Formal Languages, Automata and Codes

Oleg Gutik

Lecture 16

One of the most important uses of the theory of formal languages is in the definition of programming languages and in the construction of interpreters and compilers for them. The basic problem here is to define a programming language precisely and to use this definition as the starting point for the writing of efficient and reliable translation programs. Both regular and context-free languages are important in achieving this. As we have seen, regular languages are used in the recognition of certain simple patterns that occur in programming languages, but as we argue in the introduction to this part of lectures, we need context-free languages to model more complicated aspects.

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5.3 Context-Free Grammars and Programming Languages

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Many parts of C-like programming languages are susceptible to definition by restricted forms of context-free grammars. For example, the while statement in C can be defined as

$$\langle \texttt{while\_statement} \rangle ::= \texttt{while} \langle \texttt{expression} \rangle \langle \texttt{statement} \rangle.$$

Here the keyword `while` is a terminal symbol. All other terms are variables, which still have to be defined. If we check this against Definition 5.4, we see that this looks like an s-grammar production. The variable $\langle \texttt{while statement} \rangle$ on the left is always associated with the terminal while on the right. For this reason such a statement is easily and efficiently parsed. We see here a reason why we use keywords in programming languages. Keywords not only provide some visual structure that can guide the reader of a program, but also make the work of a compiler much easier.

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Here the keyword **while** is a terminal symbol. All other terms are variables, which still have to be defined. If we check this against Definition 5.4, we see that this looks like an s-grammar production. The variable $\langle \texttt{while statement} \rangle$ on the left is always associated with the terminal while on the right. For this reason such a statement is easily and efficiently parsed. We see here a reason why we use keywords in programming languages. Keywords not only provide some visual structure that can guide the reader of a program, but also make the work of a compiler much easier.

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In connection with this, the issue of ambiguity takes on added significance. The specification of a programming language must be unambiguous, otherwise a program may yield very different results when processed by different compilers or run on different systems. As Example 5.11 shows, a naive approach can easily introduce ambiguity in the grammar. To avoid such mistakes we must be able to recognize and remove ambiguities. A related question is whether a language is or is not inherently ambiguous. What we need for this purpose are algorithms for detecting and removing ambiguities in context-free grammars and for deciding whether or not a context-free language is inherently ambiguous. Unfortunately, these are very difficult tasks, impossible in the most general sense, as we will see later.

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5.3 Context-Free Grammars and Programming Languages

Those aspects of a programming language that can be modeled by a context-free grammar are usually referred to as its syntax. However, it is normally the case that not all programs that are syntactically correct in this sense are in fact acceptable programs. For C, the usual Backus-Naur form definition allows constructs such as

$$\texttt{char} \qquad a, b, c;$$

followed by

$$c = 3.2;$$

This combination is not acceptable to C compilers since it violates the constraint, "*a character variable cannot be assigned a real value*." Context-free grammars cannot express the fact that type clashes may not be permitted. Such rules are part of programming language semantics, since they have to do with how we interpret the meaning of a particular construct.

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Programming language semantics are a complicated matter. Nothing as elegant and concise as context-free grammars exists for the specification of programming language semantics, and consequently some semantic features may be poorly defined or ambiguous. It is an ongoing concern both in programming languages and in formal language theory to find effective methods for defining programming language semantics. Several methods have been proposed, but none of them has been as universally accepted and are as successful for semantic definition as context-free languages have been for syntax.

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Thank You for attention!