14

a. There's two houses you might be interested in:

b. House A is in Palo Alto. It's got 3 bedrooms and 2 baths, and was built in 1950. It's on a quarter acre, with a lovely garden, and the owner is asking $425K. But *that* 's all I know about it.

c. House B is in Portola Vally. It's got 3 bedrooms, 4 baths and a kidney-shaped pool, and was also built in 1950. It's on 4 acres of steep wooded slope, with a view of the mountains. The owner is asking $600K. I heard all *this* from a real-estate friend of mine.

d. Is *that* enough information for you to decide which to look at?

That in each case it is an interpretation of an immediately preceding segment that, through its contribution to the discourse model, yields the referent of the deictic pronoun, can be seen by presenting the same information in an interleaved fashion, a technique often used when comparing two items:

[4] I informally analyzed 177 consecutive instances of pronominal reference using *it*, *this* and *that*, distinguishing those that could be taken to co-refer with some noun phrase and those that could only possibly be taken to refer to the interpretation of one or more clauses. There were 96 instances of the latter. Of those, only 15 (~16%) used the pronoun *it* while the other 81 (~84%) used either *this* or *that* (19 instances of *that* and 62 instances of *this*). Of the 81 that co-referred with a noun phrase, 79 (~98%) used *it* while only 2 (~2%) used *this* or *that*. My data comes from Taylor (1986); Hillis (1988); an editorial from *The Guardian*, 15 December 1987; two reviews in *TLS*, 23-29 October 1987, pp.1163-1164 and 20-26 November 1987, p.1270; and Kaelbling(1987).

Example 15

a. There's two houses you might be interested in:

b. House A is in Palo Alto, House B in Portola Vally. Both were built in 1950, and both have 3 bedrooms. House A has 2 baths, and B, 4. House B also has a kidney-shaped pool. House A is on a quarter acre, with a lovely garden, while House B is on 4 acres of steep wooded slope, with a view of the mountains. The owner of House A is asking $425K. The owner of House B is asking $600K. *That*'s all I know about House A. *This/That* I heard from a real-estate friend of mine. **3.** Is *that* enough information for you to decide which to look at?

The two examples clearly have different segmental structures (at a gross level, one that corresponds to the structure of the paragraphs). The question that readers should ask themselves is whether the deictic pronouns in paragraphs in (15b,c) have the same referents as they do in Example (14). I believe they do not, and that this is because it is not the houses being referred to, but rather a distinct chunk of information one has been told about the houses. Example 15 does not contain separate segments describing what the speaker knows about house A and about house B. Rather, there is only one discourse segment containing information about both houses. The only deictic that refers easily and successfully is the final *that*, which successfully refers to the information conveyed about both houses through entire segment.

Another piece of evidence that it is focused regions of the discourse model that yield referents for deictic pronouns comes from the (partially) recursive nature of discourse structure (cf. Section 2.1). At any given point in a discourse, segments embedded at different depths can yield referents for deictic pronouns. To see this, consider the following quote from (Hillis, 1988):

Example 16

...it should be possible to identify certain functions as being unnecessary for thought by studying patients whose cognitive abilities are unaffected by locally confined damage to the brain. $\{_1$For example, binocular stereo fusion is known to take place in a specific area of the cortex near the back of the head. $\{_2$Patients with damage to this area of the cortex have visual handicaps but $\{_3$ [they] show no obvious impairment in their ability to think.$_3\}_2\}$ *This*$_i$ suggests that stereo fusion is not necessary for thought.$_1\}$ *This*$_j$ is a simple example, and the conclusion is not surprising.... (Hillis, 1988, p.185)

(I have added brackets to indicate some of discourse segments at the points where deictic pronouns occur, with subscripts indicating the depth of embedding.) The most likely referent for *this*$_i$ is the fact that visual cortex-damaged patients have visual handicaps but no impairment to their thinking abilities. This comes from Segment 2. The most likely referent for *this*$_j$ is the whole "brain damage" example. This comes from the more inclusive Segment 1.

Not only do deictic pronouns get their referents from regions of the model corresponding to nodes on the *right frontier* of the current DST. These are the *only* regions that can provide such referents. Consider the following variation of (14). (Here, the individual clauses are numbered for later discussion.)

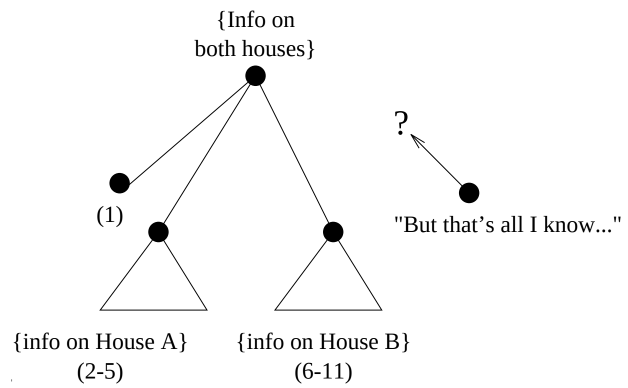

Figure 9: Discourse Segmentation at the point of processing "But that's all ..."

Example 17

a. (1) There's two houses you might be interested in:

b. (2) House A is in Palo Alto. (3) It's got three bedrooms and two baths, and was built in 1950. (4) It's on a quarter acre, with a lovely garden, and (5) the owner is asking $425K.

c. (6) House B is in Portola Vally. (7) It's got three bedrooms, four baths and a kidney-shaped pool, and (8) was also built in 1950. (9) It's on 4 acres of steep wooded slope, with a view of the mountains. (10) The owner is asking $600K. (11) I heard all *this* from a real-estate friend of mine. (12) But *that*'s all I know about House A.

d. (13) Is *that* enough information for you to decide which to look at?

What is at issue is the referent of (unstressed) *that* in clause (12). The rest of the clause constrains the referent of *that* to be information about House A. However its position in the text is only compatible with its referring in one of three ways:

- It can co-refer with *all this* in clause (11), as in "But *that*'s all she said." (In this paper, I do not discuss deictic pronouns that refer to NP-evoked entities.)
- It can refer to something associated with clause (11), such as its corresponding assertion as in "Of course, *that*'s what I always tell people."
- It can refer to something associated with clauses 2-11 (the information regarding both houses), similar to the perceived interpretation of *that* in clause 13.

Schematically, one might represent the discourse segmentation at the point in processing *that* , roughly as in Figure 9. The oddity of Example 17 comes from the conflicting demands of text position and clause predication in the process of resolving *that*.

Let me emphasize here that I am only considering written text and unstressed instances of *this* and *that*. It is well-known that stressing a pronoun can shift its preferred referent. In the case of clause (12), stressing *that*, reinforced by information conveyed by the rest of the sentence, can force its referent to be the block of information about House A, even though its corresponding region in the discourse model is no longer *in focus*.

Notice that even if it is true that unstressed *this* and *that* must come from focused regions of the model (ones corresonding to nodes on the right frontier of the DST), there is still an ambiguity as to *which* region. To see this, consider the first part of the Hillis' example (repeated here) as a "discourse completion task".

Example 18

> ...it should be possible to identify certain functions as being unnecessary for thought by studying patients whose cognitive abilities are unaffected by locally confined damage to the brain. For example, binocular stereo fusion is known to take place in a specific area of the cortex near the back of the head. Patients with damage to this area of the cortex have visual handicaps but show no obvious impairment in their ability to think. *This* ....

At this point in the discourse, there are many possible ways of completing the last sentence, among them –

Example 19

a. *This* is obvious when they are asked to solve word problems presented orally.
b. *This* suggests that stereo fusion is not necessary for thought.
c. *This* is only a simple example, and the conclusion is not surprising.

In (19a), *this* refers to the *fact* that patients with damage to the area of the cortex near the back of the head show no obvious impairment in their ability to think. In (19b), *this* must refer to the more inclusive claim that patients with damage to the particular area of the cortex near the back of the head have visual handicaps but show no obvious impairment in their ability to think. (This is what shows that one doesn't need stereo fusion in order to think.) Finally, in (19c) *this* clearly refers to the entire example about binocular stereo vision. Which discourse segment provides the referent for *this* depends on what is compatible with the meaning of the rest of the sentence, as I noted in Section 1.3 in connection with example (20):

Example 20

a. Segal, however, had his own problems with women: he had been trying to keep his marriage of seven years from falling apart; when *that* became impossible ...

that ≡ keeping his marriage from falling apart

b. Segal, however, had his own problems with women: he had been trying to keep his marriage of seven years from falling apart; when *that* became inevitable ...

that ≡ his marriage falling apart

As with other types of ambiguity, there may be a default preference (e.g., based on recency, position, etc.) in a "neutral" context but, if there is one, it can easily be over-ridden by the demands of the actual context (Crain & Steedman, 1985; Steedman, 1989).

This ambiguity as to where a deictic pronoun takes its referent seems very similar to the ambiguity associated with the use of deixis for pointing within a shared physical context. Both Quine (1971) and Miller (1982) have observed in this regard that *all pointing* is ambiguous: the intended demonstratum of a pointing gesture can be any of the infinite number of points "intersected" by the gesture or any of the structures encompassing those points. (Or, one might add, any interpretation of those structures.) The ambiguity here – how inclusive a segment is providing an interpretation for *this* or *that* – seems very similar.

4 Referring Functions and the Interpretation of Deictic Pronouns

Having set up what I hope is all the necessary groundwork in the previous three sections, I hope now to pull it together and show how deictic pronouns get their referents. The solution I propose is based on distinguishing between what can be *pointed to* (the *demonstratum*) and what can be *referred to* by virtue of pointing (the *referent*). I claim that it is focussed regions of the discourse model that deictic pronouns can point to (via the discourse entity "proxies" of those segments), and that it is possibly new discourse entities that they can refer to by virtue of that pointing. What links the two, I claim, are what Nunberg (1979) has called *referring functions*.

Nunberg (1979) introduces the notion of referring function in connection with some rather extreme examples of demonstratum/referent pairs, such as in (17) below (Nunberg's numbering):

> For example, a restaurant waiter going off duty might remind his replacement:
>
> (16) The ham sandwich is sitting at table 20.
>
> And in just those constexts, he could equally well point at a ham sandwich and say,
>
> (17) He is sitting at table 20. (Nunberg 1979, p.149)

Here, the ham sandwich serves as the demonstratum of the pointing act and the guy who ordered the ham sandwich serves as the referent of the associated pronoun "He". Formally, *referring functions* map *demonstrata* into *intended referents.*

$$\mathbf{f}\text{: } \mathbf{D} \rightarrow \mathbf{R}$$

where **f** is the referring function, **D** is the domain of demonstrata and **R**, the range of intended referents. The problem for the listener, given the ambiguity of pointing mentioned in Section 3, is to simultaneously constrain the demonstratum and the referring function, such that the intended referent results.

Aiding the listener are factors that Nunberg takes as constraining the referring functions that can be used in a particular case. These include:

- that **R**, the range of the referring function, intersect "the set of things that the speaker might rationally be construed as intending to refer to in a given context", where the latter is determined by "the nature of the predication, by the morphology of the demonstrative pronoun, and by such contextual considerations at 'topic of conversation"' (Nunberg, 1979, p.157);
- that it be possible for the listener to determine, in practice, just what stands in that relationship. (For example, if one wants to refer to a particular *place* by pointing to a particular object, the listener should recognize what place is salient to that object. A wine bottle labelled "Medoc" may make the Medoc a salient place, while a bottle of Coca Cola may not make any particular place salient.)
- that it be a more likely referring function, under the circumstance, than any other.

Similar assumptions are made by Hirschberg (1986) with respect to which *scales* a spekaer can use to make scalar implications in a given case.

To see that these assumptions make sense, consider the "ham sandwich" example given earlier. Here, **R** must intersect with males (given the pronoun "he") who are able to sit at a table (given the verb phrase). The listener can be expected to figure out which particular person stands in that relation, because it must be a man sitting at table 20. Finally, the circumstances of an order waiting in the kitchen to be delivered make it more like that *f* picks out "the man who ordered the hame sandwich" than "the man who made it".

I claim that the same approach can be extended to cover discourse deixis as well as external ostension, simply by taking a different domain **D** of demonstrata. Specifically, I noted in Section 1.3 that I was making the same assumption as that made in DRT (Asher, 1987; Bäuerle, 1989) that each context – region of the discourse model – has a discourse entity that "stands proxy" for its propositional content. If one takes **D** to comprise the discourse entity "proxies" of those regions of the discourse model that are currently *in focus* – those corresponding to (and whose discourse segments correspond to) nodes on the *right frontier* of the DST, then everything can proceed as before.

To illustrate this approach, I will apply it to the first examples given in the paper (repeated here, with the initial clauses numbered):

Example 21

> It's always been presumed that (2) when the glaciers receded, (3) the area got very hot. (4) The Folsum men couldn't adapt, and (5) they died out. (6) *That*'s what is supposed to have happened. It's the textbook dogma. But it's wrong.

Example 22

> (1) Using microscopes and lasers and ultrasound, (2) he removes tumors (3) that are intertwined with children's brain stems and spinal cords. (4) There is only the most minute visual difference between the tumors and normal tissue. (5) Operations can last 12 hours or more. (6) The tiniest slip can kill, paralyze or leave a child mentally retarded.
> (7) *This* is the easy part of his job. (*New York Times*, 11 August 1990)

First consider example (21). Here at least four regions of the discourse model can be said to be *in focus* at the point in the discourse at which *that* appears:

- the region associated with clause 5,
- the region associated with clauses 4 and 5,
- the region associated with clauses 2-5, and
- the region associated with clauses 1-5.

Thus **D**, the domain of **f**, will comprise at least their four "proxies". **R**, the range of **f**, should be a subset of event tokens (i.e things that can happen). It is easy to imagine a function that could apply to each of the first three proxies to yield an event token, because their propositional content can be taken to convey a particular event. The intended referent could be any of these, but given the rest of the story (Tony Hillerman's *Dance Hall of the Dead*), it is probably either the second or third.

Now consider example (22). Here at least two regions of the discourse model can be said to be *in focus*:

- the region associated with clause 6, and
- the region associated with clauses 1-6.

Thus **D** will comprise at least their two proxies. I assume that it is intentional act types that are parts of jobs, so that **R** will intersect this set. It is hard to associate an intentional act type with the first proxy. (If clause 7 had been something like "*This* would paralyze some people into inaction", where **R** would comprise (probably difficult) situations, it would be easier to associate such a referent with the first proxy.) So the intended referent of *that* in cluase 7 most likely derives from applying **f** to the second proxy – most likely paraphrasable as "removing these difficult tumors".

Notice that this approach in terms of referring functions avoids a problem that Bäuerle (1989) cannot, because his approach requires separate mechanisms to handle event token reference, event type reference and proposition (token) reference. That is, the current approach does not require introducing yet a fourth mechanism to handle deictic reference to proposition types (not discussed in Bäuerle's paper) such as the following:

Example 23

a. Fred and Amy always cheat on their homework.
b. Well, I'd believe *that* of Fred, but not of Amy.

Finally, let me stress both the similarities and differences between this account of discourse deixis and the process called *accommodation* (Section 1.3). Like *accommodation*, this account of discourse deixis postulates that new individuals – new entities in the discourse model – can be introduced by virtue of a referring action. These entities have the same status in the model as any introduced through the use of an indefinite noun phrase. That event tokens, event types, facts, descriptions, actions, etc., introduced this way can be individuals in their own right seems in line with the view gaining currency in formal semantics that the domain of the type *individual* has a very rich substructure (Bach, 1989; Link, 1983; 1987; Schubert & Pelletier, 1987).

However, one should maintain a distinction between discourse deixis and the more general process of *accommodation*, because the former is more constrained. In accommodating a definite noun phrase, the discourse context must provide the listener with a discourse entity with which he or she can presume to associate a unique individual that satisfies the descriptive content of the noun phrase. Understanding definite noun phrases can thus be said to require all of a listener's world knowledge. Unlike a definite noun phrase, however, a deictic pronoun has no descriptive content of its own. Thus what the discourse context must provide is a small set of entities that can be pointed to, whose propositional content is the source of new intended referents. Finding an appropriate referrring function and intended referent in this case seems to be a less comprehensive task.

5 Conclusion

In this paper I have argued for an account of discourse deixis, based on current views of discourse structure. In particular, I argued that what provides referents for these expressions are the interpretations of discourse segments corresponding to nodes on the *right frontier* of a formal tree structure analogue. I also argued that the manner by which these expressions get their referents could be viewed as an extension of Nunberg's use of referring functions. For natural-language understanding systems, what lies ahead now is more work on discourse-level semantics, so that (1) systems can build appropriately structured discourse models in response to a text and (2) they can identify intended demonstrata and reference functions and thereby resolve this interesting class of referring forms.

References

[1] Allen, J. *Natural Language Understanding.* Menlo Park CA: Benjamin/Cummings Publ. Co., 1987.

[2] Asher, N. A Typology for Attitude Verbs and their Anaphoric Properties. *Linguistics and Philosophy* 10, pp. 125-197, 1987.

[3] Asher, N. *Abstract objects, semantics and anaphora.* (Forthcoming)

[4] Bach, E. *Informal Lectures on Formal Semantics.* Albany NY: State University of NY Press, 1989.

[5] Bäuerle, R. Aspects of Anaphoric Reference to Events and Propositions in German. In C. Rohrer and Wedekind (eds.)*untitled.* Reidel. To appear. Also appears as Evénements et propositions: quelques aspects de la référence anaphorique en allemand. In P. Engel (ed.), *Recherches sur la philosophie et le langage 10* (Cahier du groupe de recherches sur la philosophie et le langage, Université des Sciences Sociales de Grenoble), 1989.

[6] Cohen, R. *A Computational Model for the Analysis of Arguments.* PhD thesis, Technical Report 151, Computer Systems Research Group, University of Toronto, 1983.

[7] Cohen, R. Analyzing the Structure of Argumentative Discourse, *Computational Linguistics* 13(1-2):11-24, 1987.

[8] Crain, S. and Steedman, M. On not being led up the garden path: the use of context by the psychological parser. In *Natural Language Parsing*, D. Dowty, L. Karttunen & A. Zwicky (eds.), Cambridge: Cambridge University Press, 1985.

[9] Di Eugenio, B. Clausal Reference in Italian. *Proc. Penn Linguistics Conference*, University of Pennsylvania, February 1989.

[10] Fox, B. *Discourse Structure and Anaphora.* Cambridge: Cambridge University Press, 1987.

[11] Grosz, B. The Representation and Use of Focus in a System for Dialog Understanding. Technical Report 151, SRI International, Menlo Park CA, 1977.

[12] Grosz, B. The Representation and Use of Focus in a System for Understanding Dialogs. In *Elements of Discourse Understanding*, A. Joshi, B. Webber and I. Sag (eds.), Cambridge: Cambridge Univ. Press, 1981. (Reprinted in *Readings in Natural Language Processing*, B. Grosz, K. Sparck Jones and B. Webber (eds.), Los Altos: Morgan Kaufmann Publ., 1986.)

[13] Grosz, B., Joshi, A. and Weinstein, S. Providing a Unified Account of Noun Phrases in Discourse. *Proceedings of the 21st Annual Meeting of the Association for Computational Linguistics*, pp.44-50.

[14] Grosz, B. and Sidner, C. Attention, Intention and the Structure of Discourse. *Computational Linguistics*, 12(3), July-Sept. 1986, pp.175-204.

[15] Heim, I. File Change Semantics and the Familiarity Theory of Definiteness. In *Meaning, Use and Interpretation of Language*, R. Bauerle, C. Schwarze and A. von Stechow (eds.). Berlin: de Gruyter, 1983.

[16] Hillis, W.D. Intelligence as an Emergent Behavior, *Daedalus*, Winter 1988, pp.175-190.

[17] Hinds, J. Organizational Patterns in Discourse. In T. Givon (ed.) *Syntax and Semantics 12: Discourse and Syntax*, New York: Academic Press, 1979.

[18] Hirschberg, J. *A Theory of Scalar Implicature.* PhD thesis, Department of Computer & Information Science, University of Pennsylvania, Philadelphia PA, 1986.

[19] Hirschberg, J. & Litman, D. Now Let's Talk about Now: Identifying Cue Phrases Intonationally. *Proc. 25th Annual Meeting, Association for Computational Linguistics*, Stanford Univ. Stanford CA, July 1987.

[20] Hobbs, J. , Stickel, M., Martin, P. & Edwards, D. Interpretation as Abduction. *Proc. 26th Annual Meeting, Association for Computational Linguistics*, SUNY Buffalo, Buffalo NY, June 1988, pp.95-103.

[21] Kaelbling, L. An Architecture for Intelligent Reactive Systems. Technical report, SRI International, Menlo Park CA, 1987.

[22] Kamp, H. A Theory of Truth and Semantic Representation. In *Formal Methods in the Study of Language*, J. Groenendijk, T. Janssen and M. Stokhof (eds). Amsterdam: Mathematical Center Tracts, 1981.

[23] Karttunen, L. Discourse Referents. In *Syntax and Semantics*, Volume 7, J. McCawley (ed.). New York: Academic Press, 1976.

[24] Lakoff, R. Remarks on *this* and *that*. *Proceedings of the Chicago Linguistics Society*, 1974, pp.345-356.

[25] Lewis, D. Score Keeping in a Language Game. In R. Bäuerle et al. (eds.), *Semantics from a Different Point of View*. Berlin: Springer Verlag, 1979.

[26] Linde, C. Focus of Attention and the Choice of Pronouns in Discourse. In T. Givon (ed.) *Syntax and Semantics 12: Discourse and Syntax*, New York: Academic Press, 1979.

[27] Link, G. The Logical Analysis of Plurals and Mass Terms: A lattice-theoretical approach. In R. Bäuerle *et al. Meaning, Use and the Interpretation of Language*, Berlin: de Gruyter, 1983, pp.302-323.

[28] Link, G. Algebraic Semantics for Event Structures. In Groenendijk, Stokhof and Veltman (eds.), *Proc. 6th Amsterdam Colloquium ITLI*, Amsterdam, 1987.

[29] Lyons, J. *Semantics*. Cambridge: Cambridge University Press, 1977.

[30] Miller, G. Problems in the Theory of Demonstrative Reference. In R. Jarvella & W. Klein (eds.), *Speech, Place and Action*. New York: Wiley, 1982.

[31] Nakhimovsky, A. Aspect, Aspectual Class and the Temporal Structure of Narrative. *Computational Linguistics*, 14(2):29-43, 1988.

[32] Nunberg, G. The Non-Uniqueness of Semantic Solutions: Polysemy. *Lingustics and Philosophy*, 3(2):143-184, 1979.

[33] Passonneau, R. Getting at Discourse Referents, *Proc. 27th Annual Meeting, Association for Computational Linguistics*, Univ. British Colubia, Vancouver, Canada, June 1989.

[34] Polanyi, L. The Linguistic Discourse Model: Towards a formal theory of discourse structure. TR-6409. BBN Laboratories Incorp., Cambridge MA, November 1986.

[35] Prince, E. On the Syntactic Marking of Presupposed Open Propositions. *Papers from the Parasession on Pragmatics and Linguistic Theory.* 22nd Annual Regional Meeting of the Chicago Linguistics Society. Chicago IL, 1986, pp. 202-222.

[36] Quine, W. The Inscrutability of Reference. In D. Steinberg and L. Jacobovits (eds.), *Semantics: An Interdisciplinary Reader*. Cambridge: Cambridge University Press, 1971. pp.142-154.

[37] Reichman, R. *Getting Computers to Talk like You and Me*. Cambridge MA: MIT Press, 1985.

[38] Reingold, E. and Hansen, W. *Data Structures*. Boston: Little, Brown and Co., 1983.

[39] Roberts, C. Modal Subordination and Pronominal Anaphora in Discourse. *Linguistics and Philosophy* 12(6), pp. 683-721, 1989.

[40] Sadock, J. Read at Your Own Risk: Syntactic and semantic horrors you can find in your medicine chest. *Proc. Chicago Linguistics Society* 10, 1974, pp.599-607.

[41] Scha, R. and Polanyi, L. An Augmented Context Free Grammar for Discourse. *Proceedings of the 12th International Conference on Computational Linguistics*, August 1988, Budapest Hungary.

[42] Schubert, L., and Pelletier, F. Problems in the Representation of the Logical Form of Generics, Plurals, and Mass Nouns. In *New Directions in Semantics.* London: Academic Press, 1987, pp.385-451.

[43] Sidner, C. Focusing in the Comprehension of Definite Anaphora. In M. Brady & R. Berwick (eds.), *Computational Models of Discourse.* Cambridge MA: MIT Press, 1982, pp.267-330.

[44] Steedman, M. Grammar, Interpretation and Processing from the Lexicon. In W. Marslen-Wilson (ed.) *Lexical Representation and Process.* Cambridge MA: MIT Press (Bradford Books), 1989.

[45] Steedman, M. Structure and Intonation in Spoken Language Understanding. *Proceedings of the 28th Annual Meeting of the Association for Computation Linguistics*, Pittsburgh PA, 1990.

[46] Strunk, W. Jr. and White, E.B. *Elements of Style* third edition), New York: Macmillan Co, 1959.

[47] Taylor, P. *Summons to Memphis.* New York: Ballentine Books, 1986.

[48] Webber, B. *A Formal Approach to Discourse Anaphora.* New York: Garland Press, 1979.

[49] Webber, B. So What can we Talk about Now? In M. Brady and R. Berwick (eds.), *Computational Models of Discourse.* Cambridge MA: MIT Press, 1982, pp.331-371.

[50] Webber, B. Tense as Definite Anaphor. *Computational Linguistics*, 14(2):61-73, 1988.

[51] Wilson, D. and Sperber, D. Ordered Entailments. In *Syntax and Semantics XI: Presuppositions.* London: Academic Press, 1979.