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Controlling Parsing By Passing Messages

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CONTROLLING PARSING BY PASSING MESSAGES

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1.0 INTRODUCTION

The functional segmentation of linguistic knowledge, into rules about form and rules about meaning, has been vital in unravelling the complexities of language. However, it does not follow that the process of analysis will respect the same boundaries and so the very segmentation that provided the insights can be troublesome when one seeks to create a dynamic model of language. Here we are concerned with how linguistic knowledge is used rather than what knowledge is used. The study of process is one of the contributions of a computational linguistics to the study of language (Hays, 1971).

Improper control strategies result in one of the apparent paradoxes of current knowledge-based systems: the more knowledgeable they are, the more inefficient they become. The systems are unable to handle the combinatorial explosion of possibilities that searches of the knowledge space produce. This situation is obviously counter to intuition, and to human behavior: more knowledgeable systems should perform better.

We believe that a language understanding system should have the ability to bring syntactic and semantic knowledge to bear on the analysis at many points in the computation. This enables it to resolve the alternatives as soon as possible and prevent the flow of extraneous analyses to later phases.

Existing conceptual analyzers fall into three major categories: linear control parsers (Woods & Kaplan, 1971), semantic grammars (Hendrix, 1977), and semantic analyzers (Schank, 1975). None permits the flexible, data-governed interaction of syntax and semantics.

Our approach to creating such a model is to use the notion of a society of communicating, knowledge-based, problem-solving experts, called "actors" (Hewitt, 1976). These actors can communicate by passing messages to any other actor in the system. This flexible control structure allows actors at any level of the analysis to interact with actors at other levels. The routing of information in the system is determined by the content of the linguistic act, thus achieving a data-driven control structure. The ability to direct information to the actor that needs it, is expected to improve efficiency. Each subsystem in language contributes to the process of understanding, but often offers several different views of the data. In our scheme, actors communicate to achieve a mutually consistent analysis, out of which comes an understanding of the data.

The capabilities of each actor are determined by the functional segmentation, e.g., an actor can have the ability to use constituent rules that describe the structure of a noun phrase, thus retaining this important facet of linguistic theory.

2.0 DESIGN FEATURES

In the system we are trying to achieve several other design goals in addition to the gain in efficiency:

We agree with Schank (1975) that the goal of analysis is not to produce a parse tree. It should not even be a subgoal, as is the case in systems that first produce a parse tree, then perform semantic interpretation. The parse tree should be considered a data structure that is constructed incidentally to the analysis, or can be constructed if it is needed. But syntax cannot be ignored; it is often useful in determining antecedents of proforms, for example.

Schank's (1975) hypothesis of semantic prediction appears to be a good approach. But one cannot always have expectations. We envisage a system that can flow into a predictive mode when the situation is appropriate, with a default control structure of syntax-then-semantics.

The output of the system should be semantic description of the input as instantiated case-frames. The novelty of the situation is captured by the way in which these case-frames are linked and by their spatio-temporal settings. The semantic description augments the encyclopedia, the store of world knowledge, and is thus available as pragmatic knowledge in the continuing analysis of the input.

3.0 THE ACTORS

Most of our actors are "experts" on aspects of the primitive organizing principles of syntax and of semantics. They become associated with domain knowledge, i.e., the grammar of a language, or world knowledge for a problem area. The job of an actor is to instantiate a model it has been given (top-down analysis), or if it was not given a model, then to find a model (bottom-up analysis). The process of instantiation is performed by eliciting information from other actors that can use their expertise on the problem; they, of course, may have to consult still other actors.

3.1 The Syntactic Experts

The organizing principle of syntax is constituency; the principal actor in syntax thus uses the constituency rules of the grammar to associate words into higher level constructs. The constituent actor recognizes syntactic constructions primarily by matching words to syntactic rules using the dictionary entries of words to determine their syntactic categories.

3.2 The Semantic Experts

The primitive organizing principles of conceptual knowledge are relations of sequence, contingency, enablement, equivalence, taxonomy, part-whole, etc. (Phil[illegible] [illegible]ow how [illegible] [illegible]" expert, for example, knows how to use "contingency", "sequence", and "enable" links.

3.3 Translation Experts

The actors have vocabularies that are peculiar to their domains. Therefore, messages may require translation from the terminology of the sender to that of the receiver. Take, for example, messages between clause actors (CLA) and case-frame actors (CFA). The former uses concepts like subject, object, and verb, whereas the latter uses event, state, agent, etc. There are special actors in the system to handle this.

4.0 A FRAGMENT OF AN ANALYSIS

We will show how the system analyzes:

(1) The left front tire is flat.
(2) I will change it.

and determines the referent of "it" in (2).

The goal of the system is to create a meaning representation by instantiating a CF. Through equivalency and part-whole relations, a CF can be equivalent to a complex of CF´s; thus the top-level instantiation may be achieved by instantiating the lower rank CF´s.

A CFA normally has a model of a CF that it is trying to instantiate. Initially this cannot be the case and the system has to revert to a bottom-up approach. The CFA sends a message to the CLA requesting that it be sent a translation of a syntactic analysis of a clause. The CLA has to find a clause using the rules of the grammar in. A series of instances of the constituent actor are invoked to analyze the rules. As they process the rules, they simultaneously notify an "input actor" of the terminal categories that they have encountered.

When all necessary constituents have been expanded, the constituent actors are halted, waiting to know which of the parse paths might be consistent with the input. The input actor prompts the user for a word. It then sends messages to constituent actors to cause the deletion of paths inconsistent with the input and then messages to those constituent actors that still have valid paths. Effectively there is parallel processing synchronized by the input.

When a clause, i.e., (1), has been found, a translation can be sent to the case-frame expert, but first it must be translated as discussed in the previous section. A request is sent to the translation expert from the clause expert. This translation can be sent to the case-frame expert directly.

The CFA next knows to ask Chronology for the NEXT-EVENT. Chronology predicts that "change tire" will be the next act. The Chronology Expert now passes this information back to the CFA.

The CFA has now processed the first case frame to the best of its abilities and sets out to instantiate the prediction. It is now working in a top-down manner. When the prediction is passed to the CLA and translated, "tire" will be available as a match for the pronoun "it".

5.0 OTHER TOPICS

It is our belief that our message-passing control structure can yield more than improved efficiency. Several of the more difficult problems in natural language processing come about due to the inability of different types of knowledge to be brought to bear at the same time. Once we have a better understanding of the basic principles of message passing we would like to look at such phenomena as:

5.1 Robustness

Rather than having a predefined selection of rules to relax (Sondheimer & Weischedel, 1980), or using exhaustive backtracking, we believe that with message passing we can use the nature and context of errors to seek information from other actors on ways of circumventing the impasse.

5.2 Noun Groups

Oft-found noun groups such as "The staff of the Select Commission on Immigration and Refugee Policy" are fraught with perils for the unwary natural language processor. Examples like these led Gershman (1979) to conclude "Both linguistic and world knowledge are required for correct and efficient handling of noun groups." He went on to argue for "the advantages of the simultaneous application of both kinds of knowledge, without separating the process of understanding into syntactic and semantic stages." (p. 57)

5.3 Parallelism

The origins of the actor methodology are in an investigation of parallel processing. Kornfeld (1979) has pointed out an interesting phenomenon, "combinatorial implosion," in communicating systems. In his example,a parallel and communicating search algorithm dramatically reduces the time behavior, even when the algorithm is run in a pseudoparallel, time-sliced environment. One of our overwhelming interests is to find whether this behavior is manifest in language understanding systems written using the actor methodology.

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