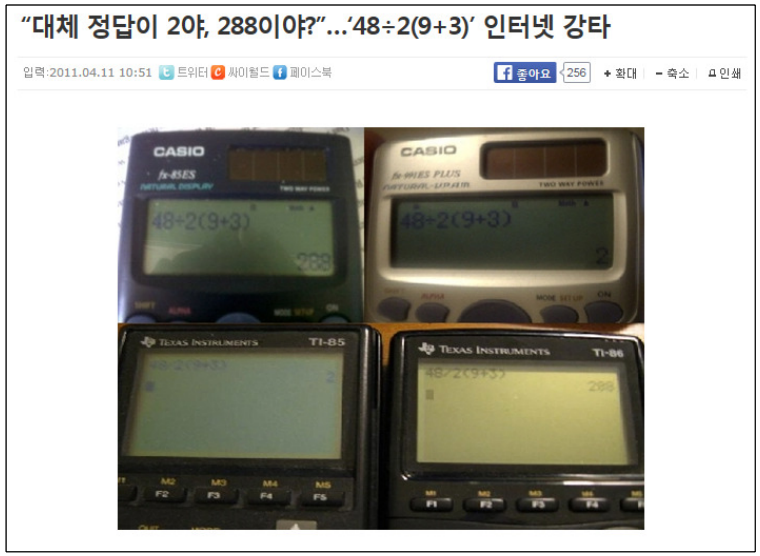
Chapter 7

Expressions and the Assignment Statement

7.1 Introduction
7.2 Arithmetic Expressions
7.3 Overloaded Operators
7.4 Type Conversion
7.5 Relational and Boolean Expressions
7.6 Short-Circuit Evaluation
7.7 The Assignment Statement
7.8 Mixed-mode Assignment



http://news.kukinews.com/article/view.asp?page=1&gCode=cul&arcid=0004842193&code=41171111&cp=nv1

"The operator evaluation order of expressions is governed by the associativity and precedence rules of the language. In the environment of von-Neumann architecture, assignment is the most fundamental statement."

7.2 Arithmetic Expressions

- *Automatic evaluation of arithmetic expressions* similar to those found in mathematics was one of the primary goals of the first programming languages

(1) Operator Evaluation Order

- Hierarchy of evaluation priorities

a = a * c + b
오른쪽에서 evlauate하고 = 로 assign
어떤 operator를 먼저 실행시킬 것인가 - precedence rule

- *Operator Precedence rules*
  - the order in which "adjacent" operators of different precedence levels are evaluated

    ⇔ `A + B * C`
  - identity operator (unary operator : no effect on its operand)

    ⇔ `+A, A + (-B) *C`
  - the operator precedence rules of the common imperative languages are nearly all the same
  - Precedence of arithmetic operators

    ⇔ FORTRAN : `**` -> `*,/` -> all `+,-`

    ⇔ Pascal : `*,/,div,mod` -> all `+,-`

    ⇔ ANSI C : `++,--,unary +,-` -> `*,/,%` -> `binary +,-`

    ← *highest* — *lowest* →

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

- ***Associativity Rule***
  - When expression contains two adjacent occurrences of operators with the same level of precedence, the question of which operator is evaluated first is answered by the associativity rules of the language

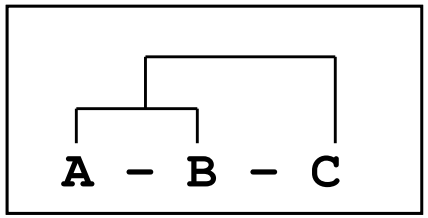
```
A - B + C - D
```

  - **Associativity rules**

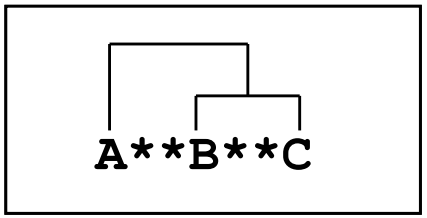
fortran은 사칙연산이 같은 precedence고, associative rule로는 왼->오

⇔ FORTRAN

⇒ left : *, /, +, – right : **



left-> right



right -> left

⇔ Pascal

⇒ left : all

⇔ ANSI C

⇒ left : *, /, %, binary +, binary –

⇒ right : ++, --, unary +, unary –

⇔ APL

⇒ No precedence, only associative rule (Right -> Left)

  - If the compiler is allowed to reorder the evaluation of operators, it may be able to produce slightly faster code for expression evaluation (as in C) (because the arithmetic operations are mathematically associative)

⇔ A + B + C + D

순서가 바뀌면 결과가 달라질 수 있다

⇔ Overflow ? (Integer addition on a computer is not associative !)

- ***Parentheses***
  - Programmers can alter the precedence and associativity rules by placing parentheses in expression

⇔ `(A + B) * C`

(2) Operand Evaluation Order

- If operands of an operator have side effect, then operand evaluation order is important

- *Side Effect*
  - A side effect of a function, called *a functional side effect*, occurs when the function either changes one of it parameters or a global variable

```
procedure sub1(....) ;
    var a : integer
    function fun(x:integer) : integer ;
        ....
        a := 27 ;
        return(5);
    end
    procedure sub2(....) ;
        ....
        a := 10 ;
        b := a + fun(b) ;
        print(b) ;
    end
end
```

an operand is a function call

a를 먼저로드하고 + fun(b)을 하면 5 + 5가 되지만
fun(b)을 먼저 하면 fun이 a를 27로 바꿈으로 27 + 5가 될 수 있다
어떤 것을 먼저 evaluate하느냐에 따라 결과가 달라진다

  - How to handle it ?
    - ⇔ By disallowing functional side effect c언어에서는 함수가 있으면 그걸 먼저 evaluate한다
    - ⇔ By language definitions (particular order)
      - ⇒ Java requires that operands appear to be evaluated in left-to-right order

(3) Conditional Expressions

- Sometimes `if-then-else` statements are used to perform a conditional expression assignment
  - In Pascal,

```
if (count = 0) then average := 0 ;
               else average := sum/count ;
```

  - In C (using ternary operator '?') (operand가 3개)

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

7.3 Overloaded Operator

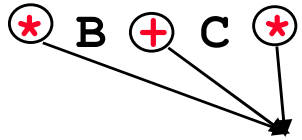
하나의 operator simbol이 여러 일을 한다
floating 더하기랑 Int 더하기 모두 + 심볼을 사용

- The multiple use of an operator is called *operator overloading* and generally thought to be acceptable, as long as readability and/or reliability do not suffer
  - Examples :
    - ⇔ '+' operator in FORTRAN
      - ⇒ `1 + 3, 1.0 + 3.0`
      - ⇒ `AVG = SUM / COUNT`

pascal은 int 나누기는 div 심볼을 사용

```
float  f ;
int i = 3, j = 2;
f = i/j ; /* f: ?? */
```

    - ⇔ '&' operator in C (operator overloading을 하지 않는다면 - 심볼의 개수의 한계, 같은 개념을 수행하는 operator가 다른 심볼이면 헷갈림(float, int 더하기 다른 심볼이면 헷갈린다)
      - ⇒ `c = a & b ; c = &b ;` C언어에서 and랑 주소 접근하는 operator가 같다 - semantic하게 다른 operation을 overload함 (나쁜거)
    - ⇔ '/' (*floating point division*) and '`div`' (*integer division*) operators in Pascal
    - ⇔ *user-defined overloaded operator* in Ada, C++, C#, F# (user가 operator를 정의한다)
      - ⇒ The Ada compiler will choose the correct meaning when an overloaded operator is specified, based on the type of operands
      - ⇒ `A * B + C * D` (A,B,C,D : Matrix data type (2D Array))



a new operator defined by programmer

compiler가 operator랑 같이 오는 operand를 보고 operand 타입에 맞게 operator를 overload시킴
어떤 명령을 수행하는지는 operand가 알려준다
ex. 5 / 2 -> operand가 int. int divide
5 / 2.0 -> 나누는 operand가 float. float divide

7.4 Type Conversions

- Languages that do allow ***mixed-mode expressions*** must define conventions, called ***coercions***, because computers usually do not have operations that use the operands of different types
  - ***coercion*** : an ***implicit type conversion*** that is initiated by compiler
  - ***casting*** : an ***explicit type conversions*** explicitly requested by programmers
- Type conversion
  - ***Narrowing conversion*** : converting an object to a type that cannot include all of the values of the original type (예 : converting a ***double*** to ***real)***
  - ***Widening conversion*** : converting an object to a type that can include at least approximations of all of the values of the original types (예 : converting a ***real*** to ***double)***
    - ⇔ always safe, but how about to convert *integer* to *float* ? Is it OK always ?
      - ⇒ some accuracy may be lost
        - → Integer 32 bit : 9 decimal digit, float 32 bit : 7 decimal digit

float 유효 숫자 6(확정)-7(일부)자리. 2^23(mantissa) = 8388608 7자리 일부까지
double 유효 숫자 15 - 16자리. 2^52 = 16자리 일부가지

- Coercion design choices
  - In FORTRAN 77 :
    - ⇔ numeric data types : integer, real, double, complex
    - ⇔ all coercions are widening conversion
  - In (original) C
    - ⇔ numeric data types : int, short int, long int, float, double
    - ⇔ although *float* and *short int* are legitimate data types, they are always coerced to *double* and *int*, respectively, when they are appear in an expression or actual parameter list

- **Mixed Mode Expression vs. Type Checking**
  - **Potential problems in coercions**
    - ⇔ In FORTRAN 77,

```
INTEGER  A,B,C
REAL D  (float)
....
C = FUN(A+D)
```

```
function FUN (K:INTEGER){
….
}
```

no type checking in parameter passing in FORTRAN77

  - In Ada and Modula-2, a는 Int고 d는 real 타입인데 둘의 혼용을 할 수 없다
    - ⇔ do not allow mixing of integer and floating-point operands in expressions
- **Explicit conversions (Casting)**
  - In Ada and Modula-2,
    - ⇔ using the syntax of function call

```
AVG := FLOAT(SUM) / FLOAT(COUNT) ;
```

  - In C,

```
AVG = (int) SUM ;
```

- **Errors in Expressions**
  - **Raise a Exception** runtime에 발생하는 에러
    - ⇔ Overflow
    - ⇔ Underflow
    - ⇔ Divide by Zero

7.5 Relational and Boolean Expressions

- **Relational Expression** `(a > b)`

  relational expression의 결과는 true, false c에서는 true면 1 false면 0을 리턴

  - it has two operands and one relational operator
  - a relational operator is an operator that compares the values of its two operands
  - the value of relational expression is Boolean
  - the relational operators are usually overloaded for a variety of types

    ⇔ the operation that determines the truth or falsehood of a relational expression depends on the operand types
  - relational operators always have lower precedence than the arithmetic operators; `z + 1 > 2 * b` ⟶ `(z + 1) > (2 * b)`
  - Syntax of relational operators

Operation	Pascal	Ada	C	FORTRAN 77
equal	=	=	==	.EQ.
not equal	<>	/=	!=	.NE.
greater than	>	>	>	.GT.
less than	<	<	<	.LT.
greater than or equal	>=	>=	>=	.GE.
less than or equal	<=	<=	<=	.LE.

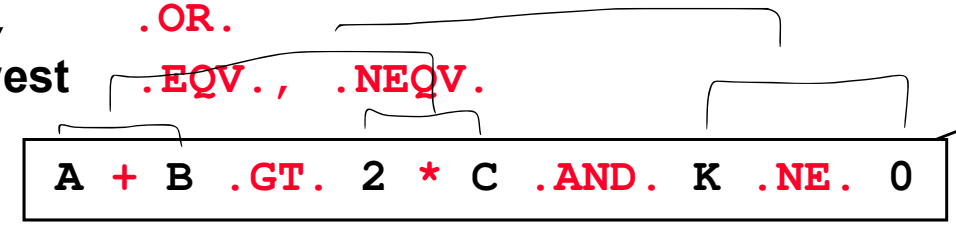
string is corced

("7" == 7) : T
("7" === 7) : F

JavaScript, PHP
'===', '!=='
➔ do not coerce their operands

- **Boolean Expression**
  - it consists of boolean variables, boolean constants (`TRUE, FALSE`), relational expressions, boolean operators
    - ⇔ Boolean operators : `AND, OR, NOT`
      - ⇒ It also has precedence order
      - ⇒ In FORTRAN 77,

Highest : `**`
`*, /`
`+, -`
`//` (string catenation)
`.EQ., .NE., .GT., .LT., .LE., .GE.`
`.NOT.`
`.AND.`
`.OR.`
Lowest `.EQV., .NEQV.`



evaluation order ?

  - In C,
    - ⇔ no Boolean types and thus no Boolean values
    - ⇔ numeric values are used to represent Boolean values
      - ⇒ zero : false
      - ⇒ all nonzero values : true
    - ⇔ *hard to detect errors in boolean expressions !*

in C,

```
b = 1 ;
if (a=b) {….}
```

```
a=11; b=22; c=3;
if (a<b<c) {….}
```

left associative

7.6 Short-Circuit Evaluation

- A *short-circuit evaluation* of an expression is one in which the result is determined *without evaluating all of the operands and/or operators*

```
(13 * A) * (B / 13 –1)
```

if (A == 0)

```
(A >= 0) and (B < 10)
```

if (A >= 0) is False

- In Pascal,
  - most Pascal implementations do not use short-circuit evaluation

    -> sometimes causes some run-time errors

```
int list[10] ;
int listlen = 10 ;
index := 1 ;
while (index <= listlen) and (list[index] <> key) do
      index := index + 1 ;
```

- In FORTRAN,
  - implementor may choose not to evaluate any more of an expression than is necessary to determine the result
  - how to handle if unevaluated expression has a side effect ?
- In 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 `|`)

- In Ada,
  - allows the programmer to specify short-circuit evaluation of the Boolean operators AND and OR by using the two-word operators *and_then* and *or_else*

```
INDEX := 1 ;
while (INDEX <= LISTLEN) and_then (LIST[INDEX] \= key)
      loop
          INDEX := INDEX + 1 ;
      end loop ;
```

- In C and Modula-2
  - every evaluation of AND and OR expression is *short-circuit*
  - trade-off between *efficiency* and *responsibility*

7.7 The Assignment Statement

- one of the central constructs in imperative language
- provides a mechanism by which the user can dynamically change the binding of value to variable

- **The Simple Assignment**
  - **Basic Form**

```
<target_variable> <assignment_operator> <expression>
```

⇔ In FORTRAN, BASIC, PL/1, C,

⇒ use equal sign ('=') for the assignment operator

⇒ confused with relational operator

→ `A = B = C` (in PL/1)

⇔ In Algol 60,

⇒ use ':=' for the assignment operator

- **Multiple Targets**
  - allowing assignment of the expression value to more than one location

⇔ In PL/1

⇒
```
SUM, TOTAL = 0
```

- **Conditional Targets**
  - In C++

```
flag ? count1 : count2 = 0 ;
```

결과 : l-value

```
sum = flag ? cont1:count2 ;
```

결과 : r-value

- **Compound Assignment Operators**
  - It is a shorthand method for the assignment in which destination variable also appears as the first operand in the expression on the right side

⇔ In C, (+=, -=, *=, /=)

```
sum = sum + value ;
⇒ sum += value ;
```

- **Unary Assignment Operators**
  - In C,

⇔ "++" : for increment

⇔ "--" : decrement

⇔ as *prefix operators* : they precede the operands

```
sum = ++count ;
```

→

```
count = count+1;
sum = count ;
```

⇔ as *postfix* operators : they follow their operands

```
sum = count++ ;
```

→

```
sum = count ;
count = count+1;
```

⇔ as unary increment operator

```
count++ ;
```

→

```
count = count+1;
```

- **Assignment Statements as Operands**
  - In C, *the assignment statement produces a result*, which is the value assigned to the target. It can therefore be used as an operand in expressions

(ch = get()) 의 값은 get()이다

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

≠

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

  - it can lead to expressions that are very difficult to read and understand
  - allows the effect of *multiple-target assignments*

```
sum = count = 0 ;
```

  - a loss of error detection

```
if (x = y) ..... /* not a syntax error */
```

7.8 Mixed-Mode Assignment

- **Design question**
  - Does the type of expression have to be the same as the type of the variable being assigned, or can coercion be used in some case of type mismatch ?
  - In FORTRAN,

    ⇔ *the same coercion rules* for mixed type assignment that it uses for mixed type expressions; that is, many of possible type mixes are legal, with coercion freely applied
  - In Pascal,

    ⇔ includes some assignment coercion

    ⇒ integers can be assigned to floating-point variables
  - In Ada and Modula-2

    ⇔ *do not allow the coercion* of integer to floating-point in their assignment

```
int i ;
float a, b ;
i = a * i ;
```

- **Homework**

1. Assume the following rules of associativity and precedence for expressions

Precedence Highest	*, /, **not**
	+, –, &, **mod**
	– (unary)
	=, /=, < , <=, >=, >
	and
Lowest	**or**, **xor**
Associativity Left to right	

Show the order of evaluation of the following expressions by parenthesizing all subexpressions and placing a superscript on the right parenthesis to indicate order. For example, for the expression

```
a + b * c + d   ⇨   ((a + (b * c)1)2 + d)3
```

① `a * b - 1 + c`
② `a * (b - 1) / c mod d`
③ `(a - b) / c & (d * e / a - 3)`
④ `-a or c = d and e`
⑤ `a > b xor c or d <= 17`
⑥ `-a + b`

2. Show the order of evaluation of the expressions of Problem 1, assuming that there are no precedence rules and all operators associate right to left.

3. Let the function **fun** and its usage be defined as

```
int fun(int *k) {
  *k += 4;
    return 3 * (*k) - 1;
}
```

```
void main() {
        int i = 10, j = 10, sum1, sum2;
        sum1 = (i / 2) + fun(&i);
        sum2 = fun(&j) + (j / 2);
}
```

What are the values of sum1 and sum2

① if the operands in the expressions are evaluated left to right ?

② if the operands in the expressions are evaluated right to left ?

4. Consider the following C program:

```
int fun(int *i) {
        *i += 5;
        return 4;
}
void main() {
        int x = 3;
        x = x + fun(&x);
}
```

What is the value of x after the assignment statement in main, assuming

① operands are evaluated left to right.

② operands are evaluated right to left.

5. Let the function **fun** and its usage be defined as

```
int a, b;
main() {
        a = 10;
        b = a + fun();
        printf("With the function call on the right, ");
        printf(" b is: %d\n", b);
        a = 10;
        b = fun() + a;
        printf("With the function call on the left, ");
        printf(" b is: %d\n", b);
}

fun() {
        a = a + 10;
        return(a);
}
```

Explain the results.