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
  - mode mixing 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
  – APL is different; all operators have equal precedence and all operators associate right to left

• Precedence and associativity rules can be overridden with parentheses
Arithmetic Expressions: Conditional Expressions

- **Conditional Expressions**
  - C-based languages (e.g., C, C++)
  - An example:
    
    \[
    \text{average} = (\text{count} == 0)? 0 : \frac{\text{sum}}{\text{count}}
    \]
  
  - Evaluates as if written like
    
    ```
    if (count == 0) average = 0
    else average = \text{sum} / \text{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
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:

```c
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 two-way parameters and non-local references
  2. Write the language definition to demand that operand evaluation order be fixed
     • **Disadvantage:** limits some compiler optimizations
• 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.

\[
\text{result1} = \frac{(\text{fun}(a) + b)}{(\text{fun}(a) - c)}; \\
\text{temp} = \text{fun}(a); \\
\text{result2} = \frac{(\text{temp} + b)}{(\text{temp} - c)};
\]

If \text{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
  - Can be avoided by introduction of new symbols (e.g., Pascal’s `div` for integer division)
Overloaded Operators (continued)

- C++ and Ada allow user-defined overloaded operators
- 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 Ada, there are virtually no coercions in expressions
Explicit Type Conversions

- Explicit Type Conversions
- Called *casting* in C–based language
- Examples
  - C: (int) angle
  - Ada: Float (sum)

Note that Ada’s syntax is similar to function calls
Type Conversions: 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., <>, #)
Relational and Boolean Expressions

- **Boolean Expressions**
  - Operands are Boolean and the result is Boolean
  - Example operators

<table>
<thead>
<tr>
<th>FORTRAN 77</th>
<th>FORTRAN 90</th>
<th>C</th>
<th>Ada</th>
</tr>
</thead>
<tbody>
<tr>
<td>.AND.</td>
<td>and</td>
<td>&amp;&amp;</td>
<td>and</td>
</tr>
<tr>
<td>.OR.</td>
<td>or</td>
<td></td>
<td></td>
</tr>
<tr>
<td>.NOT.</td>
<td>not</td>
<td>!</td>
<td>not</td>
</tr>
</tbody>
</table>

xor
Relational and Boolean Expressions: No Boolean Type in C

- C 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., \( c \))
Relational and Boolean Expressions: Operator Precedence

- Precedence of C-based operators

  postfix ++, --
  unary +, -, prefix ++, --, !
  *, /, %
  binary +, -
  <, >, <=, >=
  ==, !=
  & &
  | |
Short Circuit Evaluation

• An expression in which the result is determined without evaluating all of the operands and/or operators

• Example:  
  \[(13*a) \times (b/13-1)\]
  
  If \(a\) is zero, there is no need to evaluate \((b/13-1)\)

• Problem with non-short-circuit evaluation

```
index = 1;
while (index < length) && (LIST[index] != value)
    index++;
```

  - When \(index=\text{length}\), \(LIST[\text{index}]\) will cause an indexing problem (assuming \(LIST\) has \text{length - 1} elements)
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 |)
- Ada: programmer can specify either (short-circuit is specified with and then and or else)
- Short-circuit evaluation exposes the potential problem of side effects in expressions
e.g. (a > b) || (b++ / 3)
Assignment Statements

• The general syntax
  \(<\text{target\_var}>\ <\text{assign\_operator}>\ <\text{expression}>\)

• The assignment operator
  \(=\) FORTRAN, BASIC, PL/I, C, C++, Java
  \(:=\) ALGOLs, Pascal, Ada

• \(=\) can be bad when it is overloaded for the relational operator for equality
Assignment Statements: Conditional Targets

• Conditional targets (C, C++, and Java)
  
  \[(\text{flag})? \text{total} : \text{subtotal} = 0\]

  Which is equivalent to

  ```
  if (flag)
    total = 0
  else
    subtotal = 0
  ```
Assignment Statements: Compound Operators

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

\[ a = a + b \]

is written as

\[ a += b \]
Assignment Statements: Unary Assignment Operators

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

• Examples

  \[ \text{sum} = \text{++count} \] (count incremented, added to sum)
  \[ \text{sum} = \text{count}++ \] (count to sum, count incremented )
  \[ \text{count}++ \] (count incremented)
  \[ -\text{count}++ \] (count incremented then negated)
Assignment as an Expression

• In C, C++, and Java, the assignment statement produces a result and can be used as operands

• An example:
  
  ```
  while ((ch = getchar()) != EOF) {...}
  ```

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

• Assignment statements can also be mixed-mode, for example
  
  ```
  int a, b;
  float c;
  c = a / b;
  ```

• In Pascal, integer variables can be assigned to real variables, but real variables cannot be assigned to integers

• In Java, 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