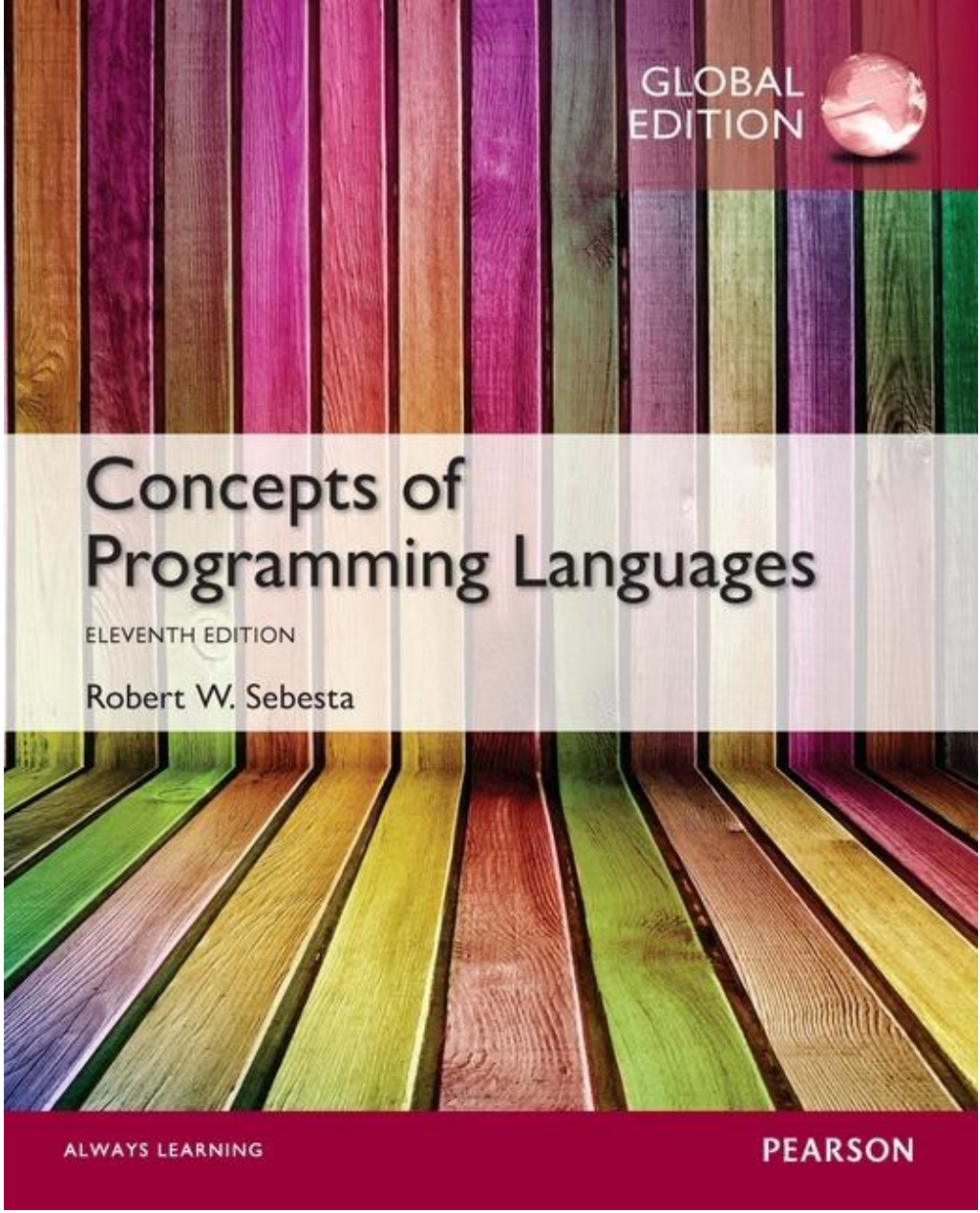
# Chapter 7

## Expressions and Assignment Statements



# Chapter 7 Topics

- Introduction
- Arithmetic Expressions
- Overloaded Operators
- Type Conversions
- Relational and Boolean Expressions
- Short-Circuit Evaluation
- Assignment Statements
- Mixed-Mode Assignment

# Introduction

- Expressions are the fundamental means of specifying computations in a programming language
- To understand expression evaluation, need to be familiar with the orders of operator and operand evaluation
- Essence of imperative languages is dominant role of assignment statements

# Arithmetic Expressions

- Arithmetic evaluation was one of the motivations for the development of the first programming languages
- Arithmetic expressions consist of operators, operands, parentheses, and function calls

# Arithmetic Expressions: Design Issues

- Design issues for arithmetic expressions
  - Operator precedence rules?
  - Operator associativity rules?
  - Order of operand evaluation?
  - Operand evaluation side effects?
  - Operator overloading?
  - Type mixing in expressions?

# Arithmetic Expressions: Operators

- A unary operator has one operand
- A binary operator has two operands
- A ternary operator has three operands

# Arithmetic Expressions: Operator Precedence Rules

- The *operator precedence rules* for expression evaluation define the order in which "adjacent" operators of different precedence levels are evaluated
- Typical precedence levels
  - parentheses
  - unary operators
  - ** (if the language supports it)
  - *, /
  - +, -

Consider the following expression:

a + b * c

Suppose the variables a, b, and c have the values 3, 4, and 5, respectively.

If evaluated left to right (the addition first and then the multiplication), the result is 35. If evaluated right to left, the result is 23.

# Arithmetic Expressions: Operator Associativity Rule

- The *operator associativity rules* for expression evaluation define the order in which adjacent operators with the same precedence level are evaluated
  - Associativity in common languages is left to right
  - Ex: In the Java expression $a - b + c$, the left operator is evaluated first.
- Typical associativity rules
  - Left to right, except **, which is right to left
  - Sometimes unary operators associate right to left (e.g., in FORTRAN)
- APL is different; all operators have equal precedence and all operators associate right to left
- Precedence and associativity rules can be overridden with parentheses

# Expressions in Ruby and Scheme

- Ruby
  - All arithmetic, relational, and assignment operators, as well as array indexing, shifts, and bit-wise logic operators, are implemented as methods
  - One result of this is that these operators can all be overriden by application programs
- Scheme (and Common Lisp)
  - All arithmetic and logic operations are by explicitly called subprograms
  - `a + b * c` is coded as `(+ a (* b c))`

# Arithmetic Expressions: Conditional Expressions

- Conditional Expressions
  - C-based languages (e.g., C, C++)
  - An example:

```
average = (count == 0)? 0 : sum / count
```

  - Evaluates as if written as follows:

```
if (count == 0)
   average = 0
else
   average = sum /count
```

# Arithmetic Expressions: Operand Evaluation Order

- *Operand evaluation order*
  1. Variables: fetch the value from memory
  2. Constants: sometimes a fetch from memory; sometimes the constant is in the machine language instruction
  3. Parenthesized expressions: evaluate all operands and operators first
  4. The most interesting case is when an operand is a function call

# Arithmetic Expressions: Potentials for Side Effects

- *Functional side effects:* when a function changes a two-way parameter or a non-local variable
- Problem with functional side effects:
  - When a function referenced in an expression alters another operand of the expression; e.g., for a parameter change:

```
a = 10;
/* assume that fun changes its parameter */
b = a + fun(&a);
```

# Functional Side Effects

- Two possible solutions to the problem
  1. Write the language definition to disallow functional side effects
     - No two-way parameters in functions
     - No non-local references in functions
     - **Advantage**: it works!
     - **Disadvantage**: inflexibility of one-way parameters and lack of non-local references
  2. Write the language definition to demand that operand evaluation order be fixed
     - **Disadvantage**: limits some compiler optimizations
     - Java requires that operands appear to be evaluated in left-to-right order

# Referential Transparency

- A program has the property of *referential transparency* if any two expressions in the program that have the same value can be substituted for one another anywhere in the program, without affecting the action of the program

```
result1 = (fun(a) + b) / (fun(a) - c);
temp = fun(a);
result2 = (temp + b) / (temp - c);
```

If `fun` has no side effects, `result1 = result2`

Otherwise, not, and referential transparency is violated

# Referential Transparency (continued)

- Advantage of referential transparency
  - Semantics of a program is much easier to understand if it has referential transparency
- Because they do not have variables, programs in pure functional languages are referentially transparent
  - Functions cannot have state, which would be stored in local variables
  - If a function uses an outside value, it must be a constant (there are no variables). So, the value of a function depends only on its parameters

# Overloaded Operators

- Use of an operator for more than one purpose is called *operator overloading*
- Some are common (e.g., + for **`int`** and **`float`**)
- Some are potential trouble (e.g., * in C and C++)
  - Loss of compiler error detection (omission of an operand should be a detectable error)
  - Some loss of readability

**Ex:** Suppose a user wants to define the * operator between a **scalar integer** and **an integer array** to mean that each element of the array is to be multiplied by the scalar.

# Overloaded Operators (continued)

- C++, C#, and F# allow user-defined overloaded operators
  - When sensibly used, such operators can be an aid to readability (avoid method calls, expressions appear natural)
  - Potential problems:
    - Users can define nonsense operations
    - Readability may suffer, even when the operators make sense

# Type Conversions

- A *narrowing conversion* is one that converts an object to a type that cannot include all of the values of the original type e.g., `float` to `int`
- A *widening conversion* is one in which an object is converted to a type that can include at least approximations to all of the values of the original type
  e.g., `int` to `float`

# Type Conversions: Mixed Mode

- A *mixed-mode expression* is one that has operands of different types
- A *coercion* is an implicit type conversion
  - Coercion was defined as an implicit type conversion that is initiated by the compiler.
- Disadvantage of coercions:
  - They decrease in the type error detection ability of the compiler
- In most languages, all numeric types are coerced in expressions, using widening conversions
- In ML and F#, there are no coercions in expressions

# Explicit Type Conversions

- Called *casting* in C-based languages
- Examples
  - `C: (int)angle`
  - `F#: float(sum)`

**Note that F#'s syntax is similar to that of function calls**

# Errors in Expressions

- Causes
  - Inherent limitations of arithmetic
    e.g., division by zero
  - Limitations of computer arithmetic
    e.g. overflow
- Often ignored by the run-time system

# Relational and Boolean Expressions

- Relational Expressions
  - Use relational operators and operands of various types
  - Evaluate to some Boolean representation
  - Operator symbols used vary somewhat among languages (`!=`, `/=`, `~=`, `.NE.`, `<>`, `#`)
- JavaScript and PHP have two additional relational operator, `===` and `!==`
  - Similar to their cousins, `==` and `!=`, except that they do not coerce their operands
  - Ruby uses `==` for equality relation operator that uses coercions and `eql?` for those that do not

# Relational and Boolean Expressions

- Boolean Expressions
  - Operands are Boolean and the result is Boolean
  - Example operators
- C89 has no Boolean type--it uses `int` type with 0 for false and nonzero for true
- One odd characteristic of C's expressions: `a < b < c` is a legal expression, but the result is not what you might expect:
  - Left operator is evaluated, producing 0 or 1
  - The evaluation result is then compared with the third operand (i.e., `c`)

# Short Circuit Evaluation

- An expression in which the result is determined without evaluating all of the operands and/or operators
- Example: `(13 * a) * (b / 13 - 1)`

  If `a` is zero, there is no need to evaluate `(b / 13 - 1)`
- Problem with non-short-circuit evaluation

```
index = 0;
while (index <= length) && (LIST[index] != value)
      index++;
```

  - When `index=length`, `LIST[index]` will cause an indexing problem (assuming `LIST` is `length - 1` long)

# Short Circuit Evaluation (continued)

- C, C++, and Java: use short-circuit evaluation for the usual Boolean operators (`&&` and `||`), but also provide bitwise Boolean operators that are not short circuit (`&` and `|`)
- All logic operators in Ruby, Perl, ML, F#, and Python are short-circuit evaluated
- Short-circuit evaluation exposes the potential problem of side effects in expressions
  e.g. `(a > b) || (b++ / 3)`

# Assignment Statements

- The general syntax

  `<target_var> <assign_operator> <expression>`

- The assignment operator

  = Fortran, BASIC, the C-based languages

  := Ada

- = can be bad when it is overloaded for the relational operator for equality (that's why the C-based languages use == as the relational operator)

# Assignment Statements: Conditional Targets

- Conditional targets (Perl)

```
($flag ? $total : $subtotal) = 0
```

Which is equivalent to

```
if ($flag){
  $total = 0
} else {
  $subtotal = 0
}
```

# Assignment Statements: Compound Assignment Operators

- A shorthand method of specifying a commonly needed form of assignment
- Introduced in ALGOL; adopted by C and the C-based languaes
  - Example

```
a = a + b
```

can be written as

```
a += b
```

# Assignment Statements: Unary Assignment Operators

- Unary assignment operators in C-based languages combine increment and decrement operations with assignment
- Examples

  `sum = ++count` (`count` incremented, then assigned to `sum`)

  `sum = count++` (`count` assigned to `sum`, then incremented

  `count++` (`count` incremented)

  `-count++` (`count` incremented then negated)

# Assignment as an Expression

- In the C-based languages, Perl, and JavaScript, the assignment statement produces a result and can be used as an operand

```
while ((ch = getchar())!= EOF){...}
```

`ch = getchar()` is carried out; the result (assigned to `ch`) is used as a conditional value for the **`while`** statement

- Disadvantage: another kind of expression side effect

# Multiple Assignments

- Perl, Ruby, and Lua allow multiple-target multiple-source assignments

```
($first, $second, $third) = (20, 30, 40);
```

Also, the following is legal and performs an interchange:

```
($first, $second) = ($second, $first);
```

# Assignment in Functional Languages

- Identifiers in functional languages are only names of values
- ML
  - Names are bound to values with **`val`**

```
val fruit = apples + oranges;
```

  - If another val for fruit follows, it is a new and different name
- F#
  - F#'s **`let`** is like ML's **`val`**, except **`let`** also creates a new scope

# Mixed-Mode Assignment

- Assignment statements can also be mixed-mode
- In Fortran, C, Perl, and C++, any numeric type value can be assigned to any numeric type variable
- In Java and C#, only widening assignment coercions are done
- In Ada, there is no assignment coercion

# Summary

- Expressions
- Operator precedence and associativity
- Operator overloading
- Mixed-type expressions
- Various forms of assignment