

# 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
- In most languages, binary operators are infix, except in Scheme and LISP, in which they are prefix; Perl also has some prefix binary operators
- Most unary operators are prefix, but the `++` and `--` operators in C-based languages can be either prefix or postfix

# 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)
  - $*$ ,  $/$
  - $+$ ,  $-$

# 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
- 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 overridden 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

# 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



# 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
- 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

# Relational and Boolean Expressions

---

- 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  $\text{index} = \text{length}$ ,  $\text{LIST}[\text{index}]$  will cause an indexing problem (assuming  $\text{LIST}$  is  $\text{length} - 1$  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 languages
  - 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 and Ruby 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);
```

# 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