Linguistically Motivated Complementizer Choice in Surface Realization

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Abstract
This paper shows that using linguistically motivated features for English that-complementizer choice in an averaged perceptron model for classification can improve upon the prediction accuracy of a state-of-the-art realization ranking model. We report results on a binary classification task for predicting the presence/absence of a that-complementizer using features adapted from Jaeger's (2010) investigation of the uniform information density principle in the context of that-mentioning. Our experiments confirm the efficacy of the features based on Jaeger's work, including information density–based features. The experiments also show that the improvements in prediction accuracy apply to cases in which the presence of a that-complementizer arguably makes a substantial difference to fluency or intelligibility. Our ultimate goal is to improve the performance of a ranking model for surface realization, and to this end we conclude with a discussion of how we plan to combine the local complementizer-choice features with those in the global ranking model.

1 Introduction
Johnson (2009) observes that in developing statistical parsing models, “shotgun” features — that is, myriad scattershot features that pay attention to superficial aspects of structure — tend to be remarkably useful, while features based on linguistic theory seem to be of more questionable utility, with the most basic linguistic insights tending to have the greatest impact. Johnson also notes that feature design is perhaps the most important but least understood aspect of statistical parsing, and thus the disappointing impact of linguistic theory on parsing models is of real consequence. In this paper, by contrast, we show that in the context of surface realization, using linguistically motivated features for English that-complementizer choice can improve upon the prediction accuracy of a state-of-the-art realization ranking model, arguably in ways that make a substantial difference to fluency and intelligibility. In particular, we report results on a binary classification task for predicting the presence or absence of a that-complementizer using features adapted from Jaeger’s (2010) investigation of the uniform information density principle in the context of that-mentioning. This information-theoretic principle predicts that language production is affected by a preference to distribute information uniformly across the linguistic signal. In Jaeger’s study, uniform information density emerges as an important predictor of speakers’ syntactic reduction preferences even when taking a sizeable variety of controls based on competing hypotheses into account. Our experiments confirm the efficacy of the features based on Jaeger’s work, including information density–based features.

1The term “shotgun” feature appears in the slides for Johnson’s talk (http://www.cog.brown.edu/~mj/papers/johnson-eacl109-workshop.pdf), rather than in the paper itself.

2For German surface realization, Cahill and Riester (2009) show that incorporating information status features based on the linguistics literature improves performance on realization ranking.
That-complementizers are optional words that introduce sentential complements in English. In the Penn Treebank, they are left out roughly two-thirds of the time, thereby enhancing conciseness. This follows the low complementizer rates reported in previous work (Tagliamonte and Smith, 2005; Ca- coullos and Walker, 2009). While some surface re-presenters, such as FUF/SURGE (Elhadad, 1991), have made use of input features to control the choice of whether to include a that-complementizer, for many applications the decision seems best left to the real-izer, since multiple surface syntactic factors appear to govern the choice, rather than semantic ones. In our experiments, we use the OpenCCG\textsuperscript{3} surface real-izer with logical form inputs underspecified for the presence of that in complement clauses. While in many cases, adding or removing that results in an acceptable paraphrase, in the following example, the absence of that in (2) introduces a local ambiguity, which the original Penn Treebank sentence avoids by including the complementizer.

(1) He said that for the second month in a row, food processors reported a shortage of nonfat dry milk. (WSJ0036.61)

(2) ?He said for the second month in a row, food processors reported a shortage of nonfat dry milk.

The starting point for this paper is White and Ra-jkumar’s (2009) realization ranking model, a state-of-the-art model employing shotgun features gal-lore. An error analysis of this model, performed by comparing CCGbank Section 00 realized derivations with their corresponding gold standard derivations, revealed that out of a total of 543 that-complementizer cases, the realized output did not match the gold standard choice 82 times (see Table 3 in Section 5 for details). Most of these mismatches involved cases where a clause originally containing a that-complementizer was realized in reduced form, with no that. This under-prediction of that-inclusion is not surprising, since the realization ranking model makes use of baseline n-gram model features, and n-gram models are known to have a built-in bias for strings with fewer words.

\footnote{openccg.sf.net}

We report here on experiments comparing this global model to ones that employ local features specifically designed for that-choice in complement clauses. As a prelude to incorporating these features into a model for realization ranking, we study the efficacy of these features in isolation by means of a binary classification task to predict the presence/absence of that in complement clauses. In a global realization ranking setting, the impact of these phenomenon-specific features might be less evident, as they would interact with other features for lexical selection and ordering choices that the ranker makes. Note that a comprehensive ranking model is desirable, since linear ordering and that-complementizer choices may interact. For example, Hawkins (2003) reports examples where explicitly marked phrases can occur either close to or far from their heads as in (3) and (4), whereas zero-marked phrases are only rarely attested at some distance from their heads and prefer adjacency, as (5) and (6) show.

(3) I realized [that he had done it] with sadness in my heart.
(4) I realized with sadness in my heart [that he had done it].
(5) I realized [he had done it] with sadness in my heart.
(6) ?I realized with sadness in my heart [he had done it].

2 Background

CCG (Steedman, 2000) is a unification-based categorial grammar formalism defined almost entirely in terms of lexical entries that encode sub-categorization as well as syntactic features (e.g. number and agreement). OpenCCG is a parsing/generation library which includes a hybrid symbolic-statistical chart realizer (White, 2006). The chart realizer takes as input logical forms represented internally using Hybrid Logic Dependency Semantics (HLDS), a dependency-based approach to representing linguistic meaning (Balridge and Kruijff, 2002). To illustrate the input to OpenCCG, consider the semantic dependency graph in Figure 1. In the graph, each node has a lexical predication (e.g. make.03) and a set of semantic features (e.g.
Figure 1: Semantic dependency graph from the CCGbank for *He has a point he wants to make [...]*, along with gold-standard supertags (category labels)

\(\langle \text{NUM}\rangle\text{sg}\); nodes are connected via dependency relations (e.g. \(\langle \text{Arg0} \rangle\)). In HLDS, each semantic head (corresponding to a node in the graph) is associated with a nominal that identifies its discourse referent, and relations between heads and their dependents are modeled as modal relations. We extract HLDS-based quasi logical form graphs from the CCGbank and semantically empty function words such as complementizers, infinitival-to, expletive subjects, and case-marking prepositions are adjusted to reflect their purely syntactic status. Alternative realizations are ranked using an averaged perceptron model described in the next section.

3 Feature Design

White and Rajkumar’s (2009) realization ranking model serves as the baseline for this paper. It is a global, averaged perceptron ranking model using three kinds of features: (1) the log probability of the candidate realization’s word sequence according to three linearly interpolated language models (as well as a feature for each component model), much as in the log-linear models of Velldal & Oepen (2005) and Nakanishi et al. (2005); (2) integer-valued syntactic features, representing counts of occurrences in a derivation, from Clark & Curran’s (2007) normal form model; and (3) discriminative \(n\)-gram features (Roark et al., 2004), which count the occurrences of each \(n\)-gram in the word sequence.

Table 1 shows the new complementizer-choice features investigated in this paper. The example features mentioned in the table are taken from the two complement clause (CC) forms (with-\textit{that} CC vs. \textit{that}-less CC) of the sentence below:

(7) The finding probably will support those who \textbf{argue} \{ \textit{that} / \emptyset \textit{the U.S. should regulate the class of asbestos including crocidolite more stringently than the common kind of asbestos, chrysotile, found in most schools and other buildings} \}, Dr. Talcott said. (WSJ0003.19)

The first class of features, dependency length and position of CC, have been adapted from the related control features in Jaeger’s (2010) study. For the above example, the position of the matrix verb with respect to the start of the sentence (feature name \textit{mvInd} and having the value 7.0), the distance between the matrix verb and the onset of the CC (feature name \textit{mvCCDist} with the value 1.0) and finally the length of the CC (feature \textit{ccLen} with value of 29.0 for the \textit{that}-CC and 28.0 for the \textit{that}-less CC) are encoded as features. The second class of features includes various properties of the matrix verb viz. POS tag, form, stem and supertag (feature names \textit{mvPos}, \textit{mvStem}, \textit{mvForm}, \textit{mvSt}, respectively). These features were motivated by the fact that Jaeger controls for the per-verb bias of this construction, as attested in the earlier literature. The third class of features are related to information density. Jaeger (2010) estimates information density at the CC onset by using matrix verb subcategorization frequency. In our case, more like the \(n\)-gram features employed by Levy and Jaeger (2007), we used log probabilities from two existing \(n\)-gram models, viz. a trigram word model and trigram word model with semantic class replacement. For each CC, two features (one per language model) were extracted by calculating the average of the log probs of individual words from the beginning of the complement clause. In the \textit{that}-CC version of the example above, local CC-features having the prefix \textit{SuidCCMean} were calculated by averaging the individual log probs of the 3 words \textit{that} \textit{the U.S.} to get feature values of -0.8353556 and -2.0460036 per language model (see
Table 1: New features introduced (the prefix of each feature encodes the type of CC; subsequent parts supply the feature name)

Table 2: Classification accuracy results (Section 00 has 170/543 that-CCs; Section 23 has 192/579 that-CCs)

Table 3: Section 00 construction-wise that-CC proportions and model accuracies (total CC counts given in brackets alongside labels); gold standard obviously has 100% accuracy; models are local that-classification and White and Rajkumar’s (2009) global realization ranking model

difference to intelligibility or fluency. In order to better understand the effect of the complementizer-specific features, we examined three construction types in the development data, viz. non-adjacent complement clauses, gerundive matrix verbs and a host of sub-cases involving a matrix be-verb (wh-clefts, be+adjective etc.), where the presence of that seemed to make the most difference. The results are provided in Table 3. As is evident, the global realization ranking model under-proposes the that-choice, most likely due to the preference of n-gram models towards fewer words, while the local classification-
**Conclusions and Future Work**

In this paper, we have shown that using linguistically motivated features for English *that*-complementizer choice in a local classifier can improve upon the prediction accuracy of a state-of-the-art global realization ranking model employing myriad shotgun features, confirming the efficacy of features based on Jaeger’s (2010) investigation of the uniform information density principle in the context of *that*-mentioning. Since *that*-complementizer choice interacts with other realization decisions, in future work we plan to investigate incorporating these features into the global realization ranking model. This move will require binning the real-valued features, as multiple complement clauses can appear in a single sentence. Should feature-level integration prove ineffective, we also plan to investigate alternative architectures, such as using the local classifier outputs as features in the global model.

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