

Topics

- Arithmetic Expressions
 - Side effects
 - Referential Transparency
 - Overloaded Operators
 - Type Conversion
- Relational Expressions
- Boolean Expressions
 - Short Circuit Evaluation
- 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: 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
- 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
 - 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

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
- Ruby uses `==` for equality relation operator that uses coercions and `eq?` 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 $\text{index} = \text{length}$, $\text{LIST}[\text{index}]$ will cause an indexing problem (assuming LIST is length 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