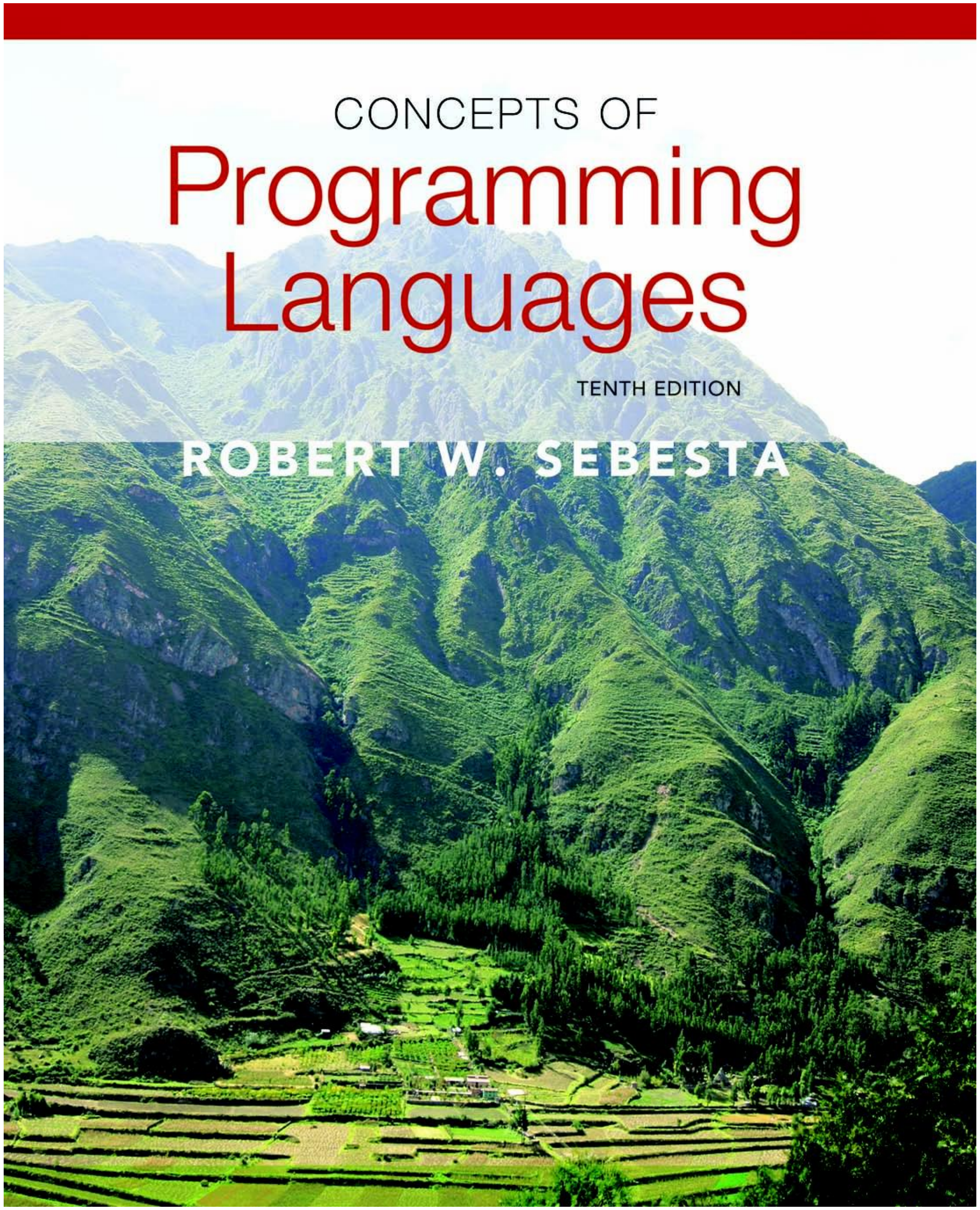
Chapter 4

Lexical and Syntax Analysis



Chapter 4 Topics

- **Introduction**
- **Lexical Analysis**
- **The Parsing Problem**
- Recursive-Descent Parsing
- Bottom-Up Parsing

Introduction

- Language implementation systems must **analyze source code**, regardless of the specific implementation approach
- Nearly all **syntax analysis** is based on a formal description of the syntax of the source language (**BNF**)

Syntax Analysis

- The syntax analysis portion of a language processor nearly always consists of two parts:
  - A low-level part called a *lexical analyzer* (mathematically, a finite automaton based on a regular grammar)
  - A high-level part called a *syntax analyzer*, or parser (mathematically, a push-down automaton based on a context-free grammar, or BNF)

Advantages of Using BNF to Describe Syntax

- Provides a **clear** and **concise** syntax description
- The parser can be **based** directly on the **BNF**
- Parsers based on BNF are **easy** to maintain

Reasons to Separate Lexical and Syntax Analysis

- *Simplicity* – less complex approaches can be used for lexical analysis; separating them simplifies the parser
- *Efficiency* – separation allows optimization of the lexical analyzer
- *Portability* – parts of the lexical analyzer may not be portable, but the parser always is portable

Lexical Analysis

- A lexical analyzer is a **pattern matcher** for character strings
- A lexical analyzer is a "**front-end**" for the parser
- Identifies substrings of the source program that belong together – *lexemes*
  - **Lexemes** match a character pattern, which is associated with a lexical category called a *token*
  - `sum` is a lexeme; its token may be `IDENT`

Example

result = oldsum – value / 100;

Token	Lexeme
IDENT	result
ASSIGN_OP	=
IDENT	oldsum
SUB_OP	–
IDENT	value
DIV_OP	/
INT_LIT	100
SEMICOLON	;

Lexical Analysis (continued)

- The lexical analyzer is usually a function that is called by the parser when it needs the next token
- Three approaches to building a lexical analyzer:
  - Write a formal description of the tokens and use a software tool that constructs a **table-driven lexical analyzer** from such a description
  - Design a **state diagram** that describes the tokens and write a program that implements the state diagram
  - Design a **state diagram** that describes the tokens and **hand-construct a table-driven implementation** of the state diagram

State Diagram Design

- A naïve state diagram would have a transition from every state on every character in the source language – such a diagram would be very large!

Lexical Analysis (continued)

- In many cases, transitions can be combined to simplify the state diagram
  - When recognizing an identifier, all uppercase and lowercase letters are equivalent
    - Use a character class that includes all letters
  - When recognizing an integer literal, all digits are equivalent – use a digit class

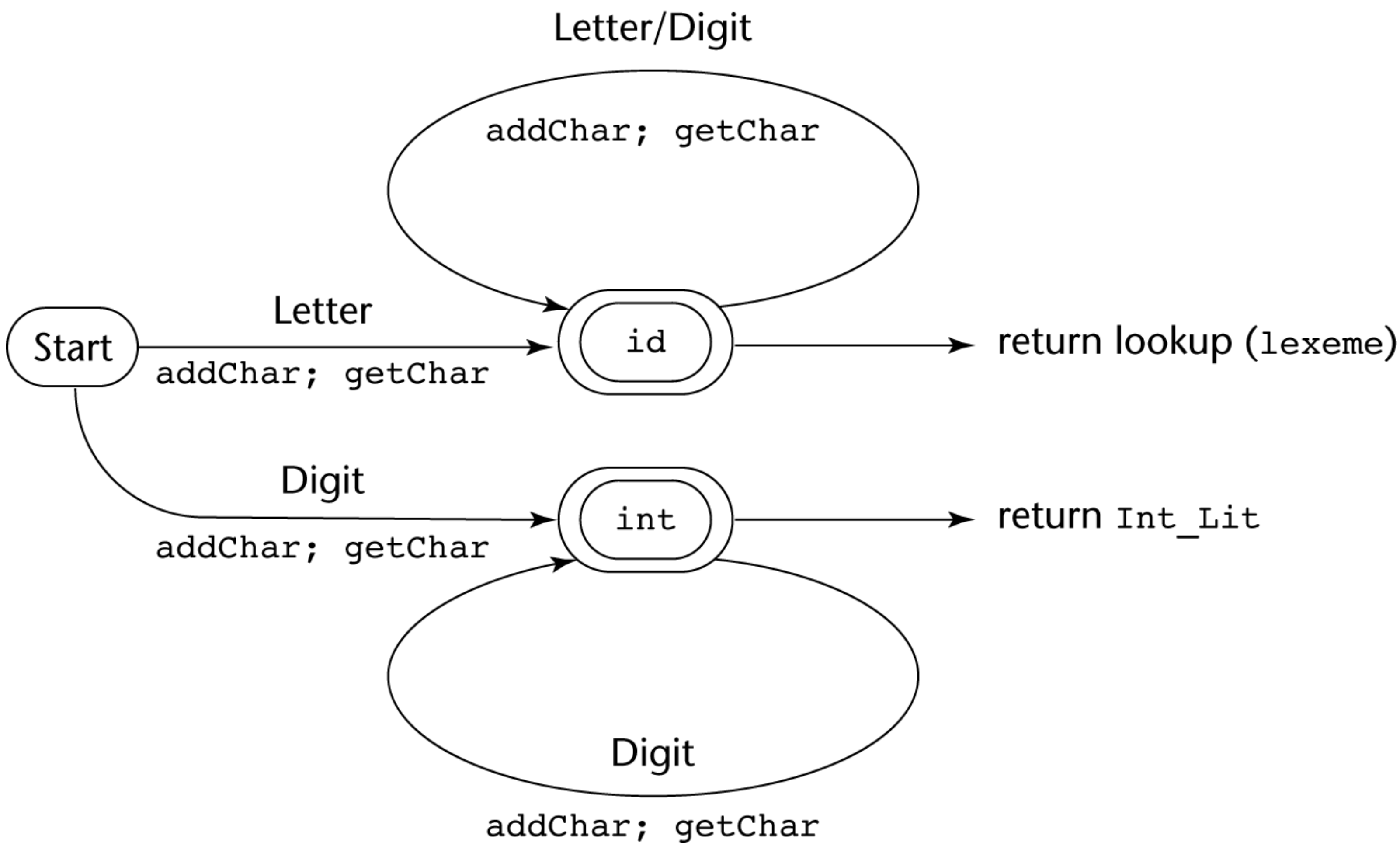
Lexical Analysis (continued)

- Reserved words and identifiers can be recognized together (rather than having a part of the diagram for each reserved word)
  - Use a table lookup to determine whether a possible identifier is in fact a reserved word

Lexical Analysis (continued)

- Convenient utility subprograms:
  - **`getChar`** - gets the next character of input, puts it in **`nextChar`**, determines its class and puts the class in **`charClass`**
  - **`addChar`** - puts the character from **`nextChar`** into the place the lexeme is being accumulated, **`lexeme`**
  - **`lookup`** - determines whether the string in **`lexeme`** is a reserved word (returns a code)

State Diagram



Lexical Analyzer

Implementation:

→ SHOW `front.c` (pp. 172-177)

– Following is the output of the lexical analyzer of `front.c` when used on `(sum + 47) / total`

```
Next token is: 25 Next lexeme is (
Next token is: 11 Next lexeme is sum
Next token is: 21 Next lexeme is +
Next token is: 10 Next lexeme is 47
Next token is: 26 Next lexeme is )
Next token is: 24 Next lexeme is /
Next token is: 11 Next lexeme is total
Next token is: -1 Next lexeme is EOF
```

The Parsing Problem

- Goals of the parser, given an input program:
  - **Find all syntax errors**; for each, produce an appropriate diagnostic message and recover quickly
  - **Produce** the **parse tree**, or at least a trace of the parse tree, for the program

The Parsing Problem (continued)

- Two categories of parsers
  - *Top down* – produce the parse tree, beginning at the root
    - Order is that of a leftmost derivation
    - Traces or builds the parse tree in preorder
  - *Bottom up* – produce the parse tree, beginning at the leaves
    - Order is that of the reverse of a rightmost derivation
- Useful parsers look only one token ahead in the input

The Parsing Problem (continued)

- Top-down Parsers
  - Given a sentential form, $xA\alpha$, the parser must choose the correct A-rule to get the next sentential form in the leftmost derivation, using only the first token produced by A
- The most common top-down parsing algorithms:
  - Recursive descent – a coded implementation
  - LL parsers – table driven implementation

The Parsing Problem (continued)

- Bottom-up parsers
  - Given a right sentential form, α, determine what substring of α is the right-hand side of the rule in the grammar that must be reduced to produce the previous sentential form in the right derivation
  - The most common bottom-up parsing algorithms are in the LR family

The Parsing Problem (continued)

- The Complexity of Parsing
  - Parsers that work for any unambiguous grammar are complex and inefficient ($O(n^3)$, where n is the length of the input)
  - Compilers use parsers that only work for a subset of all unambiguous grammars, but do it in linear time ($O(n)$, where n is the length of the input)

Bottom-Up Example

- S → aAc
- A → aA | b
- S => aAc => aaAc => aabc

Bottom-Up:

- aabc —> b should be A
- aaAc —> aA should be A
- aAc —> aAc should be S
- S