3. Structure of a C Program

[ECE10002/ITP10003] C Programming

Overview of C Language

- Introduction -> chap 1-2
- Program structure
  - Declaration/definition -> chap 2
  - Function -> chap 4
- Storing data
  - Type, constant, variable -> chap 2
  - Array, pointer -> chap 9-12
  - Structure/union/enum -> chap 13
- Operation
  - Expression -> chap 3, 15
  - Statement
    - Expression statement -> chap 3
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- Input/Output
  - Console I/O -> chap 2, 4, 5
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Agenda

- Expression
- Precedence and Associativity
- Type Conversion
- Statement

Expressions and Statements

- Important elements in C language
  - Variables are used to store data

    Ex) int i = 5;

  - Expressions are mainly used to calculate values

    Ex) (i / j + 10) * 2

    Note! Expression can also specify action by side effect

  - Statements are used to specify actions

    Ex) i = j + 5;

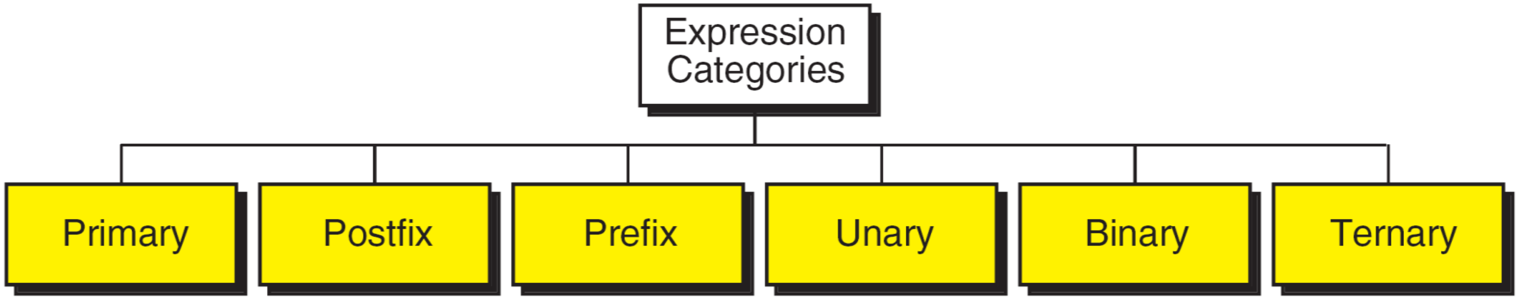
    printf(“Hello, World!₩n”);

Expressions

- Expression: a sequence of operands and operators that reduces to a single value

  Ex) 2 + 5, 2 + 5 * 7, …

- Categories of expressions



Primary Expression

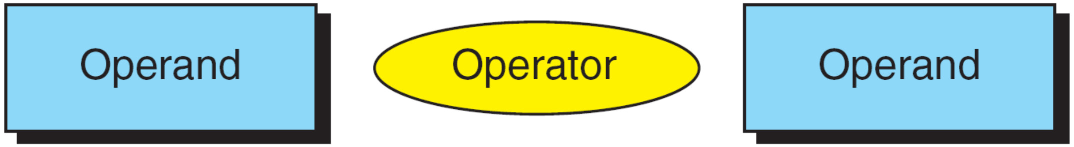
- Primary expression: expression consists of one operand and no operator
  - Names
    - □ Identifier of a variable, a function, or any other objects

      Ex) a, b12, price, calc, INT_MAX, SIZE
  - Literal constants

    Ex) 5, 123.98, ‘A’, “Welcome”
  - Parenthetical expressions
    - □ (2 * 3 + 4), (a = 23 + b * 6)

Binary Expressions

- Binary expression: operand-operator-operand combination



  - Multiplicative expressions(*, /, %)

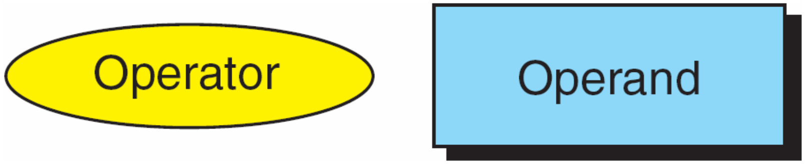
    Ex) 10 * 3, true * 4, 'A' * 2, 22.3 * 2, …

    Note! % is not available for floating point types.
  - Additive expressions(+, -)

    Ex) 3 + 7, 5 – 8, …

Unary Expression

- Unary expression: expression containing single operand



  - Unary plus/minus

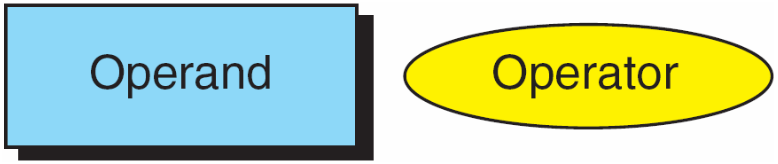
    Ex) +5, –3, –a, …
  - sizeof: size (in byte) of a type or primary expression
    - sizeof(int)
    - sizeof(–345.23), sizeof(x)
  - Cast operator: type conversion (*type*)

    Ex) int x = 10;

    (float)x // result: 10.0F

Postfix Expression

- Postfix expression: operator follows operands


Operand

Operator

  - Postfix increment/decrement
    - a++/a−− (equivalent to a = a + 1 / a = a − 1)

    Ex) x = a++; is equivalent to …

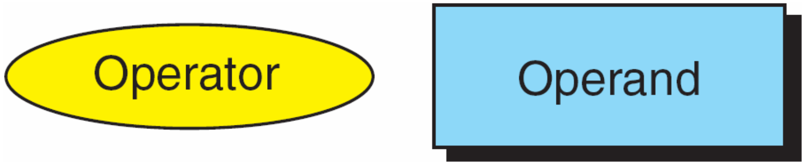
    ```
    x = a;
    a = a + 1;
    ```

Ex) int a = 4;

```
printf(“value of a =        %2d₩n”, a);
printf(“value of a++ =      %2d₩n”, a++);
printf(“new value of a =    %2d₩n”, a);
```

Prefix Expressions

- Prefix expressions: operator precedes operand



Operator

Operand

  - Prefix increment/decrement
    - ++a/--a (equivalent to a = a + 1 / a = a – 1)

    Ex) x = ++a; is equivalent to …

    ```
    a = a + 1;
    x = a;
    ```

Ex) int a = 4;

```
printf("value of a =         %2d₩n", a);
printf("value of ++a =       %2d₩n", ++a);
printf("new value of a =     %2d₩n", a);
```

Assignment Expressions

- Assignment expression(=): evaluates operand on right side and places its value in variable on left side

  Ex) a = 5, b = x + 1, i = i + 1

  - Value of total expression: the assigned value

  Ex) printf("Value of ₩"a = 5 ₩" = %d₩n", a = 5);

- Compound assignment (*=, /=, %=, +=, -=): binary operator + assignment

  Ex) x *= y + 3;   // equivalent to x = x * (y + 3)

Demonstration of Compound Assignment

- Source code

```
#include <stdio.h>

int main (void)
{
    int x = 10, y = 5;

    printf("x: %2d  |  y: %2d ", x, y);
    printf("  |  x *= y + 2: %2d ", x *= y + 2);
    printf("  |  x is now: %2d₩n",  x);

    x = 10;
    printf("x: %2d  |  y: %2d ",    x, y);
    printf("  |  x /= y + 1: %2d ", x /= y + 1);
    printf("  |  x is now: %2d₩n",  x);

    x = 10;
    printf("x: %2d  |  y: %2d ",     x, y);
    printf("  |  x %%= y − 3: %2d ", x %= y − 3);
    printf("  |  x is now: %2d₩n", x);

    return 0;
}   // main
```

```
x: 10  |  y:  5  |  x *= y + 2: 70  |  x is now: 70
x: 10  |  y:  5  |  x /= y + 1:  1  |  x is now:  1
x: 10  |  y:  5  |  x %= y − 3:  0  |  x is now:  0
```

Exercises

- Write a program digit3.c that reads a 3-digit number ABC and prints each digit in <A, B, C>.

  Ex) digit3.exe

  ```
  input a 3-digit number: 345
  <3, 4, 5>
  ```

- Write a program comma.c that read a 9-digit number and prints in format of *ABC,DEF,GHI*

  Ex) comma.exe

  ```
  input a 9-digit number: 472839509
  Your number = 472,839,509
  ```

Review

- What is the result of the following program?

```
#include <stdio.h>

int main()
{
    int x = 4;
    int y = 0;

    printf("₩"x = 4₩" = %d₩n", x = 4);
    printf("₩"y = ++x₩" = %d₩n",y = ++x);

    printf("₩n");
    printf("₩"x = 4₩" = %d₩n", x = 4);
    printf("₩"y = x++₩" = %d₩n",y = x++);

    return 0;
}
```

```
"x = 4" = 4
"y = ++x" = 5

"x = 4" = 4
"y = x++" = 4
```

Side Effects

- Side effect: action that results from evaluation of an expression

  Ex) Assignment, increment, decrement, …

  ```
  x = 4;            // evaluation result: 4
  y = ++x;          // evaluation result: 5
  ```

  - Side effect makes an expression simple, but difficult to understand

Side Effects

- Evaluation of expressions with side effect

  Ex) --a * (3 + b) / 2 – c++ * b, given a = 3, b = 4, c = 5

  1. Parenthesis

     --a * 7 / 2 – c++ * b

  2. Postfix expression

     --a * 7 / 2 – 5 * b // c is increased after evaluation

  3. Prefix expression

     2 * 7 / 2 – 5 * b // a is increased at this point

  4. Multiplication and division

     7 – 20

  5. Subtraction

     -13

  - Side effects after evaluation: a = 2, b = 4, c = 6

- Warning: in C, if an expression variable is modified more than once during its evaluation, the result is undefined.

Example

- SideEffect.c

```
int main (void)
{
    int a = 3, b = 4, c = 5;
    int x = 0, y = 0;

    printf("Initial values of the variables: ₩n");
    printf("a = %d₩tb = %d₩tc = %d₩n₩n", a, b, c);
    x = a * 4 + b / 2 - c * b;
    printf ("Value of   a *  4 + b  / 2 - c   * b:  %d₩n", x);

    y = --a * (3 + b) / 2 - c++ * b;
    printf ("Value of --a * (3 + b) / 2 - c++ * b: %d₩n", y);
    printf("₩nValues of the variables are now: ₩n");
    printf("a = %d₩tb = %d₩tc = %d₩n₩n", a, b, c);

    return 0;
}   // main
```

Example

- Result

```
Initial values of the variables:
a = 3        b = 4   c = 5

Value of   a *  4 + b  / 2 - c   * b:  -6
Value of --a * (3 + b) / 2 - c++ * b: -13

Values of the variables are now:
a = 2        b = 4   c = 6
```

Exercises

- Read two integers and find the maximum and minimum.

  Hint) if-statement

  ```
  if(<condition>){
          <statements1>
  } else {
          <statements2>
  }
  ```

  - Green part can be omitted

- Read 10 integers and find the maximum and minimum.

  Hint) Repeating 10 times: for-statement

  ```
  int i = 0;                          // declared somewhere
  ...
  for(i = 0; i < 10; i++){            // i is an integer variable
          <statements>
  }
  ```

minmax2.c

```
#include <stdio.h>

int main()
{
        int x = 0, y = 0;
        int min = 0, max = 0;

        // read two numbers
        printf("Input two integers : ");
        scanf("%d %d", &x, &y);

        // find min and max
        if(x > y){                      // if x is bigger, set max by x and min by y
                max = x;
                min = y;
        } else {                        // otherwise, set max by y and min by x
                max = y;
                min = x;
        }

        // print the results
        printf("min = %d, max = %d₩n", min, max);

        return 0;
}
```

minmax10.c

```
#include <stdio.h>

int main()
{
        int x = 0;
        int min = 10000000, max = 0;
        int i = 0;

        for(i = 0; i < 10; i++){
                printf("Input an integer : ");
                scanf("%d", &x);

                if(x < min)
                        min = x;
                if(x > max)
                        max = x;
        }

        printf("min = %d, max = %d₩n", min, max);

        return 0;
}
```

Loop Statements

- while-statement

  ```
  while(<condition>){
        <statements>
  }
  ```

  - Repeats <statements> while <condition> is true

- for-statement

  ```
  for(<initialization> ; <condition> ; <update>){
        <statements>
  }
  ```

  - Runs <initialization> once.
  - Repeats <statements> and <update> while <condition> is true

Operators for Logic Expression

- Comparison
  - <, <=, >, >=
  - ==, !=

- Logic operators
  - AND: &&
  - OR: ||
  - NOT: !

Agenda

- Expression
- Precedence and Associativity
- Type Conversion
- Statement

Precedence and Associativity

- Precedence: order of different operators in a complex expression

  Ex) 2 + 3 * 4 = 2 + (3 * 4) = 14

  -b++ = -(b++)　　　　// postfix precedes prefix

- Associativity: order of operators with the same precedence

  Ex) 5 – 3 + 2 = (5 – 3) + 2 = 4

  - Left-to-right associativity: *, /, %, +, -

    Ex) 3 * 8 / 4 % 4 * 5

  - Right-to-left associativity: assignment operators

    Ex) a += b *= c -= 5 : (a += (b *= (c -= 5)))

Precedence and Associativity

Operators	Associativity
() [] -> .	left to right
! ~ ++ -- + - * & (type) sizeof	right to left
* / %	left to right
+ -	left to right
<< >>	left to right
< <= > >=	left to right
== !=	left to right
^	left to right
|	left to right
&&	left to right
||	left to right
?:	right to left
= += -= *= /= %= &= ^= |= <<= >>=	right to left
,	left to right

Agenda

- Expression
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Type Conversion

- What happens when we write an expression that involves different data types?

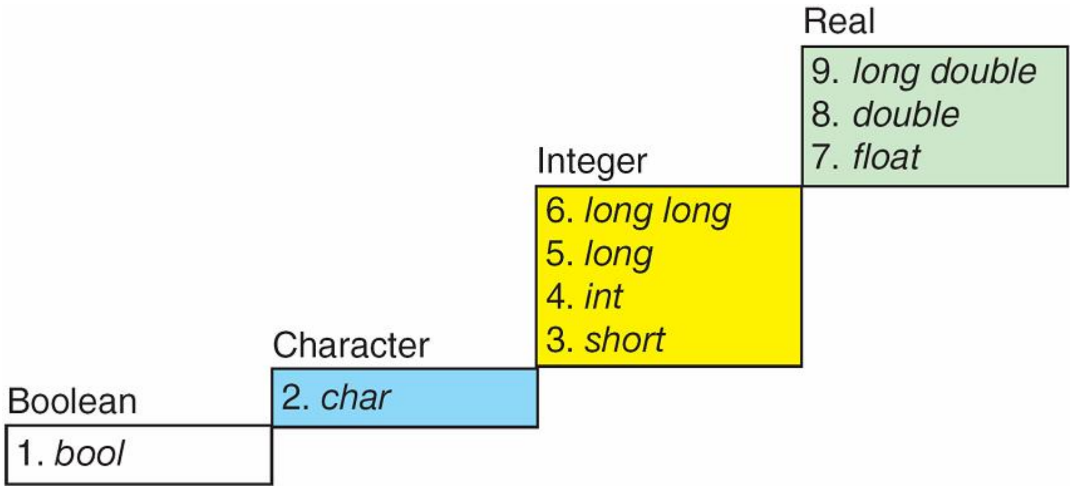
  Ex) 2 * 3.141592

  → Integer 2 is converted to floating-point (double) type (2.0)

- Type conversion: changing an entity of one data type into another
  - Implicit type conversion
  - Explicit type conversion (casting)

Implicit Type Conversion

- Implicit type conversion: when two operands in a binary expression are of different types, C automatically converts one type to another.
  - The conversion is decided by conversion rank.
    (The actual conversion rule is more complex.)



Real

9. *long double*
8. *double*
7. *float*

Integer

6. *long long*
5. *long*
4. *int*
3. *short*

Character

2. *char*

Boolean

1. *bool*

Ex) <int value: 4> + <float value: 7>

→ <int value> is converted into <float value>

Implicit Type Conversion

- Conversions in assignment
  - For an assignment expression, C makes right expression the same rank with left variable.

```
Ex) char c = 'A';            // 'A' == 0x41 == 65
    int i = 1234;
    double d = 3458.0004;
    i = c;                   // char -> int (promotion)
    i = d;                   // double -> int (demotion)
```

  - Promotion: lower rank → higher rank

```
Ex) float f = 10;
```

  - Demotion: higher rank → lower rank

```
Ex) int i = 10.5;
```

    - A problem can occur, if value of right expression is too large to be accommodated in left variable

char c = INT_MAX;   // INT_MAX is usually $2^{31}-1$

Explicit Type Conversion

- Explicit type conversion: type conversion through cast operator

```
Ex) int -> float
        int a = 10;
        (float) a            // result: 10.F

Ex) int totalScores = 250;
         int numScores = 3;
        float average = 0.F;
        average = totalScores / numScores;                // 83.000000
        average = (float) totalScores / numScores;        // 83.333333
        average = (float) (totalScores / numScores);      // 83.000000
```

Exercises

- Write a program average4.c that read 4 integers and prints their average and variation.

```
Ex) average4.exe
    input 4 numbers: 100 125 150 175
    average = 137.500000, variance = 781.250000
```

Agenda

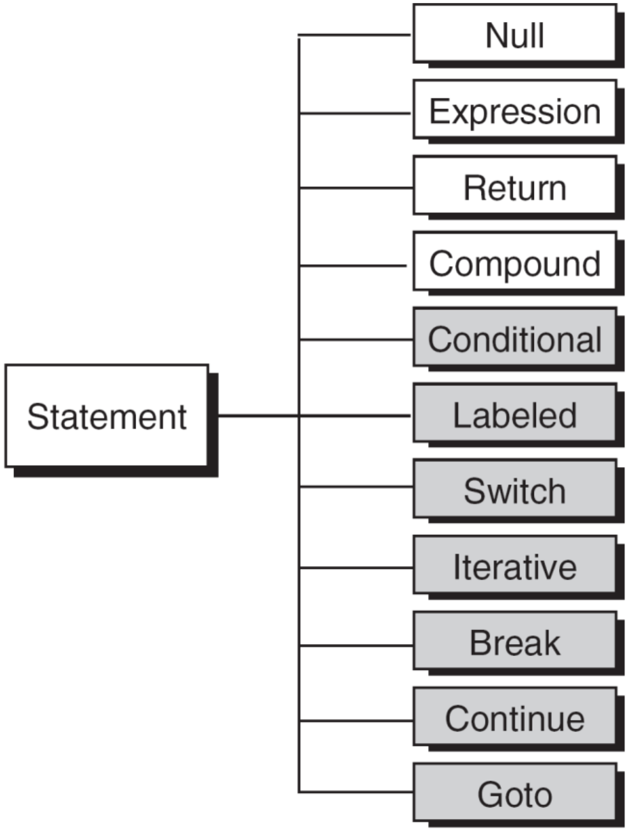
- Expression
- Precedence and Associativity
- Type Conversion
- <u>Statement</u>

Statements

- Statement: an instruction to execute something that will not return a value.
  - Most C statements are terminated by semicolon

  Ex) printf(“Hello₩n”);

- Types of statements
  - Null/expression/return/compound
  - Control statements
    - Explained in later chapters.



Statements

- Null statement: a semicolon

  Ex) ;

- Expression statement: expression + semicolon

```
Ex) a = 2;
    a = b = 3;        // equivalent to a = (b = 3);
    ioResult = scanf("%d", &x);
    a++;
```

- Return statement: termination of a function

  Ex) return expression;

Statements

- Compound statement (block): a unit of code consisting of zero or more statements, enclosed by braces

Ex)

```
{
    // local declarations
    int x, y, z;

    // statements
    x = 1;
    y = 2;
}  //          semicolon is not needed for compound statement
```

Use of Semicolon

- Every declaration in C is terminated by semicolon.
- Most statements in C are terminated by a semicolon.
- A semicolon SHOULD NOT be used with a preprocessor directives.

```
Ex 1) #include <stdio.h>
      #define MY_SALARY 2000000

Ex 2) #define SALES_TAX_RATE 0.0825;
      salesTax = SALES_TAX_RATE * salesAmount;
```