ON SOME FORMAL PROPERTIES OF METARULES

1. Introduction

Grammars contain rules for generating sentences. Metarules are statements about these rules. They are metagrammatical devices that can be used to generate rules of the grammar or to encode certain relations among them such as redundancies in their form.

The linguistic framework of Generalized Phrase Structure Grammar (GPSG) (Gazdar 1982; Gazdar, Pullum, and Sag 1981; Gazdar and Pullum 1982) utilizes metarules in describing natural languages. The rules of a GPSG are context-free (CF) phrase-structure rules. A metarule is an ordered pair of rule templates \((A, B)\) (often written \(A \Rightarrow B\)) that is to be interpreted as follows: if the grammar contains a rule of the form \(A\), it also contains a corresponding rule of the form \(B\). As this interpretation suggests, the set of grammar rules is closed under application of the metarules. It is therefore possible to give an inductive definition of the grammar by listing just a subset of the rules – called the basic rules – together with the list of metarules; the full set of rules is derived by applying the metarules to the basic rules and then, recursively, to the output of all such applications.

In GPSG, metarules are used to describe many of the linguistic phenomena for which transformations have previously been employed. Gazdar and other proponents of GPSG claim that GPSGs are powerful enough to capture all the generalizations about natural languages that were expressed by transformations and, at the same time, sufficiently constrained to generate only context-free languages. The design of the framework is built on the conjecture that all natural languages are CF.

We neither aim to discuss the theory of GPSG in its entirety nor to restrict our attention to this individual framework. We do not concern ourselves here with most of the mechanisms used by GPSG: derived categories, feature cooccurrence restrictions, ID/LP notation, subcategorization by rule, etc. Instead we are interested in certain formal properties of all grammars that use metarules of the form and in the way described above to close a set of CF grammar rules. Since our definitions are abstract enough to make our results applicable to several such theories, we term the grammars studied in this paper Metarule Phrase Structure or MPS grammars (see the Appendix for definitions).
Our results mainly concern the weak generative capacity of MPS grammars. We show that the power of the formalism is greater than was previously assumed. Unconstrained MPS grammars have Turing machine power, i.e., they are capable of generating the full family of recursively enumerable string sets. Some constrained versions of the MPS grammar formalism still exhibit a certain degree of incommensurate excessive generative power. Finding a strong enough constraint that is both linguistically motivated and descriptively adequate will be a difficult task.

2. The role of variables and phantom symbols

What provides such a degree of generative power to a formalism that enumerates CF phrase structure rules? Clearly, a finite list of (basic) CF phrase-structure rules will generate only a CF language. How can metarules that merely add more CF rules alter the picture? To find an answer to this question, we begin by taking a closer look at metarules.

We have not yet said anything about the form of the rule templates that occur in metarules. A simple template might look exactly like a CF rule. It then matches just that one rule. Most metarules proposed so far for grammars of natural language fragments are more general, in that they use templates that match a larger set of rules. This is achieved by employing variables in metarules. It is helpful to classify the variables that have been used into two categories. The first consists of abbreviatory, or inessential, variables, which range over finite sets of admissible values. Such variables may be useful in permitting the expression of linguistically important generalizations. However, abbreviatory variables can always be eliminated from a grammar, since each metarule containing them can be replaced by the finitely many metarules obtained when these variables are instantiated in all admissible ways. Thus, inessential variables do not affect either the set of strings that can be generated or the sets of tree structures that can be assigned to generated strings by MPS grammars.

The second kind of variables are nonabbreviatory, or essential, variables, which range over all strings of terminal and nonterminal symbols. Rule (1) is an example of a metarule that contains both abbreviatory and essential variables. Here X and Y are essential variables and A is an abbreviatory variable with the range \{NP, PP\} and \(\alpha\) is an abbreviatory variable ranging over agreement feature specifications. The rule is supposed to generate VP rules with subject-controlled reflexivized constituents; the variable \(\alpha\) over agreement features also determines the appropriate reflexive pronoun.\(^3\)