Flow of Control

Fall 2015

Jinkyu Jeong
(jinkyu@skku.edu)

Flow of Control

- **C is a sequential language**
  - Statements in a program are executed one after another

- **To change flow of control, use**
  - Choice instructions: `if, switch`
  - Iterative instructions: `while, for`
  - OR recursion
  - You may need operators

Operators for them

Type of Operators	Informal Description	Operator Mnemonic
Relational Operators	Less than Greater than Less than or equal to Greater than or equal to	< > <= >=
Equality Operators	Equal to Not equal to	== !=
Logical Operators	(unary) negation Logical and Logical or	! && ||

Operators

Operator precedence and associativity	
Operators	Associativity
`() [] . -> ++ (postfix) -- (postfix)`	left to right
`! ~ ++(prefix) --(prefix) + - * & (type) sizeof`	right to left
`* / % (binary)`	left to right
`+ - (binary)`	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

True/False Representation in C

- **True**
  - `int value 1`
  - `a = 2 > 1; /* a == 1 */`
- **False**
  - `int value 0`
  - `a = 1 < 2; /* a == 0 */`
- **Zero values**
  - `0, 0.0, '\0', NULL` are deemed **false**
  - `if(0) {}, while(0) {}`
- **Non-zero values**
  - `1, 1.0, 2, 3, …` are deemed **true**
  - `if(1) {}, while(2) {}`

Relational Operators

- `>, <, >=, >=`
- **Common mistakes**
  - `a => b, a =< b /* out of order */`
  - `a < = b /* space not allowed */`
  - `a >> b /* different operator */`
  - `a < b < c /* equals 1 < c or 0 < c */`

Relational Operators Examples

Declarations and initializations

```
char        c = 'w'
int         i = 1, j = 2, k = -7
double      x = 7e+33, y = 0.001
```

Expression	Equivalent expression	Value
`'a' + 1 < c`	`('a' + 1 ) < c`	1
`- i - 5 * j >= k + 1`	`((- i) - (5 * j)) >= (k + 1)`	0
`3 < j < 5`	`(3 < j ) < 5`	1
`x - 3.333 <= x + y`	`(x - 3.333) <= (x + y)`	1
`x < x + y`	`x < (x + y )`	0?

Equality Operators

- **Equality expression ::=**

  expression == expression |

  expression != expression

- **Examples**

```
c == 'A'
k != 2
x + y == 3 * z -7
```

- **Common mistakes**

```
a = b instead of a == b
a = = b
a =! b
```

Equality Operators Examples

Declarations and initializations		
`int i = 1, j = 2, k = 3;`		
Expression	Equivalent expression	Value
`i == j`	`i == j`	`0`
`i != j`	`i != j`	`1`
`i + j + k == -2 * -k`	`((i + k) + k) == ((-2) * (-k)`	`1`

Logical Operators

- **Logical expressions**
  - Negative: `!expr`
  - Or: `expr || expr`
  - And: `expr && expr`
- **Examples**

```
!a          !(x + 7.3)        !(a < b || c < d)
a && b      a || b            !(a<b) && c
```

- **Common mistakes**

```
a!
a&&
a & b
& b --- this is serious
```

Logical Operators Examples

Declarations and initializations

```
char    c = 'A';
int     i = 7, j = 7;
double  x = 0.0, y = 2,3;
```

Expression	Equivalent expression	Value
`! c`	`! c`	`0`
`! ( i - j )`	`! ( i - j )`	`1`
`! i - j`	`(! i ) - j`	`-7`
`! ! (x + y)`	`! (! (x + y))`	`1`
`! x * ! ! y`	`(! x) * (!(! y))`	`1`

Logical Operators Examples

Declarations and initializations

```
char    c = 'B';
int     i = 3, j = 3, k = 3;
double  x = 0.0, y = 2,3;
```

Expression	Equivalent expression	Value
`i && j && k`	`(i && j ) && k`	1
`x || i && j - 3`	`x || (i && (j - 3 ))`	0
`i < j && x < y`	`(i < j) && (x < y)`	0
`i < j || x < y`	`(i < j) || (x < y)`	1
`'A' <= c && c <= 'Z'`	`('A' <= c ) && ( c <= 'Z')`	1
`c-1 == 'A' || c+1 == 'Z'`	`((c-1) == 'A' || ((c+1) == 'Z')`	1

Short-circuit

- **The evaluation stops as soon as the outcome is known**
- **expr1 && expr2**
  - If **expr1** is evaluated to be **false**, expr2 needs not be evaluated
- **expr 1 || expr 2**
  - If **expr1** is evaluated to be **true**, expr2 needs not be evaluated

Compound Statement

- A compound statement is a series of declarations and statements surrounded by braces { }

```
{
    int a, b, c;
    a += b += c;
    printf("a = %d, b = %d, c = %d\n", a, b, c);
}
```

- A compound is usually called "block"
- Expression statements

```
a + b + c;
; /* empty statement */
```

if Statement (1)

- if (expr) (then) statement | block
- if (expr) (then) statement | block
  else statement | block

```
if ( y != 0.0 )
    x /= y;
if ( c == ‘ ‘) {
    ++blank_cnt;
    printf(“found another blank\n”);
}
if b == a // parentheses missing
    area = a * a;
```

- Statement can be an empty one
- Same for else statement

if Statement (2)

```
if ( c >= ‘a’ && c <= ‘z’)
    ++lc_cnt;
else {
    ++other_cnt;
    printf(“%c is not a lowercase letter\n”, c);
}

if ( c >= ‘a’ && c <= ‘z’ )
    ++lc_cnt;
else if ( c >= ‘A’ && c <= ‘Z’ )
    ++uc_cnt;
else {
    ++other_cnt;
    printf(“%c is not a letter\n”, c);
}

if ( i != j ) {
    i += 1;
    j += 2;
};
else
    i -= j; // syntax error
```

if Statement (3)

- else attaches to the nearest if

```
if ( a == 1 )
    if ( b == 2 )
        printf("***\n");

if ( a == 1 )
    if ( b == 2 )
        printf("***\n");
    else
        printf("###\n");
/* equals */
if ( a == 1 )
    if ( b == 2 )
        printf("***\n");
else
    printf("###\n");
```

Iterative Statements

- **`while`, `for`, and `do` statements**
  - Provide iterative action

- **`goto`, `break`, `continue`, and `return` statements cause an unconditional transfer**
  - SE people hate these (except return)

while Statement

- **`while` (expr) statement | block**
  - Repeat the statement or block while expr is true
  - Statement can be empty

```
while ( i++ < n )
    factorial *= i;

while ( (c = getchar()) == ‘ ‘ )
    ; // skip blank characters in the input stream

while ( ++i < LIMIT ) do {
    // syntax error: do is not allowed
    j = 2 * i + 3;
    printf(“%d\n”, j);
}
```

```c
#include <stdio.h>

int main(void)
{
   int   blank_cnt = 0, c, digit_cnt = 0,
         letter_cnt = 0, nl_cnt = 0, other_cnt = 0;

   while ((c = getchar()) != EOF)     /* braces not necessary */
      if (c == ' ')
         ++blank_cnt;
      else if (c >= '0' && c <= '9')
         ++digit_cnt;
      else if (c >= 'a' && c <= 'z' || c >= 'A' && c <= 'Z')
         ++letter_cnt;
      else if (c == '\n')
         ++nl_cnt;
      else
         ++other_cnt;

   printf("%10s%10s%10s%10s%10s%10s\n\n",
      "blanks", "digits", "letters", "lines", "others", "total");
   printf("%10d%10d%10d%10d%10d%10d\n\n",
      blank_cnt, digit_cnt, letter_cnt, nl_cnt, other_cnt,
      blank_cnt + digit_cnt + letter_cnt + nl_cnt + other_cnt);
   return 0;
}
```

for statements

- **for (expr1; expr2; expr3) statement | block**
  1. evaluate **expr1** first
  2. if **expr2** is true, execute statement or block
  3. evaluate **expr3**
  4. continues **step 2**

```
for (i = 1; i <= n; ++i)
    sum += i;
```

```
for (i = 1; i <= n; ++i) {
    sum += i;
    sqr += i * i;
}
```

- Any expr can be missing, but two semicolons must remain

```
for (;;)  /* infinite loop */
    sum += 1;
```

Comma operator

- `expr, expr`
  - Have the value and type of its right operand

```
for (sum = 0, i = 1; i <= n;  sum += i, ++i)
```

Declarations and initializations
`int  i, j, k = 3;` `double  x = 3.3;`

Expression	Equivalent expression	Value
`i = 1, j = 2, ++ k + 1`	`((i=1, (j=2)), ((++k)+1)`	5
`k != 1, ++x * 2.0 + 1`	`(k != 1), (((++ x) * 2.0) + 1)`	9.6

do statement

- **A variant of while statement**
  - `do` statement | block `while` (expr)`;`
  - `do { ` statements `} while` (expr)`;`
  - The block is executed first, and then the expr is evaluated
  - You should be able to convert do statement to while statement, and vice versa

```
i = 0;
sum = 0;
/* sum a series of integer inputs until 0 is input */
do {
    sum += i;
    scanf(“%d”, &i);
} while ( i > 0 );
```

Control Expression Tip!

- **Use a relational expression rather than an equality expression**

```
/* A test that fails. */

#include <stdio.h>
int main(void)
{
    int    cnt = 0;
    double sum = 0.0, x;

    for ( x = 0.0; x != 9.9; x += 0.1) {  /* trouble ! */
        sum += x;
        printf("cnt = %5d\n", ++cnt);
    }
    printf("sum = %f\n", sum);
    return 0;
}
```

goto statement

- Jump to a label

```
goto label;
…
label:    /* label is an identifier */
```

- It is considered harmful, but …..

```
goto error;
…
error: {
    printf("An error has occurred –bye!\n");
    exit(1);
}

while ( scanf("%lf", &x) == 1) {
    if ( x < 0. 0 )
        goto negative_alert;
    printf("%f %f\n", sqrt(x), sqrt(2*x));
}
negative_alert: printf("Negative value encountered!\n");
```

break statement

- An exit from a loop

```
while ( 1 ) {
    scanf("%lf", &x);
    if ( x < 0.0 )
        break;
    /* no square root if number is negative, exit loop */
    printf("%f\n", sqrt(x));
}
/* break jumps to here */

for ( ; ; ) {
    scanf("%lf", &x);
    if ( x < 0.0 )
        break;
    /* no square root if number is negative, exit loop */
    printf("%f\n", sqrt(x));
}
/* break jumps to here */
```

continue statement

- Stop the current iteration and goto the next iteration

```
for ( i = 0; i < TOTAL; ++i ) {
    c = getchar();
    if ( c >= ‘0’ && c <= ‘9’ )
        continue;
    … /* processing other characters */
/* continue transfers control to here to begin next iteration */
}

while ( i < TOTAL ) {
    ++i;
    c = getchar();
    if ( c >= ‘0’ && c <= ‘9’ )
        continue;
    … /* processing other characters */
/* continue transfers control to here to begin next iteration */
}
```

switch statement

- **switch (expr1) /* must be integral */**
  - Goto the matched case label

```
c = getchar();
switch ( c ) {
case ‘a’:
        ++a_cnt;
        break;
case ‘b’:
case ‘B’:
        ++b_cnt;
        break;
default:
        ++other_cnt;
}
```

Conditional Operators

- **expr1 ? expr2 : expr3**
  - If expr1 is true, evaluate expr2
  - Otherwise, evaluate expr3

```
a = b > c ? d : e;  /* equals */
```

```
if ( b > c )
    a = d;
else
    a = e;
```

Declarations and initializations

```
char   a = 'a', b = 'b';   // a has decimal value 97
int    i = 1, j = 2;
double x = 7.07
```

Expression	Equivalent expression	Value	Type
`i == j ? a - 1 : b + 1`	`(i == j) ? (a - 1) : (b + 1)`	99	int
`j % 3 == 0 ? i + 4 : x`	`((j % 3) == 0) ? (i + 4) : x`	7.07	double
`j % 3 ? i + 4 : x`	`(j % 3) ? (i + 4) : x`	5.0	double