WEEK FIVE

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

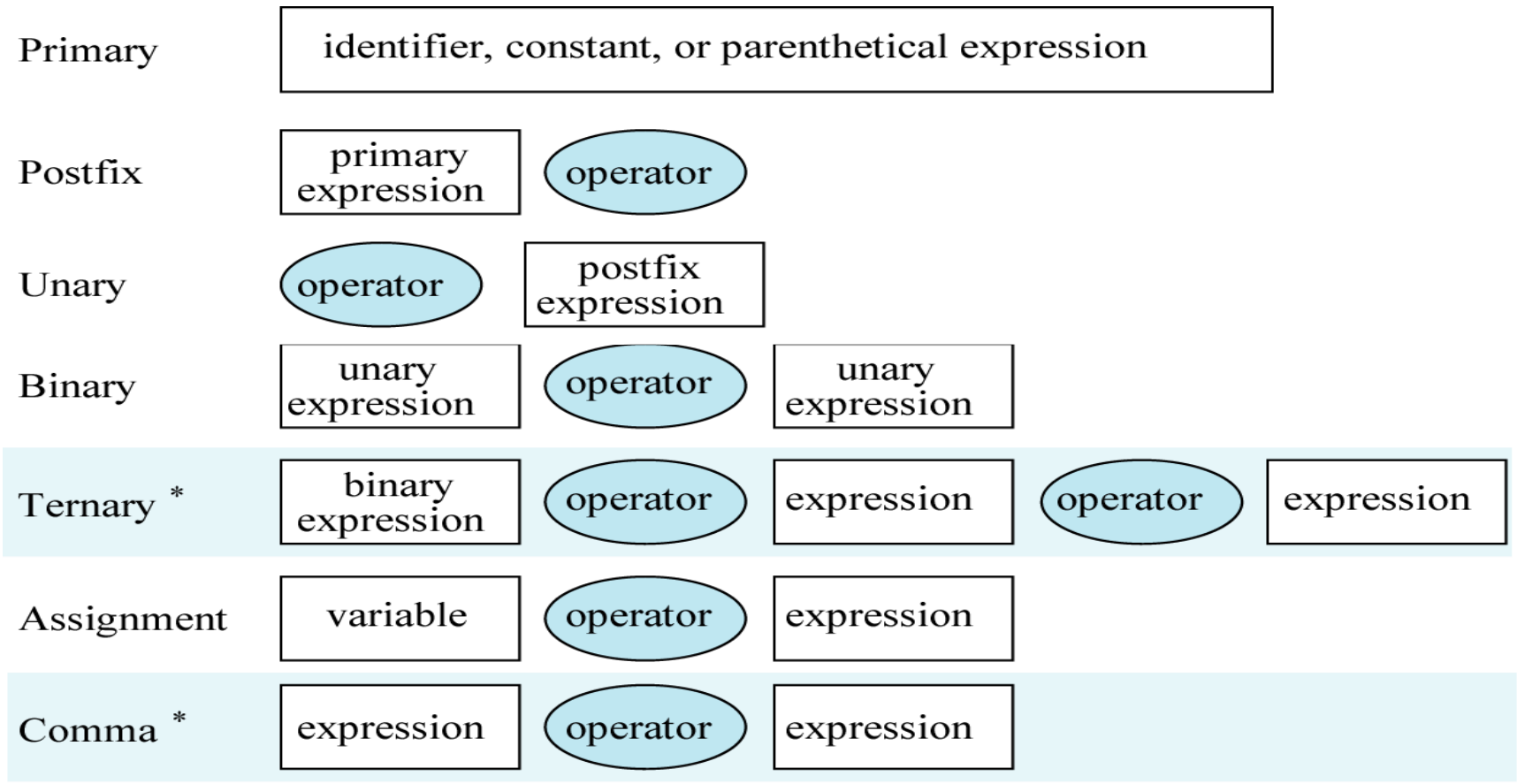
Introduction

- 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



*These expression types are unique to the C Language

Arithmetic Expressions: Operators

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

Arithmetic Expressions: Design Issues

- order of operator evaluation
  - operator precedence rules
  - operator associativity rules
  - Parentheses
  - Conditional expressions
- order of operand evaluation
  - side effects

Arithmetic Expressions: Operator Evaluation Order

- The *operator precedence rules* for expression evaluation define the order in which "adjacent" operators of different precedence levels are evaluated
- The *operator associativity rules* for expression evaluation define the order in which adjacent operators with the same precedence level are evaluated

Arithmetic Expressions: Operator Precedence Rules

- Binary operators are mostly infix.
- Some are prefix in Perl.
- Typical precedence levels
  - parentheses
  - unary operators
  - ** (if the language supports it)
  - *, /
  - +, -

Arithmetic Expressions: Operator Precedence Rules

- Precedence, associativity (see Figure 6.1)
  - C has 15 levels - too many to remember
  - Pascal has 3 levels - too few for good semantics
  - Fortran has 8
  - Ada has 6
    - Ada puts *and* & *or* at same level
  - **Lesson**: when unsure, use parentheses!

Fortran	Pascal	C	Ada
		++, -- (post-inc., dec.)	
**	not	++, -- (pre-inc., dec.), +, - (unary), &, * (address, contents of), !, ~ (logical, bit-wise not)	abs (absolute value), not, **
*, /	*, /, div, mod, and	* (binary), /, % (modulo division)	*, /, mod, rem
+, - (unary and binary)	+, - (unary and binary), or	+, - (binary)	+, - (unary)
		<<, >> (left and right bit shift)	+, - (binary), & (concatenation)
.eq., .ne., .lt., .le., .gt., .ge. (comparisons)	<, <=, >, >=, =, <>, IN	<, <=, >, >= (inequality tests)	=, /=, <, <=, >, >=
.not.		==, != (equality tests)	
		& (bit-wise and)	
		^ (bit-wise exclusive or)	
		| (bit-wise inclusive or)	
.and.		&& (logical and)	and, or, xor (logical operators)
.or.		|| (logical or)	
.eqv., .neqv. (logical comparisons)		?: (if...then...else)	
		=, +=, -=, *=, /=, %=, >>=, <<=, &=, ^=, |= (assignment)	
		, (sequencing)	

Arithmetic Expressions: Operator Associativity Rule

- 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 overriden with parentheses

Arithmetic Expressions: Conditional Expressions

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

    ```
    exp1 ?  expr2 : exp3
    ```

  - An example:

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

  - Evaluates as if written like

    ```
    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

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 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

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`

Type Conversions: Errors in Expressions

- Causes
  - Inherent limitations of arithmetic

    e.g., division by zero
  - Limitations of computer arithmetic

    e.g. overflow

- run-time errors are called *exceptions*

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

FORTRAN 77	FORTRAN 90	C	Ada
.AND.	and	&&	and
.OR.	or	||	or
.NOT.	not	!	not
			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) * (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=length, LIST [index]` will cause an indexing problem (assuming `LIST` has `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

- Simple assignments
- Conditional targets
- Compound assignment operators
- Unary assignment operators
- Assignment as an expression

Assignment Statements: Simple Assignment

- The general syntax

  `<target_var> <assign_operator> <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)

```
(flag)? total : 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

```
sum = ++count
sum = count++
count++
-(count++)
```

Assignment Statements: 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
- Assignment statements
- Mixed-type expressions
- Various forms of assignment