Programming Languages

2nd edition

Tucker and Noonan

Chapter 2
Syntax

A language that is simple to parse for the compiler is also simple to parse for the human programmer.

N. Wirth

Contents

- 2.1 Grammars
    - 2.1.1 Backus-Naur Form
    - 2.1.2 Derivations
    - 2.1.3 Parse Trees
    - 2.1.4 Associativity and Precedence
    - 2.1.5 Ambiguous Grammars
- 2.2 Extended BNF
- 2.3 Syntax of a Small Language: *Clite*
    - 2.3.1 Lexical Syntax
    - 2.3.2 Concrete Syntax
- 2.4 Compilers and Interpreters
- 2.5 Linking Syntax and Semantics
    - 2.5.1 Abstract Syntax
    - 2.5.2 Abstract Syntax Trees
    - 2.5.3 Abstract Syntax of *Clite*

2.1.4 Associativity and Precedence

A grammar can be used to define associativity and precedence among the operators in an expression.

E.g., + and - are left-associative operators in mathematics;

** and / have higher precedence than + and - .*

Consider the more interesting grammar G_1:

Expr -> Expr + Term | Expr – Term | Term

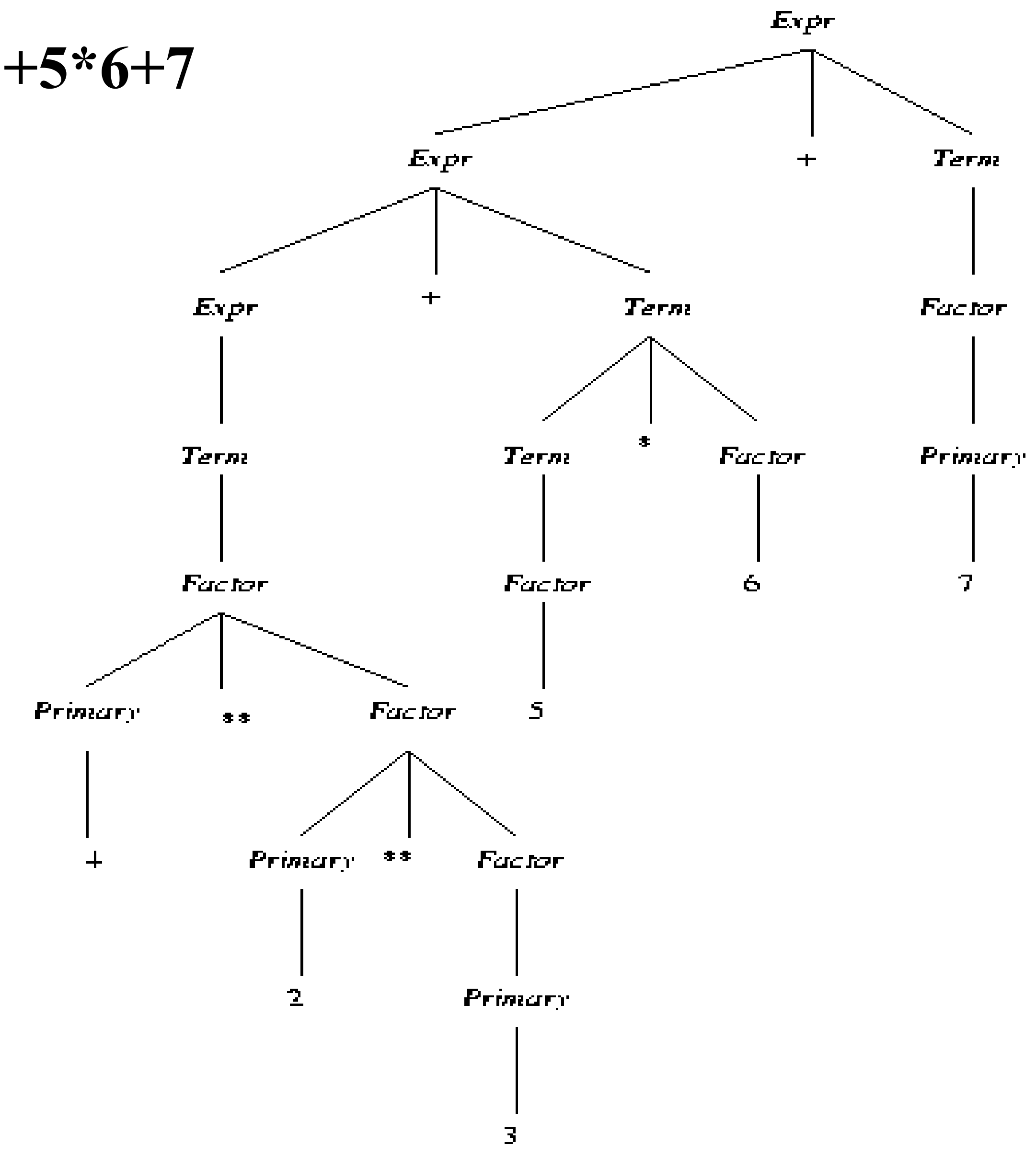
*Term -> Term * Factor | Term / Factor |*
Term % Factor | Factor

*Factor -> Primary ** Factor | Primary*

Primary -> 0 | ... | 9 | (Expr)

Parse of 4**2**3+5*6+7 for Grammar G_1

Figure 2.3



Associativity and Precedence for Grammar G_1

Table 2.1

Precedence	Associativity	Operators
3	right	**
2	left	* / %
1	left	+ -

Note: These relationships are shown by the structure of the parse tree: highest precedence at the bottom, and left-associativity on the left at each level.

2.1.5 Ambiguous Grammars

A grammar is *ambiguous* if one of its strings has two or more diffferent parse trees.

E.g., Grammar G$_1$ *above is unambiguous.*

C, C++, and Java have a large number of

- *operators and*
- *precedence levels*

Instead of using a large grammar, we can:

- *Write a smaller ambiguous grammar, and*
- *Give separate precedence and associativity (e.g., Table 2.1)*

An Ambiguous Expression Grammar G_2

Expr -> *Expr Op Expr* | (*Expr*) | *Integer*

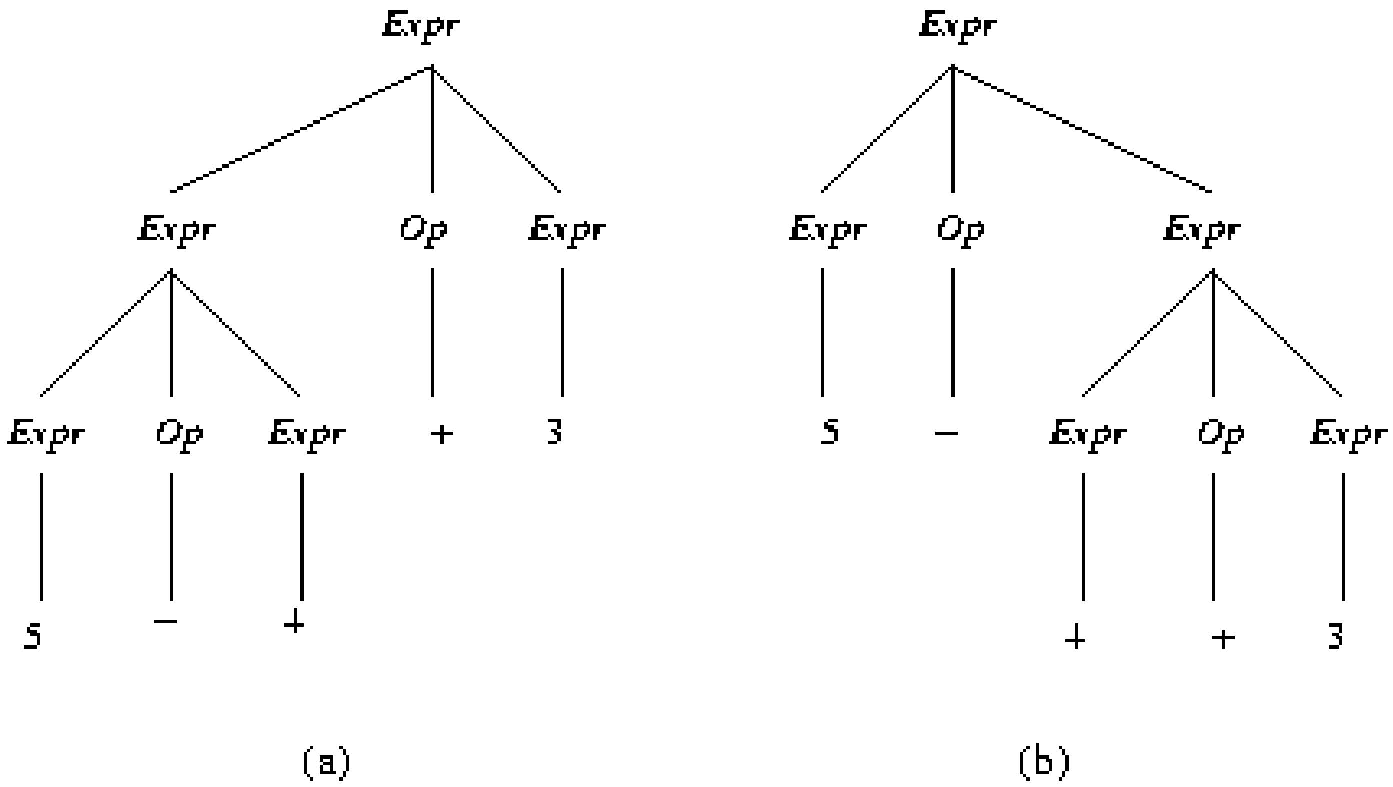
Op -> + | - | * | / | % | **

Notes:

- G_2 is equivalent to G_1. I.e., its language is the same.
- G_2 has fewer productions and nonterminals than G_1.
- However, G_2 is ambiguous.

Ambiguous Parse of 5-4+3 Using Grammar G_2

Figure 2.4



(a)

(b)

The Dangling Else

IfStatement -> if (*Expression*) *Statement* |

if (*Expression*) *Statement* else *Statement*

Statement -> *Assignment* | *IfStatement* | *Block*

Block -> { *Statements* }

Statements -> *Statements* *Statement* | *Statement*

Example

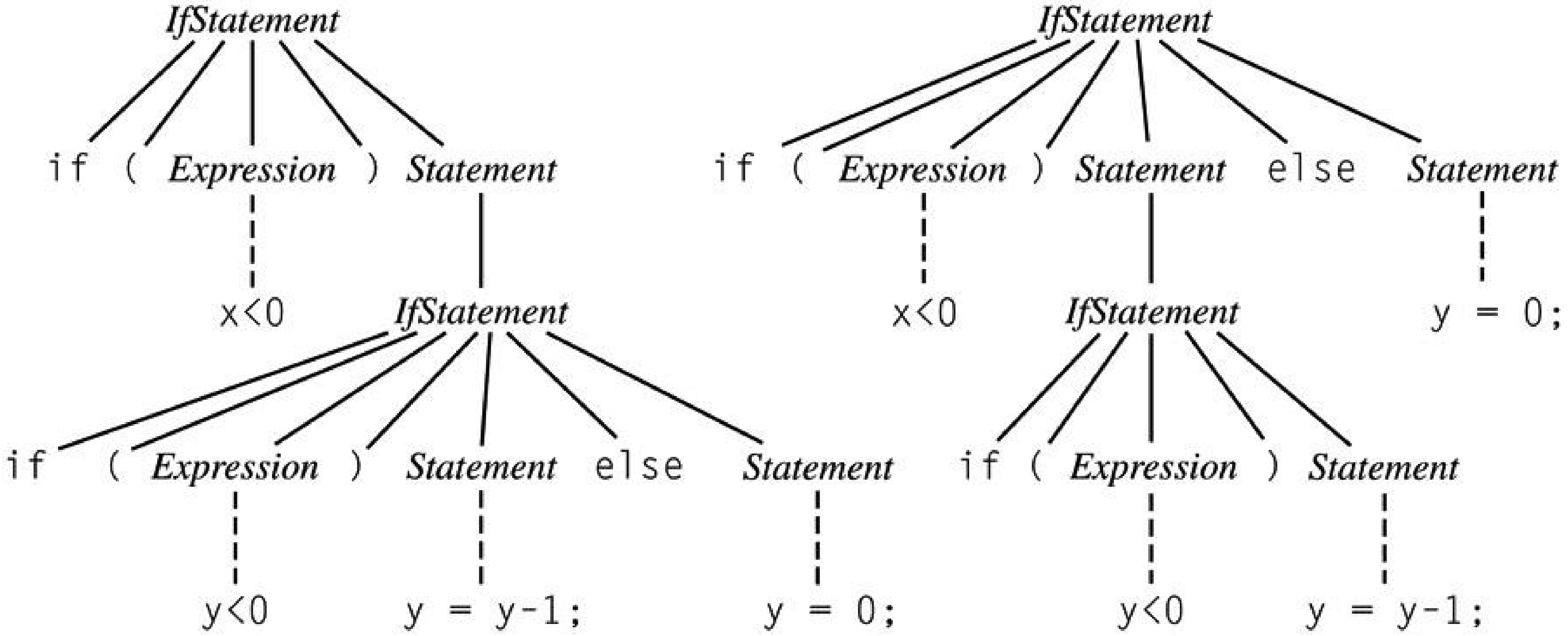
With which ‘if’ does the following ‘else’ associate

```
if (x < 0)
    if (y < 0)  y = y  - 1;
    else y = 0;
```

Answer: *either one!*

The *Dangling Else* Ambiguity

Figure 2.5



Solving the dangling else ambiguity

1. Algol 60, C, C++: associate each else with closest if; use {} or begin...end to override.
2. Algol 68, Modula, Ada: use explicit delimiter to end every conditional (e.g., if...fi)
3. Java: rewrite the grammar to limit what can appear in a conditional:

IfThenStatement -> if (*Expression*) *Statement*

IfThenElseStatement -> if (*Expression*) *StatementNoShortIf*
else *Statement*

The category *StatementNoShortIf* includes all except *IfThenStatement*.

2.2 Extended BNF (EBNF)

BNF:

- *recursion for iteration*
- *nonterminals for grouping*

EBNF: additional metacharacters

- **{ }** for a series of zero or more
- **( )** for a list, must pick one
- **[ ]** for an optional list; pick none or one

EBNF Examples

Expression is a list of one or more *Terms* separated by operators + and -

Expression -> *Term* **{ (** + | - **)** *Term* **}**

IfStatement -> if (*Expression*) *Statement* **[** else *Statement* **]**

C-style EBNF lists alternatives vertically and uses $_{opt}$ *to signify optional parts. E.g.,*

IfStatement:

if (*Expression*) *Statement* $ElsePart_{opt}$

ElsePart:

else *Statement*

EBNF to BNF

We can always rewrite an EBNF grammar as a BNF grammar. E.g.,

$$A \text{ -> } x \; \{ \; y \; \} \; z$$

can be rewritten:

$$A \text{ -> } x \; A' \; z$$

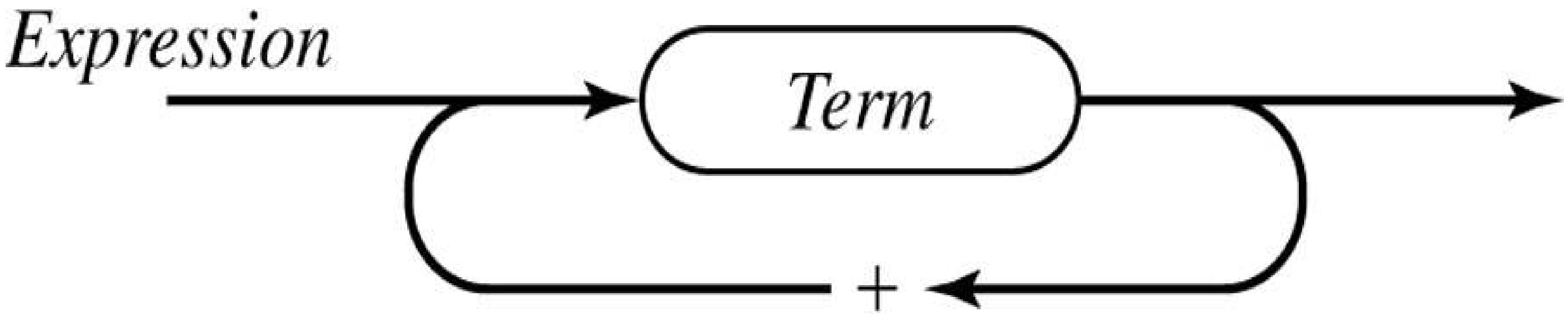
$$A' \text{ -> } \mid \; y \; A'$$

(Rewriting EBNF rules with ( ), [ ] is left as an exercise.)

While EBNF is no more powerful than BNF, its rules are often simpler and clearer.

Syntax Diagram for *Expressions* with Addition

Figure 2.6


Expression
Term
+