GRAMMATICAL RELATIONS AS THE BASIS FOR NATURAL LANGUAGE PARSING AND TEXT UNDERSTANDING*

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ABSTRACT

The KING KONG parser described by this paper attempts to apply the principles of relational grammar to the parsing of English in order to overcome the problems encountered by syntactic and semantic parsers. Specifically, this parser uses relational categories such as subject♦ direct object, and instrument to map syntactic constituents onto semantic roles within CD-like structures. Thus, the parser makes use of both syntactic and semantic information to guide its parse.

I BACKGROUND

A. Syntactic Parsing

During the 1970's, Woods, and Bresnan and Kaplan among others developed syntax driven parsers based on various kinds of ATNs, whose theoretical base derived more or less from transformational grammar and its offshoots. A more recent approach to syntax driven parsing is represented by the Marcus parser, which, unlike ATN's, does no backtracking and builds permanent structure. One of the principal difficulties with the type of parser represented by Woods's work and Marcus's work, and also to a lesser extent of Bresnan's and Kaplan's, is illustrated by the problems associated with garden path sentences, which require extended backtracking, or, in the case of the Marcus parser, more look-ahead than his theory permits.

Prepositional phrase attachment represents another problem for syntactic parsers, since this phenomenon is primarily semantic and as such does not lend itself to syntactic solutions. More abstractly, one can say that syntactic parsers generally have trouble dealing with sentences with multiple interpretations, where the ambiguity involves the placement of constituents. Marcus uses a related problem, that of locating the source of a moved WH-phrase, to argue that semantic as well as syntactic information is necessary for an accurate syntactic parse and appeals to the procedure in (woods 19/3) of Selective Modifier Placement, although he does not formally incorporate it.

One syntactic parser, the CHART parser developed by Kay for the MIND system, dealt extensively with this type of problem. The solution chosen was to keep several possibilities open at once by building constituents and, in erfect, treating them as building blocks which could be put together in a variety of ways. The final parse would be the result not only of the identifIcation and analysis of the constituents but also of the choice of how to put them together. The CHART parser relied on some semantic knowledge to make this choice and was in a way a hybrid of syntactic and semantic approaches to parsing.

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B Semantic Parsing

Another approach to ambiguity is offered by members of the semantic school of parsing, among them the developers of CDs: Schank, Abelson, and their students. The developers of such parsers recognized multiple senses of of a word from the start. Attachment problems were resolved either by reference to larger meaning structures such as a scriots or by lexical expectations.

The ability to handle ambiguity is the great advantage of semantic parsers, but this ability comes at a high price. Such a parser has great difficulty capturing generalizations between transformationally related sentences, and it also has to work harder in dealing with problems that are better analyzed in terms of constituent structure, such as gapping. Furthermore, there is no graceful way to retarget a word based parser to another language, since such parsers ignore cross-linguistic generalizations Finally, error handling is often easier in a syntactic parser both because knowledge of constituent structure can often aid in correction and because syntactically based error messages are far more intelligible to the user.

II THE NEED FOR RELATIONAL GRAMMAR

The parser being developed at MITRE differs from most parsers in that it recognizes not two but three levels of representation: the level of structure, the level of meaning, and the level of grammatical relations (subject, object, indirect object)! which mediates between the first two for the purpose of identification of semantic roles. This notion is based mainly on work in (Bayer 1984), although a similar approach in a different framework has been suggested in (Wasow 1978). The premise of this approach is that there is no straightforward mapping between structural information (which, in typical CD approaches, seems to amount to no more than appeals to position) and semantic roles. This is clear even in English, a language whose structure is quite rigid and yields more clues than most languages about the mapping between structure and semantic roles.

An approach in terms of grammatical relations may be justified by i) simplification of syntactic generalizations, ii) simplification of identification of semantic roles, and iii) generality with respect to complex sentences

A. Simplification of Syntactic Generalization

In English, as in other languages, various syntactic facts are best expressed in terms of grammatical relations. The facts of verb agreement, for example, are most elegantly captured through appeals to the categories subject, object, and indirect object (in English as well as languages with richer case marking). Semantic subcategorization facts, such as the requirement that the verb "walk" be predicated of an animate being, are also most easily expressed in terms of grammatical relations. Since final grammati-

cal relations are deduced from surface structure almost solely by positional and morphological information, one might claim that a statement of the facts of verb agreement and subcategorization in terms of this sort of information would be adequate. While it is true that this sort of description can be made, its awkwardness calls its intuitiveness and usefulness into question. The term "subject" in English is isomorphic with the phrase "the NP directly preceding the verb in an uninverted clause, or the NP directly following the initial verb in an inverted clause", but the fact that this disjunction must be employed in all those references where the word "subject" would be naturally used suggests that an important generalization is being missed, even in a language where structure is strict ana fairly unambiguous; in a language where case-marking and word-border combine to identify the subject, the description of the above phenomena in structural and morphological terms becomes much harder.

B Simplification of Identification of Semantic Roles

Analogously, the explicit identification of subject aids in the identification of semantic roles. Generalizations or defaults, such as the mapping into the ACTOR slot, can be greatly simplified by referring to the notion of subject rather tnan to the positions the NP in question may occupy. The mapping properties of classes of exceptions can also Be described easily, when the group of np's conveniently labeled "subject" map Into the OBJECT slot instead, for example.

C. Generality with Respect to Complex Sentences

We referred earlier to the notion of final grammatical relations. This phrase hints at the idea that grammatical relations may CHANGE. This is why, in the passive sentence "John was struck by Mary", the surface subject is mapped into the same semantic slot that receives the direct object of an active sentence such as "Mary struck John". The operation of Passive makes a direct object a subject, with concomitant displacement of the original subject (into the "by"-phrase in English, for example). In order to identify the original relations, we apply the operation BACKWARD in order to "undo" the application of Passive. Although English has relatively few rules which change grammatical relations, these few rules interact to derive complicated multi-clause sentences which positional approaches are hard-pressed to analyze elegantly or easily.

Consider two more of these relation-changing rules: Subject-to-Subject Raising, which makes the subject of a clause in subject position the subject of the dominating clause, relating "That John will go is likely" and "John is likely to go", and Subject-to-Object Raising, which makes the subject of a clause in direct object position the direct object of the dominating clause, relating "I believe that John left" and "1 believe John to have left". These two rules, combined with the rule of Passive above, may cooperate in their application to yield quite complex sentences. For example,

> John is believed by Mary to be likely to have left.

is derived by Subject-to-Subject Raising in the most embedded clause, followed by Subject-to-Object Raising in the next clause up, and finally Passive in the matrix clause. While a relational approach can, having identified and extracted those NP6 which bear the relevant grammatical relations, simply change the grammatical relations of the NPs involved when they undo these operations, a positional/structural approach must physically move the NPs or try to evelop a set of complicated conditions which alter the slot-mappings for a verb. These approaches are unwieldy alternatives to the relational approach; trie intuitive appeal of grammatical relations is demonstrated even in the names of the raising operations just described, names which were coined not by relational grammarians but by the classical transformational grammarians of the '50's and '60's, notably Noam Chomsky, for whom grammatical relations were (and still are) derivative.

III Implementation of the KING KONG Parser

The current implementation of the KING KONG parser contains a Marcus-type syntactic parser coupled with mechanisms for manipulating grammatical relations and semantic roles. It also relies on a semantic representation scheme in which CD type structures are embedded in a semantic net. As the parse progresses, the grammatical relations of the terms in the sentence are identified, and the changes in grammatical relations are undone. Once the initial relations have been reached. the function FILL-CD takes the relational network, along with a set of slot-mappings (which are produced by modifying a set of global defaults, such as SUBJ -> ACTOR, DOBJ -> OBJECT, with whatever verb-specific mappings are appropriate) and maps in the values for the CD.

```
(defkong fly
 (make-word newform 'fly
    semantics (make-kernel
                part-of-speech 'v
                cd fly-family)
    features (copylist *VERB-DEFAULT*)
    gr<->slots '(((subject actor command))
                 ((intrans-subject obj))
                 ((trans-subject instr
                   instrumentality))
                 ((trans-subject obj neither)
                  (dobj instr
                   instrumentality)))
    slot-completions '((obj instr
                        instrumentality)
                       (instr actor control))
                       ))
```

Figure 1.

The dictionary entries for KING KONG, although based on CD-like kernels, look quite different from standard CD's. Figure 1 contains an example of a typical verb entry, for the word "fly". The "part-of-speech" slot for the verb contains subcategorization information, and the "features" slot specifies syntactic and morphological properties. The two fields "gr<->slots" and "slot-completions" contain crucial information which ties the semantic properties of "fly" to its syntactic properties. The former maps from relational categories to semantic slots; the latter fills empty semantic slots based on already filled slots. Each can rely on the functional/semantic notions of "command" and "instrumentality" to guide the slot-filling. An actor must be able to command an action in the sense that he must be able to cause the action to occur; an instrument must be a tool useable by the commander to accomplish the action; an object is the entity primarily affected by the action. An example may clarify this.

The various senses of "fly" are illustrated in Table 1; we consider the semantic roles of these sentences to be as in Table 2.

1. The businessman flew the plane to Cairo. -
   The businessman was a passenger.

2. The pilot flew the plane to Cairo. -
   The pilot actually manipulated the plane's controls.

3. The mummy flew to Cairo. -
   The mummy was cargo.

4. The plane flew to Cairo. -
   The plane was the instrument of its own motion.

5. The pigeon flew to Cairo. -
   The bird was both the instrument and commander of the action.

Table 1.

```
1. fly: actor nil
        object businessman
        instrument plane
2. fly: actor pilot
        object plane
        instrument plane
3. fly: actor nil
        object mummy
        instrument
4. fly: actor nil
        object plane
        instrument plane
5. fly: actor pigeon
        object pigeon
        instrument pigeon
```

Table 2.

IV TESTING AND RESULTS

The parser, with a dictionary of 72 words, was tested on a set of 120 sentences to verify that it recognized the morphology of the words and syntactic constructions of the clauses properly, and that the mapping from structure to grammatical relations and from grammatical relations to semantic roles was correct.

KING KONG worked correctly under the full range of tenses, voices, and under many transformations on sentence structure including unbounded movement rules like WH movement, relation-changing rules like Passive, Dative Movement and Raising, deletion rules such as Equi, and insertion rules such as There-insertion and Extraposition (see a sampling in Table 3). However, tnere were some limitations on the capabilities of the parser arising from its insufficient handling of coordination. We are currently implementing KING KONG as an expert systems approach to parsing in order better to handle decisions about ambiguity. Even with these limitations, the range of sentence constructions it could parse was very wide. Most crucially, KING KONG successfully recognized grammatical relations. It was always able to identify the subject, object and indirect object of each verb, even when these were shifted away from the verb by transformations of the base sentence.

Finally, within the restrictions imposed by lack of context and only the most rudimentary suggestions of a semantic component, KING KONG was always able to map from grammatical relations of entities to actions, to the semantic roles of actor, instrument, and object.

```
A pilot flew the plane.

The good plane could quickly be flown by a good pilot.

Who flew the plane?

What plane is the pilot flying?

Are planes destroying boxes?

He gave the box to John.

Refuel the plane at the airbase.

I am trying to believe that John seemed to promise me to want the ecm to jam the radar.

Does John go quickly?
```

Table 3.

V CONCLUSION

We have demonstrated that the use of relational grammar as a mapping between syntax and semantics overcomes many of the weaknesses associated with other parsing strategies. We realize, of course, that a parser is only one component of an interlace; we are currently eveloping a representation of context using scripts and semantic networks. The latter should provide a capability for understanding simple word extensions, while the former will aid in understanding ill-formed but "meaningful" input. A last hope is that by making use of universal relational categories we can attempt the retargetting of KING KONG to another language-

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