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Modeling the Costs of Ambiguity Resolution and Syntax-Semantics Interaction

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A number of recent cognitive models of human sentence processing have appealed to costs and tradeoffs in resource requirements to support their positions on modularity and interaction effects in resolving syntactic and semantic ambiguities (e.g., Stowe, 1991). However, computational models that analyze the quantitative aspects of sentence processing have only dealt with syntactic parsing (e.g., Abney and Johnson, 1991). Such models have not addressed the tradeoffs in syntactic parsing decisions vis-a-vis local ambiguities and the costs and benefits of making early commitments in semantics. A computational model of the costs and benefits of making both syntactic and semantic decisions at different points in time during sentence processing would provide an excellent formal framework for analyzing the empirical factors involved in sentence processing and for designing cognitive models and experiments. I present such a formal model in this poster.

There have been many previous analyses of parsers as push-down automata that provide measures such as the stack size that enable one to compare and formally evaluate different parsing algorithms. However, one debilitating feature of these models is that their measures, such as the stack size, only take the syntactic complexity of language into account without regard to meaning or the complexity associated with ambiguities in meanings. Worse yet, some analyses do not even consider ambiguities of any kind. In order to perform a meaningful evaluation of a sentence processor, we desire a formal analysis that takes not only such syntactic complexity but also semantic complexity into account in defining a measure to be used as a yardstick to grade different sentence interpreters, not parsers, against each other. By semantic complexity we mean such factors as the costs of lexical semantic ambiguities, of holding on to individual meanings until they are composed with other, and so on.

I propose an abstract model of a sentence interpreter in the form of an enhanced push-down automaton that has a "graph-structured stack" (Mahesh, 1995) in addition to a regular stack. A set of 10 formal operations are defined on this automaton to cover the processes of sentence interpretation. Using this *sentence processing automaton*, I derive a cost metric that takes into account at least the following factors: (i) the cost of keeping around the parts of the syntactic structure of a sentence that must be accessed at a later point, (ii) the cost of syntactic ambiguities, (iii) the cost of holding on to individual word meanings before they are composed with other meanings and the cost of holding on to sentence meanings and the meanings of any embedded clauses, (iv) the difference in cost between holding on to two individual meanings and that of holding on to their composite meaning, (v) the cost of lexical semantic ambiguities, and (vi) the cost of making and holding on to expectations.

Using the above cost metric, I illustrate several tradeoffs in sentence processing with respect to modularity and interactive effects. For example, in the case of a PP-attachment ambiguity, I illustrate the syntactic and semantic tradeoffs in making attachment decisions early (at the preposition), late (at the end of the phrase), or at intermediate points (e.g., at the head noun of the PP).

References

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