Syntax

In Text: Chapter 3

Outline

- Syntax:
  - Recognizer vs. generator
  - BNF
  - EBNF

Basic Definitions

- Syntax—the form or structure of the expressions, statements, and program units
- Semantics—the meaning of the expressions, statements, and program units

- Why write a language definition; who will use it?
    - Other language designers
    - Implementors (compiler writers)
    - Programmers (the users of the language)

What is a “Language”?

- A sentence is a string of characters over some alphabet
- A language is a set of sentences
- A lexeme is the lowest level syntactic unit of a language (e.g., *, sum, begin)
- A token is a category of lexemes (e.g., identifier)

Recognizers vs. Generators

- We don't want to use English to describe a language (too long, tedious, imprecise), so …
- There are two formal approaches to describing syntax:
  - Recognizers
    - Given a string, a recognizer for a language L tells whether or not the string is in L (ex: Compiler)
  - Generators
    - A generator for L will produce an arbitrary string in L on demand. (ex: Grammar, BNF)
  - Recognition and generation are useful for different things, but are closely related

Grammars

- Developed by Noam Chomsky in the mid-1950s
- 4-level hierarchy (0-3)
- Language generators, meant to describe the syntax of natural languages
- Context-free grammars define a class of languages called context-free languages (level 2)

Backus-Naur Form

- Invented by John Backus and Peter Naur to describe syntax of Algol 58/60
- BNF is equivalent to context-free grammars
- A metalanguage: a language used to describe another language

BNF Nonterminals

- In BNF, abstractions are used to represent classes of syntactic structures—they act like syntactic variables (also called nonterminal symbols)

  <while_stmt> -> while <logic_expr> do <stmt>

- This is a rule; it describes the structure of a while
- statement

BNF Rules

- A rule has a left-hand side (LHS) and a right-hand side (RHS), and consists of terminal and nonterminal symbols
- A grammar is a finite nonempty set of rules
- An abstraction (or nonterminal symbol) can have more than one RHS:

<stmt> -> <single_stmt>
    | begin <stmt_list> end

- Syntactic lists are described using recursion:

<ident_list> -> ident
        | ident, <ident_list>

An Example Grammar

```
<program> -> <stmts>
<stmts>   -> <stmt>
           | <stmt> ; <stmts>
<stmt>    -> <var> = <expr>
<var>     -> a | b | c | d
<expr>    -> <term> + <term>
           | <term> - <term>
<term>    -> <var>
           | const
```

Derivations

- A derivation is a repeated application of rules, starting with the start symbol and ending with a sentence (all terminal symbols):

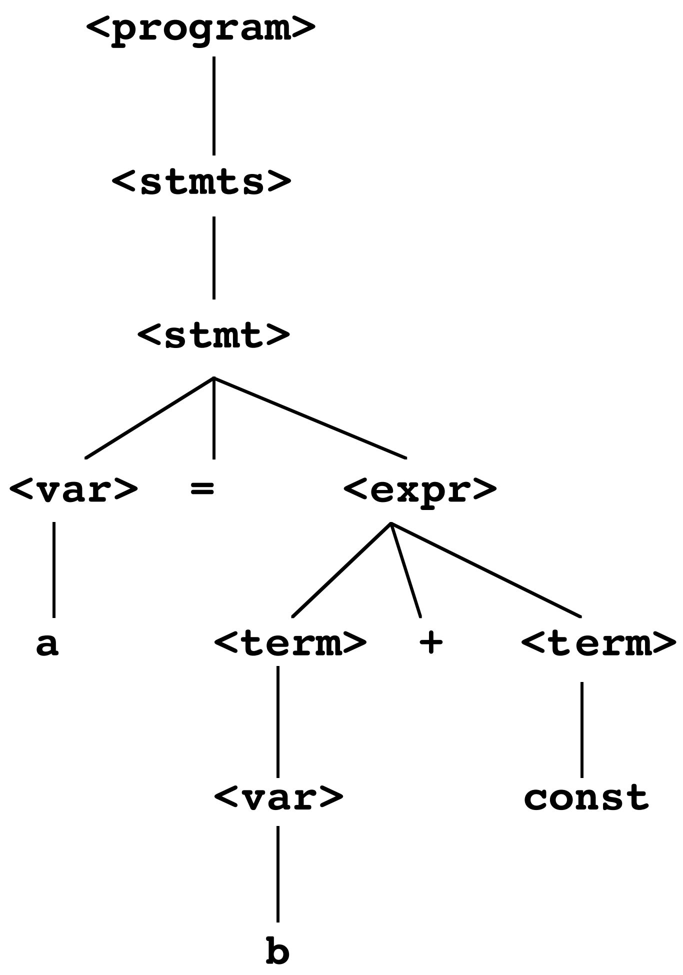
```
<program> => <stmts>
          => <stmt>
          => <var> = <expr>
          => a = <expr>
          => a = <term> + <term>
          => a = <var> + <term>
          => a = b + <term>
          => a = b + const
```

Sentential Forms

- Every string of symbols in the derivation is a sentential form
- A sentence is a sentential form that has only terminal symbols
- A leftmost derivation is one in which the leftmost nonterminal in each sentential form is the one that is expanded next in the derivation
- A rightmost derivation works right to left instead
- Some derivations are neither leftmost nor rightmost

Parse Trees

- A parse tree is a hierarchical representation of a derivation
- A grammar is ambiguous iff it generates a sentential form that has two or more distinct parse trees

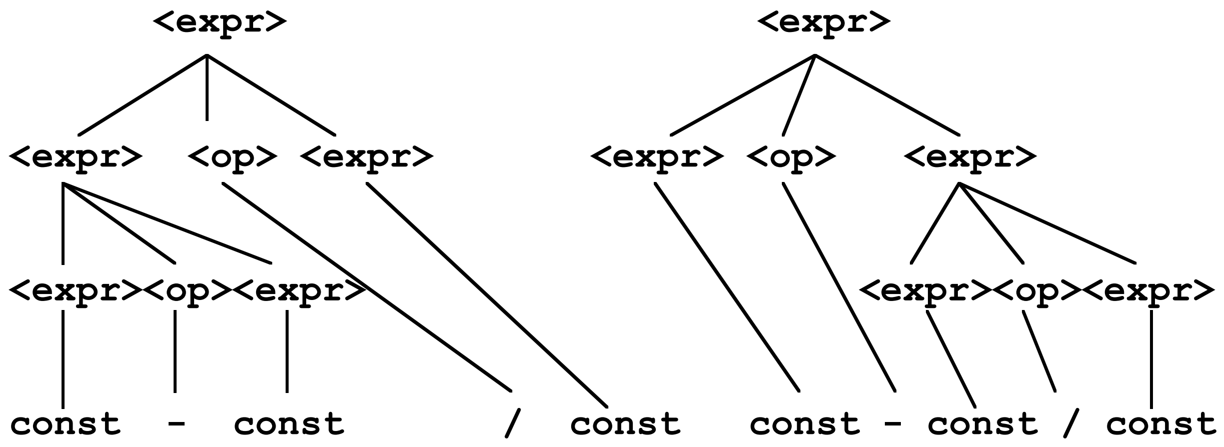


Ambigous Grammars

- An ambiguous expression grammar:

<expr> -> <expr> <op> <expr> | const

<op> -> / | -



<expr>

<expr> <op> <expr>

<expr><op><expr>

const - const / const

<expr>

<expr> <op> <expr>

<expr><op><expr>

const - const / const

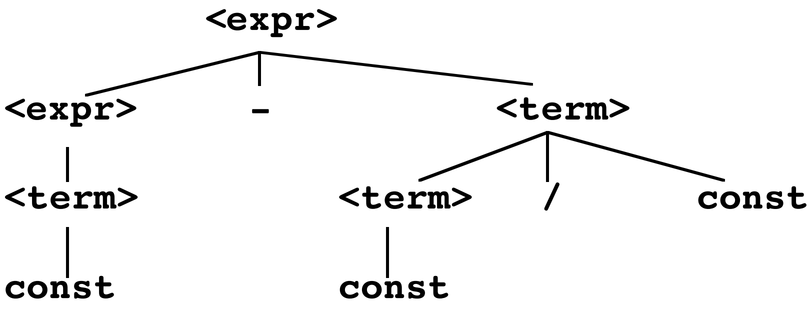
Indicating Precedence

- If we use the parse tree to indicate precedence levels of the operators, we cannot have ambiguity:

<expr> -> <expr> - <term> | <term>

<term> -> <term> / const | cons

```
<expr> => <expr> - <term>
       => <term> - <term>
       => const - <term>
       => const - <term> / const
       => const - const / const
```

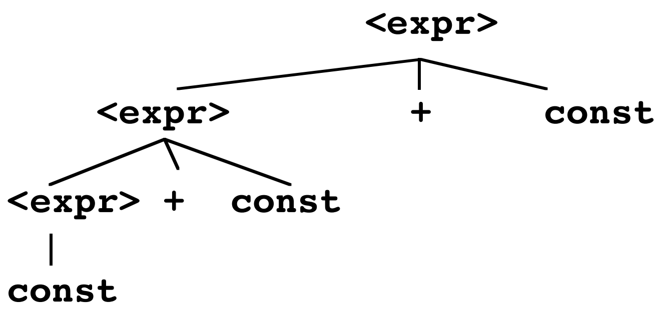


Operator Associativity

- Operator associativity can also be indicated by a grammar

<expr> -> <expr> + <expr> | const (ambiguous)

<expr> -> <expr> + const | const (unambiguous)



Extended BNF (EBNF)

- Optional parts are placed in brackets ([])

<proc_call> -> ident [(<expr_list>)]

- Put alternative parts of RHS in parentheses and separate them with vertical bars

<term> -> <term> (+ | -) const

- Put repetitions (0 or more) in braces ({})

<ident> -> letter {letter | digit}

BNF and EBNF Side by Side

- BNF:

```
<expr> -> <expr> + <term>
        | <expr> - <term>
        | <term>
<term> -> <term> * <factor>
        | <term> / <factor>
        | <factor>
```

- EBNF:

```
<expr> -> <term>  {(+ | -) <term>}
<term> -> <factor> {(* | /) <factor>}
```

Recursive Descent Parsing

- Parsing is the process of tracing or constructing a parse tree for a given input string
- Parsers usually do not analyze lexemes; that is done by a lexical analyzer, which is called by the parser
- A recursive descent parser traces out a parse tree in top-down order; it is a top-down parser
- Each nonterminal in the grammar has a subprogram associated with it; the subprogram parses all sentential forms that the nonterminal can generate
- The recursive descent parsing subprograms are built directly from the grammar rules
- Recursive descent parsers, like other top-down parsers, cannot be built from left-recursive grammars

Recursive Descent Example

- Example: For the grammar:
- <term> -> <factor> {(* | /) <factor>}
- Simple recursive descent parsing subprogram:

```
void term() {
   factor();  /* parse the first factor*/
   while (next_token == ast_code ||
         next_token == slash_code) {
     lexical();  /* get next token */
     factor();  /* parse the next factor */
   }
}
```