Incremental Interpretation of Categorial Grammar*

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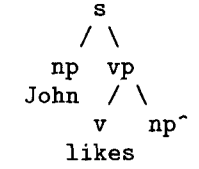
Abstract

The paper describes a parser for Categorial Grammar which provides fully word by word incremental interpretation. The parser does not require fragments of sentences to form constituents, and thereby avoids problems of spurious ambiguity. The paper includes a brief discussion of the relationship between basic Categorial Grammar and other formalisms such as HPSG, Dependency Grammar and the Lambek Calculus. It also includes a discussion of some of the issues which arise when parsing lexicalised grammars, and the possibilities for using statistical techniques for tuning to particular languages.

1 Introduction

There is a large body of psycholinguistic evidence which suggests that meaning can be extracted before the end of a sentence, and before the end of phrasal constituents (e.g. Marslen-Wilson 1973, Tanenhaus et al. 1990). There is also recent evidence suggesting that, during speech processing, partial interpretations can be built extremely rapidly, even before words are completed (Spivey-Knowlton et al. 1994)[1]. There are also potential computational applications for incremental interpretation, including early parse filtering using statistics based on logical form plausibility, and interpretation of fragments of dialogues (a survey is provided by Milward and Cooper, 1994, henceforth referred to as M&C).

In the current computational and psycholinguistic literature there are two main approaches to the incremental construction of logical forms. One approach is to use a grammar with 'non-standard' constituency, so that an initial fragment of a sentence, such as *John likes*, can be treated as a constituent, and hence be assigned a type and a semantics. This approach is exemplified by Combinatory Categorial Grammar, CCG (Steedman 1991), which takes a basic CG with just application, and adds various new ways of combining elements together[2]. Incremental interpretation can then be achieved using a standard bottom-up shift reduce parser, working from left to right along the sentence. The alternative approach, exemplified by the work of Stabler on top-down parsing (Stabler 1991), and Pulman on left-corner parsing (Pulman 1986) is to associate a semantics directly with the partial structures formed during a top-down or left-corner parse. For example, a syntax tree missing a noun phrase, such as the following



can be given a semantics as a function from entities to truth values i.e. λx. **likes(john,x)**, without having to say that *John likes* is a constituent.

Neither approach is without problems. If a grammar is augmented with operations which are powerful enough to make most initial fragments constituents, then there may be unwanted interactions with the rest of the grammar (examples of this in the case of CCG and the Lambek Calculus are given in Section 2). The addition of extra operations also means that, for any given reading of a sentence there will generally be many different possible derivations (so-called 'spurious' ambiguity), making simple parsing strategies such as shift-reduce highly inefficient.

The limitations of the parsing approaches become evident when we consider grammars with left recursion. In such cases a simple top-down parser will be incomplete, and a left corner parser will resort to buffering the input (so won't be fully

*This research was supported by the U.K. Science and Engineering Research Council, grant RR30718. I am grateful to Patrick Sturt, Carl Vogel, and the reviewers for comments on an earlier version.

[1]Spivey-Knowlton et al. reported 3 experiments. One showed effects before the end of a word when there was no other appropriate word with the same initial phonology. Another showed on-line effects from adjectives and determiners during noun phrase processing.

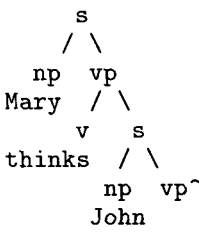
[2]Note that CCG doesn't provide a type for all initial fragments of sentences. For example, it gives a type to *John thinks Mary*, but not to *John thinks each*. In contrast the Lambek Calculus (Lambek 1958) provides an infinite number of types for any initial sentence fragment.

word-by-word). M&C illustrate the problem by considering the fragment *Mary thinks John*. This has a small number of possible semantic representations (the exact number depending upon the grammar) e.g.

λP.thinks(mary,P(john))
λP.λQ. Q(thinks(mary,P(john)))
λP.λR. (R(λx.thinks(x,P(john))))(mary)

The second representation is appropriate if the sentence finishes with a sentential modifier. The third allows there to be a verb phrase modifier.

If the semantic representation is to be read off syntactic structure, then the parser must provide a single syntax tree (possibly with empty nodes). However, there are actually any number of such syntax trees corresponding to, for example, the first semantic representation, since the **np** and the **s** can be arbitrarily far apart. The following tree is suitable for the sentence *Mary thinks John shaves* but not for e.g. *Mary thinks John coming here was a mistake.*



M&C suggest various possibilities for packing the partial syntax trees, including using Tree Adjoining Grammar (Joshi 1987) or Description Theory (Marcus et al. 1983). One further possibility is to choose a single syntax tree, and to use destructive tree operations later in the parse[3].

The approach which we will adopt here is based on Milward (1992, 1994). Partial syntax trees can be regarded as performing two main roles. The first is to provide syntactic information which guides how the rest of the sentence can be integrated into the tree. The second is to provide a basis for a semantic representation. The first role can be captured using syntactic *types*, where each type corresponds to a potentially infinite number of partial syntax trees. The second role can be captured by the parser constructing semantic representations directly. The general processing model therefore consists of transitions of the form:

$$\begin{array}{c}\text{Syntactic type}_i \\ \text{Semantic rep}_i\end{array} \rightarrow \begin{array}{c}\text{Syntactic type}_{i+1} \\ \text{Semantic rep}_{i+1}\end{array}$$

[3]This might turn out to be similar to one view of Tree Adjoining Grammar, where adjunction adds into a pre-existing well-formed tree structure. It is also closer to some methods for incremental adaptation of discourse structures, where additions are allowed to the right-frontier of a tree structure (e.g. Polanyi and Scha 1984). There are however problems with this kind of approach when features are considered (see e.g. Vijay-Shanker 1992).

This provides a state-transition or *dynamic* model of processing, with each state being a pair of a syntactic type and a semantic value.

The main difference between our approach and that of Milward (1992, 1994) is that it is based on a more expressive grammar formalism, Applicative Categorial Grammar, as opposed to Lexicalised Dependency Grammar. Applicative Categorial Grammars allow categories to have arguments which are themselves functions (e.g. **very** can be treated as a function of a function, and given the type **(n/n)/(n/n)** when used as an adjectival modifier). The ability to deal with functions of functions has advantages in enabling more elegant linguistic descriptions, and in providing one kind of robust parsing: the parser never fails until the last word, since there could always be a final word which is a function over all the constituents formed so far. However, there is a corresponding problem of far greater non-determinism, with even unambiguous words allowing many possible transitions. It therefore becomes crucial to either perform some kind of ambiguity packing, or language *tuning*. This will be discussed in the final section of the paper.

2 Applicative Categorial Grammar

Applicative Categorial Grammar is the most basic form of Categorial Grammar, with just a single combination rule corresponding to function application. It was first applied to linguistic description by Adjukiewicz and Bar-Hillel in the 1950s. Although it is still used for linguistic description (e.g. Bouma and van Noord, 1994), it has been somewhat overshadowed in recent years by HPSG (Pollard and Sag 1994), and by Lambek Categorial Grammars (Lambek 1958). It is therefore worth giving some brief indications of how it fits in with these developments.

The first directed Applicative CG was proposed by Bar-Hillel (1953). Functional types included a list of arguments to the left, and a list of arguments to the right. Translating Bar-Hillel's notation into a feature based notation similar to that in HPSG (Pollard and Sag 1994), we obtain the following category for a ditransitive verb such as *put*:

$$\begin{bmatrix} s \\ \mathbf{l}\langle np\rangle \\ \mathbf{r}\langle np,\ pp\rangle \end{bmatrix}$$

The list of arguments to the left are gathered under the feature, **l**, and those to the right, an **np** and a **pp** in that order, under the feature **r**.

Bar-Hillel employed a single application rule, which corresponds to the following:

$$L_n \ldots L_1 \begin{bmatrix} X \\ \mathtt{l}\langle L_1 \ldots L_n \rangle \\ \mathtt{r}\langle R_1 \ldots R_n \rangle \end{bmatrix} R_1 \ldots R_n \Rightarrow \mathrm{X}$$

The result was a system which comes very close to the formalised dependency grammars of Gaifman (1965) and Hays (1964). The only real difference is that Bar-Hillel allowed arguments to themselves be functions. For example, an adverb such as *slowly* could be given the type[4]

$$\begin{bmatrix} s \\ \mathtt{l}\langle np \rangle \\ \mathtt{r}\langle \begin{bmatrix} s \\ \mathtt{l}\langle np \rangle \\ \mathtt{r}\langle\rangle \end{bmatrix} \rangle \end{bmatrix}$$

An unfortunate aspect of Bar-Hillel's first system was that the application rule only ever resulted in a primitive type. Hence, arguments with functional types had to correspond to single lexical items: there was no way to form the type **np\s**[5] for a non-lexical verb phrase such as *likes Mary*.

Rather than adapting the Application Rule to allow functions to be applied to one argument at a time, Bar-Hillel's second system (often called AB Categorial Grammar, or Adjukiewicz/Bar-Hillel CG, Bar-Hillel 1964) adopted a 'Curried' notation, and this has been adopted by most CGs since. To represent a function which requires an **np** on the left, and an **np** and a **pp** to the right, there is a choice of the following three types using Curried notation:

np\((s/pp)/np)
(np\(s/pp))/np
((np\s)/pp)/np

Most CGs either choose the third of these (to give a **vp** structure), or include a rule of Associativity which means that the types are interchangeable (in the Lambek Calculus, Associativity is a consequence of the calculus, rather than being specified separately).

The main impetus to change Applicative CG came from the work of Ades and Steedman (1982). Ades and Steedman noted that the use of function composition allows CGs to deal with unbounded dependency constructions. Function composition enables a function to be applied to its argument, even if that argument is incomplete e.g.

s/pp + pp/np → s/np

This allows peripheral extraction, where the 'gap' is at the start or the end of e.g. a relative clause. Variants of the composition rule were proposed in order to deal with non-peripheral extraction, but this led to unwanted effects elsewhere in the grammar (Bouma 1987). Subsequent treatments of non-peripheral extraction based on the Lambek Calculus (where standard composition is built in: it is a rule which can be proven from the calculus) have either introduced an alternative to the forward and backward slashes i.e. / and \ for normal args, ↑ for wh-args (Moortgat 1988), or have introduced so called modal operators on the wh-argument (Morrill et al. 1990). Both techniques can be thought of as marking the wh-arguments as requiring special treatment, and therefore do not lead to unwanted effects elsewhere in the grammar.

However, there are problems with having just composition, the most basic of the non-applicative operations. In CGs which contain functions of functions (such as *very*, or *slowly*), the addition of composition adds both new analyses of sentences, and new strings to the language. This is due to the fact that composition can be used to form a function, which can then be used as an argument to a function of a function. For example, if the two types, **n/n** and **n/n** are composed to give the type **n/n**, then this can be modified by an adjectival modifier of type **(n/n)/(n/n)**. Thus, the noun *very old dilapidated car* can get the unacceptable bracketing, [[very [old dilapidated]] car]. Associative CGs with Composition, or the Lambek Calculus also allow strings such as *boy with the* to be given the type **n/n** predicting *very boy with the car* to be an acceptable noun. Although individual examples might be possible to rule out using appropriate features, it is difficult to see how to do this in general whilst retaining a calculus suitable for incremental interpretation.

If wh-arguments need to be treated specially anyway (to deal with non-peripheral extraction), and if composition as a general rule is problematic, this suggests we should perhaps return to grammars which use just Application as a general operation, but have a special treatment for wh-arguments. Using the non-Curried notation of Bar-Hillel, it is more natural to use a separate wh-list than to mark wh-arguments individually. For example, the category appropriate for relative clauses with a noun phrase gap would be:

$$\begin{bmatrix} s \\ \mathtt{l}\langle\rangle \\ \mathtt{r}\langle\rangle \\ \mathtt{w}\langle np \rangle \end{bmatrix}$$

It is then possible to specify operations which act as purely applicative operations with respect to the left and right arguments lists, but more like composition with respect to the wh-list. This is very similar to the way in which wh-movement is dealt with in GPSG (Gazdar et al. 1985) and HPSG, where wh-arguments are treated using slash mechanisms or feature inheritance principles

[4]The reformulation is not entirely faithful here to Bar-Hillel, who used a slightly problematic 'double slash' notation for functions of functions.

[5]Lambek notation (Lambek 1958).

which correspond closely to function composition.

Given that our arguments have produced a categorial grammar which looks very similar to HPSG, why not use HPSG rather than Applicative CG? The main reason is that Applicative CG is a much simpler formalism, which can be given a very simple syntax semantics interface, with function application in syntax mapping to function application in semantics[6,7]. This in turn makes it relatively easy to provide proofs of soundness and completeness for an incremental parsing algorithm. Ultimately, some of the techniques developed here should be able to be extended to more complex formalisms such as HPSG.

3 AB Categorial grammar with Associativity (AACG)

In this section we define a grammar similar to Bar-Hillel's first grammar. However, unlike Bar-Hillel, we allow one argument to be absorbed at a time. The resulting grammar is equivalent to AB Categorial Grammar plus associativity.

The categories of the grammar are defined as follows:

1. If **X** is a syntactic type (e.g. s, np), then $\begin{bmatrix} X \\ \mathtt{l}\langle\rangle \\ \mathtt{r}\langle\rangle \end{bmatrix}$ is a category.
2. If **X** is a syntactic type, and **L** and **R** are lists of categories, then $\begin{bmatrix} X \\ \mathtt{l}L \\ \mathtt{r}R \end{bmatrix}$ is a category.

Application to the right is defined by the rule[8]:

$$\begin{bmatrix} X \\ \mathtt{l}L \\ \mathtt{r}\langle R_1\rangle\bullet R \end{bmatrix} + \mathrm{R}_1 \Rightarrow \begin{bmatrix} X \\ \mathtt{l}L \\ \mathtt{r}R \end{bmatrix}$$

Application to the left is defined by the rule:

$$\mathrm{L}_1 + \begin{bmatrix} X \\ \mathtt{l}\langle L_1\rangle\bullet L \\ \mathtt{r}R \end{bmatrix} \Rightarrow \begin{bmatrix} X \\ \mathtt{l}L \\ \mathtt{r}R \end{bmatrix}$$

The basic grammar provides some spurious derivations, since sentences such as *John likes Mary* can be bracketed as either *((John likes) Mary)* or *(John (likes Mary))*. However, we will see that these spurious derivations do not translate into spurious ambiguity in the parser, which maps from strings of words directly to semantic representations.

4 An Incremental Parser

Most parsers which work left to right along an input string can be described in terms of state transitions i.e. by rules which say how the current parsing state (e.g. a stack of categories, or a chart) can be transformed by the next word into a new state. Here this will be made particularly explicit, with the parser described in terms of just two rules which take a state, a new word and create a new state[9]. There are two unusual features. Firstly, there is nothing equivalent to a stack mechanism: at all times the state is characterised by a single syntactic type, and a single semantic value, not by some stack of semantic values or syntax trees which are waiting to be connected together. Secondly, all transitions between states occur on the input of a new word: there are no 'empty' transitions (such as the reduce step of a shift-reduce parser).

The two rules, which are given in Figure 1[10], are difficult to understand in their most general form. Here we will work upto the rules gradually, by considering which kinds of rules we might need in particular instances. Consider the following pairing of sentence fragments with their simplest possible CG type:

Mary thinks: s/s
Mary thinks John: s/(np\s)
Mary thinks John likes: s/np
Mary thinks John likes Sue: s

Now consider taking each type as a description of the state that the parser is in after absorbing the fragment. We obtain a sequence of transitions as follows:

[6] One area where application based approaches to semantic combination gain in simplicity over unification based approaches is in providing semantics for functions of functions. Moore (1989) provides a treatment of functions of functions in a unification based approach, but only by explicitly incorporating lambda expressions. Pollard and Sag (1994) deal with some functions of functions, such as non-intersective adjectives, by explicit set construction.

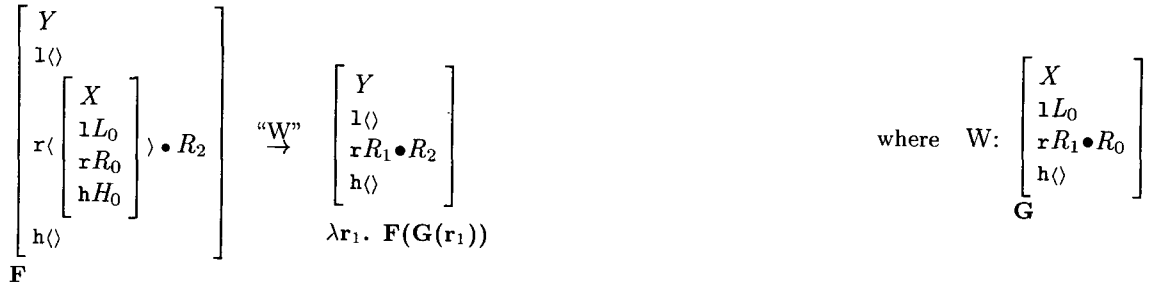
[7] As discussed above, wh-movement requires something more like composition than application. A simple syntax semantics interface can be retained if the same operation is used in both syntax and semantics. Wh-arguments can be treated as similar to other arguments i.e. as lambda abstracted in the semantics. For example, the fragment: *John found a woman who Mary* can be given the semantics **λP.∃x. woman(x) & found(john,x) & P(mary,x)**, where **P** is a function from a left argument *Mary* of type **e** and a wh-argument, also of type **e**.

[8] '•' is list concatenation e.g. ⟨np⟩•⟨s⟩ equals ⟨np,s⟩.

[9] This approach is described in greater detail in Milward (1994), where parsers are specified formally in terms of their dynamics.

[10] $\mathbf{L}_i$, $\mathbf{R}_i$, $\mathbf{H}_i$ are lists of categories. $\mathbf{l}_i$ and $\mathbf{r}_i$ are lists of variables, of the same length as the corresponding $\mathbf{L}_i$ and $\mathbf{R}_i$.

State-Application:



State-Prediction:

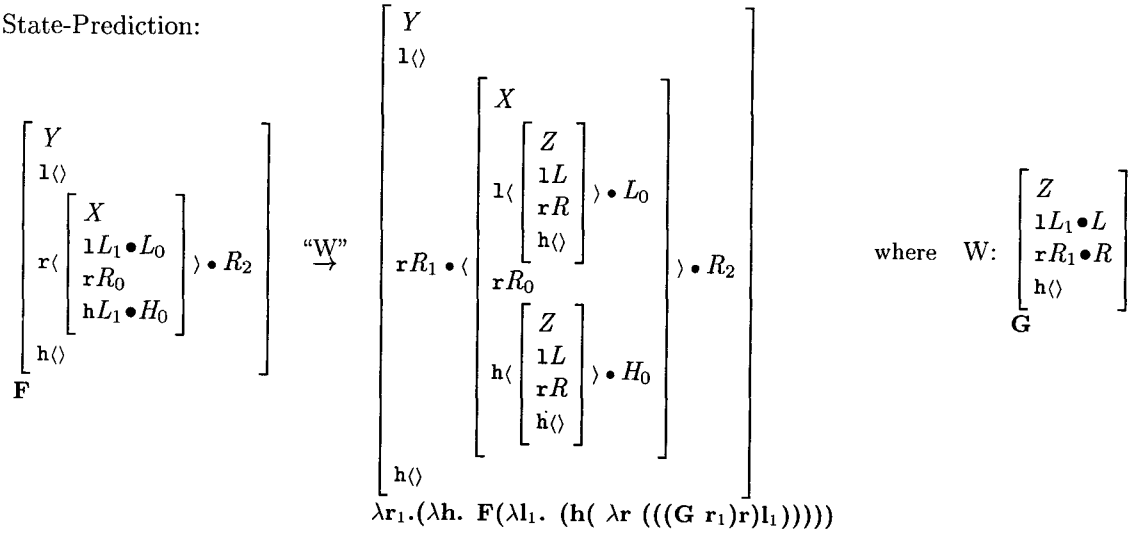


Figure 1: Transition Rules

$$s/s \xrightarrow{\text{"John"}} s/(np\backslash s) \xrightarrow{\text{"likes"}} s/np \xrightarrow{\text{"Sue"}} s$$

If an embedded sentence such as *John likes Sue* is a mapping from an **s/s** to an **s**, this suggests that it might be possible to treat all sentences as mapping from some category expecting an **s** to that category i.e. from **X/s** to **X**. Similarly, all noun phrases might be treated as mappings from an **X/np** to an **X**.

Now consider individual transitions. The simplest of these is where the type of argument expected by the state is matched by the next word i.e.

$$s/np \xrightarrow{\text{"Sue"}} s \qquad \text{where: Sue: np}$$

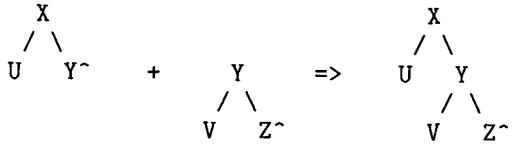
This can be generalised to the following rule, which is similar to Function Application in standard CG[11]

$$X/Y \xrightarrow{\text{"W"}} X \qquad \text{where: W: Y}$$

A similar transition occurs for *likes*. Here an **np\s** was expected, but *likes* only provides part of this: it requires an **np** to the right to form an **np\s**. Thus after *likes* is absorbed the state category will need to expect an **np**. The rule required is similar to Function Composition in CG i.e.

$$X/Y \xrightarrow{\text{"W"}} X/Z \qquad \text{where: W: Y/Z}$$

Considering this informally in terms of tree structures, what is happening is the replacement of an empty node in a partial tree by a second partial tree i.e.



The two rules specified so far need to be further generalised to allow for the case where a lexical item has more than one argument (e.g. if we replace *likes* by a di-transitive such as *gives* or a tri-transitive such as *bets*). This is relatively trivial using a non-curried notation similar to that used for AACG. What we obtain is the single rule of State-Application, which corresponds to application when the list of arguments, $\mathbf{R}_1$, is empty, to function composition when $\mathbf{R}_1$ is of length one, and to n-ary composition when $\mathbf{R}_1$ is of length **n**. The only change needed from AACG notation is

[11] It differs in not being a rule of grammar: here the functor is a state category and the argument is a lexical category. In standard CG function application, the functor and argument can correspond to a word or a phrase.

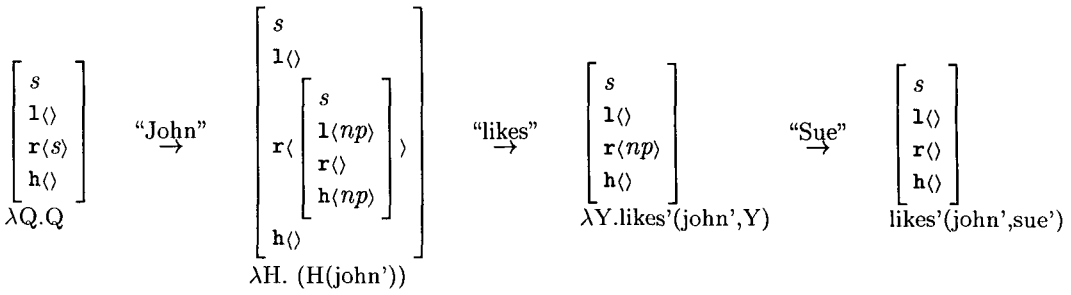


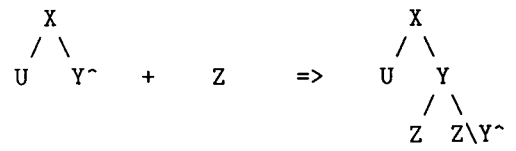
Figure 2: Possible state transitions

the inclusion of an extra feature list, the **h** list, which stores information about which arguments are waiting for a head (the reasons for this will be explained later). The lexicon is identical to that for a standard AACG, except for having h-lists which are always set to empty.

Now consider the first transition. Here a sentence was expected, but what was encountered was a noun phrase, *John*. The appropriate rule in CG notation would be:

$$X/Y \xrightarrow{\text{"W"}} X/(Z\backslash Y) \quad \text{where:} \quad W{:}\ Z$$

This rule states that if looking for a **Y** and get a **Z** then look for a **Y** which is missing a **Z**. In tree structure terms we have:



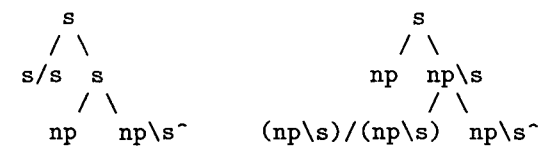
The rule of State-Prediction is obtained by further generalising to allow the lexical item to have missing arguments, and for the expected argument to have missing arguments.

State-Application and State-Prediction together provide the basis of a sound and complete parser[12]. Parsing of sentences is achieved by starting in a state expecting a sentence, and applying the rules non-deterministically as each word is input. A successful parse is achieved if the final state expects no more arguments. As an example, reconsider the string *John likes Sue*. The sequence of transitions corresponding to *John likes Sue* being a sentence, is given in Figure 2. The transition on encountering *John* is deterministic: State-Application cannot apply, and State-Prediction can only be instantiated one way. The result is a new state expecting an argument which, given an **np** could give an **s** i.e. an **np\s**.

[12]The parser accepts the same strings as the grammar and assigns them the same semantic values. This is slightly different from the standard notion of soundness and completeness of a parser, where the parser accepts the same strings as the grammar and assigns them the same syntax trees.

The transition on input of *likes* is non-deterministic. State-Application can apply, as in Figure 2. However, State-Prediction can also apply, and can be instantiated in four ways (these correspond to different ways of cutting up the left and right subcategorisation lists of the lexical entry, *likes*, i.e. as ⟨np⟩ • ⟨⟩ or ⟨⟩ • ⟨np⟩). One possibility corresponds to the prediction of an **s\s** modifier, a second to the prediction of an **(np\s)\(np\s)** modifier (i.e. a verb phrase modifier), a third to there being a function which takes the subject and the verb as separate arguments, and the fourth corresponds to there being a function which requires an **s/np** argument. The second of these is perhaps the most interesting, and is given in Figure 3. It is the choice of this particular transition at this point which allows verb phrase modification, and hence, assuming the next word is *Sue*, an implicit bracketing of the string fragment as *(John (likes Sue))*. Note that if State-Application is chosen, or the first of the State-Prediction possibilities, the fragment *John likes Sue* retains a flat structure. If there is to be no modification of the verb phrase, no verb phrase structure is introduced. This relates to there being no spurious ambiguity: each choice of transition has *semantic* consequences; each choice affects whether a particular part of the semantics is to be modified or not.

Finally, it is worth noting why it is necessary to use h-lists. These are needed to distinguish between cases of real functional arguments (of functions of functions), and functions formed by State-Prediction. Consider the following trees, where the **np\s** node is empty.



Both trees have the same syntactic type, however in the first case we want to allow for there to be an **s\s** modifier of the lower **s**, but not in the second. The headed list distinguishes between the two cases, with only the first having an **np** on its

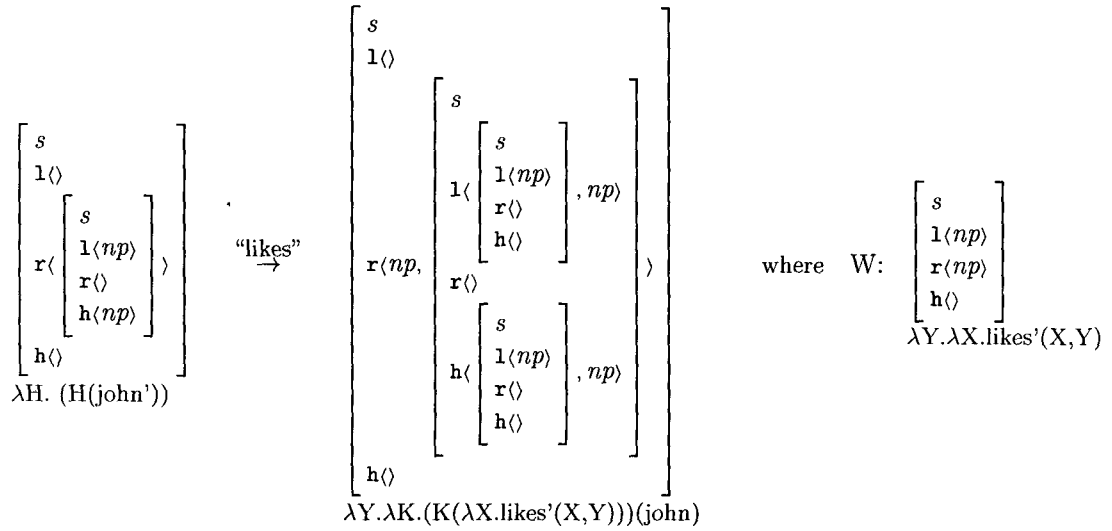


Figure 3: Example instantiation of State-Prediction

headed list, allowing prediction of an **s** modifier.

5 Parsing Lexicalised Grammars

When we consider full sentence processing, as opposed to incremental processing, the use of lexicalised grammars has a major advantage over the use of more standard rule based grammars. In processing a sentence using a lexicalised formalism we do not have to look at the grammar as a whole, but only at the grammatical information indexed by each of the words. Thus increases in the size of a grammar don't necessarily effect efficiency of processing, provided the increase in size is due to the addition of new words, rather than increased lexical ambiguity. Once the full set of possible lexical entries for a sentence is collected, they can, if required, then be converted back into a set of phrase structure rules (which should correspond to a small subset of the rule based formalism equivalent to the whole lexicalised grammar), before being parsing with a standard algorithm such as Earley's (Earley 1970).

In incremental parsing we cannot predict which words will appear in the sentence, so cannot use the same technique. However, if we are to base a parser on the rules given above, it would seem that we gain further. Instead of grammatical information being localised to the sentence as a whole, it is localised to a particular word in its particular context: there is no need to consider a **pp** as a start of a sentence if it occurs at the end, even if there is a verb with an entry which allows for a subject **pp**.

However there is a major problem. As we noted in the last paragraph, it is the nature of parsing incrementally that we don't know what words are to come next. But here the parser doesn't even use the information that the words are to come from a lexicon for a particular language. For example, given an input of 3 nps, the parser will happily create a state expecting 3 nps to the left. This might be a likely state for say a head final language, but an unlikely state for a language such as English. Note that incremental interpretation will be of no use here, since the semantic representation should be no more or less plausible in the different languages. In practical terms, a naive interactive parallel Prolog implementation on a current workstation fails to be interactive in a real sense after about 8 words[13].

What seems to be needed is some kind of *language tuning*[14]. This could be in the nature of fixed restrictions to the rules e.g. for English we might rule out uses of prediction when a noun phrase is encountered, and two already exist on the left list. A more appealing alternative is to base the tuning on statistical methods. This could be achieved by running the parser over corpora to provide probabilities of particular transitions given particular words. These transitions would capture the likelihood of a word having a particular part of speech, and the probability of a particular transition being performed with that part of speech.

[13]This result should however be treated with some caution: in this implementation there was no attempt to perform any packing of different possible transitions, and the algorithm has exponential complexity. In contrast, a packed recogniser based on a similar, but much simpler, incremental parser for Lexicalised Dependency Grammar has $O(n^3)$ time complexity (Milward 1994) and good practical performance, taking a couple of seconds on 30 word sentences.

[14]The usage of the term *language tuning* is perhaps broader here than its use in the psycholinguistic literature to refer to different structural preferences between languages e.g. for high versus low attachment (Mitchell et al. 1992).

There has already been some early work done on providing statistically based parsing using transitions between recursively structured syntactic categories (Tugwell 1995)[15]. Unlike a simple Markov process, there are a potentially infinite number of states, so there is inevitably a problem of sparse data. It is therefore necessary to make various generalisations over the states, for example by ignoring the $\mathbf{R}_2$ lists.

The full processing model can then be either serial, exploring the most highly ranked transitions first (but allowing backtracking if the semantic plausibility of the current interpretation drops too low), or ranked parallel, exploring just the **n** paths ranked highest according to the transition probabilities and semantic plausibility.

6 Conclusion

The paper has presented a method for providing interpretations word by word for basic Categorial Grammar. The final section contrasted parsing with lexicalised and rule based grammars, and argued that statistical language tuning is particularly suitable for incremental, lexicalised parsing strategies.

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[15]Tugwell's approach does however differ in that the state transitions are not limited by the rules of State-Prediction and State-Application. This has advantages in allowing the grammar to learn phenomena such as heavy NP shift, but has the disadvantage of suffering from greater sparse data problems. A compromise system using the rules here, but allowing reordering of the r-lists might be preferable.

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