Garden-pathing in a statistical dependency parser

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Introduction

This study differentiates between probability models that lead to garden-pathing and those that fail to do so in an incremental dependency parser. We use ***Dependency Grammar*** (Tesnière 1959) to describe sentence structure in terms of word-to-word connections called dependencies. Figure 1 depicts an English sentence where the head word "loves" has links to its dependents "Phoebe" and "boat ".

(1)

We apply three kinds of statistical features, examining each one's usefulness for targeting garden-path analyses that ensnare human readers in three well-studied cases. The results support models of human sentence processing that attend more to parser-state and part-of-speech pair information than surface distance.

Methods

Our parser is built to the specifications of Nivre 2004. Each state consists of four data types (Figure 2), and four possible actions can be taken to get from one state to the next (Figure 3).

(2) Parser States (*configurations*)

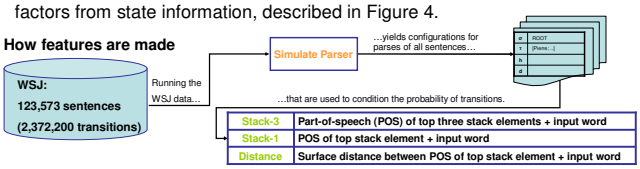
σ	A stack of already-parsed non-reduced words
τ	An ordered input list of unparsed words
h	A function from dependent words to head words
d	A function from dependent words to arc

(3) Parser actions (*transitions*)

Left-arc	σ|[Phoebe] τ: [loves,…]
Right-arc	σ: [loves] τ: [Luke,…]
Shift	σ:[loves, Phoebe] τ: [Luke,…]
Reduce	σ:[ ] τ: [loves,…]

Probability models, or ***features***, that counsel the parser on which action to choose were trained on converted sentences from the Wall Street Journal portion of the Penn Treebank. The models are based on conditioning factors from state information, described in Figure 4.

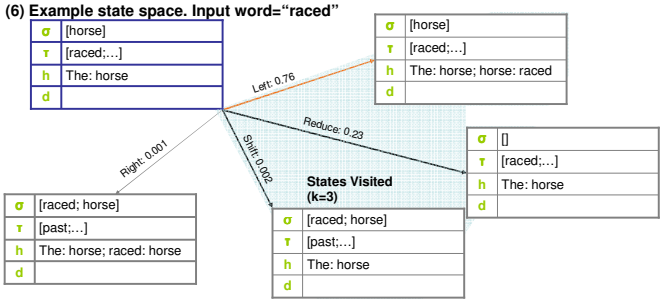
(4) How features are made



Stack-3	Part-of-speech (POS) of top three stack elements + input word
Stack-1	POS of top stack element + input word
Distance	Surface distance between POS of top stack element + input word

We extend Frazier's (1979) idea that garden-pathing is due to the mistaken pruning of the correct analysis by using ***k-best search***. *k*-best search allows the parser to maintain a certain number of analyses (called k) throughout the parse. In our model k=3. The analyses are ranked by the features. Figure 6 shows a sample state space during the parse of the garden path "A horse raced past the barn fell". If the transition that draws a left arc from "raced" to "horse", signifying the human-preferred main-verb interpretation of the sentence (Figure 7), is ranked in the top 3, the parser will garden path as a human would.

(6) Example state space. Input word="raced"

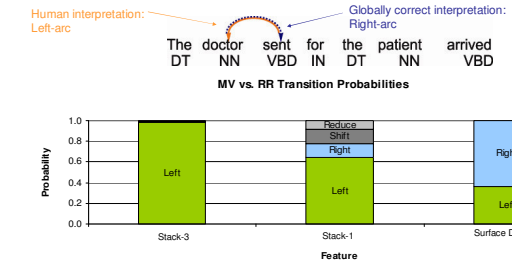


(7) Human-preferred reading

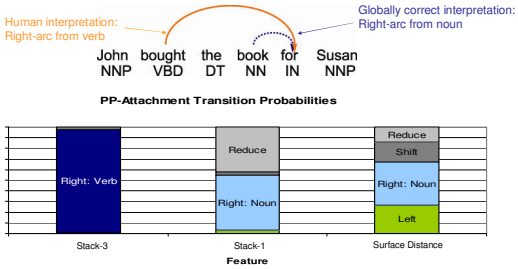
Results

We tested our parser on three garden-path phenomena. Our goal is to see which features counsel for the human-preferred (i.e., garden-path) action at each ambiguous choice point.

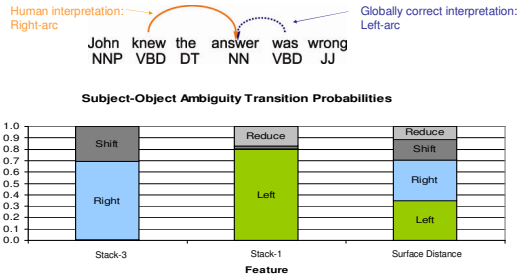
(8) Main verb/reduced relative ambiguity results



(9) Prepositional phrase attachment ambiguity results



(10) Subject/object ambiguity results



Analysis and Conclusions

The Stack-3 feature leads the parser up the attested garden path in all cases studied whereas the other two features do not, as shown in Figure 11.

(11) Results for garden-path and globally correct interpretations by feature

	MV vs. RR	PP-Attachment	Subj-Obj Ambiguities
Stack-3	✔	✔	✔
Stack-1	✔	✔	
Distance	✔	✔	

In a parser attentive to a wide variety of features, some reflect the human preferences more accurately than others. Figure 12 depicts this ranking.

(12) Distributional basis for human parsing preferences

Stack-3 >> Stack-1 >> Surface Distance

We have shown that

- An incremental dependency parser trained on the WSJ can model human ambiguity resolution.
- Our feature hierarchy defines a distributional basis for human parsing preferences.

References

Frazier, L. 1979. On Comprehending Sentences: Syntactic parsing strategies. Ph.D. Dissertation, University of Connecticut.

Nivre, J. 2004. Incrementality in Deterministic Dependency Parsing. Proceedings of the Workshop on Incremental Parsing (ACL): 50-57.

Tesnière, L. 1959. Élements de syntaxe structurale. Editions Klincksiek.

For more information

A published paper that provides further detail:
http://www.msu.edu/~mferrara/Boston&HaleMCLC.pdf

The incremental dependency parser we used:
http://www.msu.edu/~mferrara/DepParse1.3.tar.gz