CS2310 Computer Programming

LT03: Control Flow - Condition

Computer Science, City University of Hong Kong

Semester A 2023-24

Today: Conditional Statements

- We make decisions everyday
  - AC-1? AC-2? AC-3?
- Decision will be followed by one or more action(s)
- In programming:
  - Decision is based on conditions, e.g., logical expressions
  - Action is in the form of programming statements

Today’s Outline

- Logical data type, operators and expressions
- If statement
  - Simple
  - Nested
- Switch statement

Logical Data Type: *bool*

- Takes only two values: *true* and *false*
- Numeric values are *1* (true) and *0* (false)
- the *lowest-ranked* data type
- Length: 1 byte

```
bool x = false, y = true;
cout << sizeof(bool) << endl; // 1
cout << x << " " << y << endl; // 0 1
cout << x + 6 << “ ” << y + 3.14; // 6 4.14
```

9. long double
8. double
7. float

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

2. char

1. bool

Logical Data Type: *bool*

- when a *higher-ranked* type is casted to *bool*, only 0 is converted to false, all non-zero values are converted to true

```
bool x = 0, y = 3.14, z = 0x1100;
cout << x << " " << y << " " << z << endl; // 0 1 1
```

9. long double
8. double
7. float

6. long long
5. long
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1. bool

Logical Data Type: *bool*

- when a *higher-ranked* type is casted to *bool*, only 0 is converted to false, all non-zero values are converted to true

```
bool x = 0, y = 3.14, z = 0x1100;
cout << x << " " << y << " " << z << endl; // 0 1 1
```

- different with demoted conversion of numeric types, which is *direct cut*

```
long largevalue = 0xfffff;

short demoted = largevalue;          // 0xffff, which is -1
```

9. long double
8. double
7. float

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

2. char

1. bool

Comparative Operators

- Binary operators which accept two operands and compare them

relational operators	syntax	example
Less than	`<`	`x < y`
Greater than	`>`	`z > 1`
Not greater than	`<=`	`b <= 1`
Not less than	`>=`	`c >= 2`

equality operators	syntax	example
Equal to	`==`	`a == b`
Not equal to	`!=`	`B != 3`

Logical Operators: AND (&&) and OR (||)

- Used for *combining* two logical values and *create* a new logical values
- Logical AND (&&)
  - return true if both operands are true
  - otherwise return false
  - example: 18 < age && age < 60
- Logical OR (||)
  - return false if both operands are false
  - otherwise return true

x	y	x&&y
true	true	true
true	false	false
false	true	false
false	false	false

x	y	x||y
true	true	true
true	false	true
false	true	true
false	false	false

Logical Operator: NOT (!)

- Logical-NOT (!) is a *unary* operator that *takes one operand* and *inverts its value*

- `! (A && B)` is the same as `(!A) || (!B)`
- `! (A || B)` is the same as `(!A) && (!B)`

x	!x
true	false
false	true

Original Expression	Equivalent Expression
`!(x<y)`	`x>=y`
`!(x>y)`	`x<=y`
`!(x!=y)`	`x==y`
`!(x<=y)`	`x>y`
`!(x>=y)`	`x<y`
`!(x==y)`	`x!=y`

Logical Expressions

- Expressions that take comparative or logical operators
  - `x == 3`
  - `y == x`
  - `x >= 2`
  - `x != y`

- The value of a logical expression is bool, i.e., can be true or false only

DO NOT MIX: x=y VS x==y

```
int x = 0, y = 4, z = 8;
cout << x=y << endl;
```

```
cout << y==z << endl;
```

DO NOT MIX: x=y VS x==y

```
int x = 0, y = 4, z = 8;

cout << x=y << endl;    // This line will print 4, because:
                        // x=y is an assignment expression!
                        // It copies the value of y to x.
                        // The value of an assignment expression equals to
                        // the value of the right operand,
                        // i.e., 4 in this example

cout << y==z << endl;
```

DO NOT MIX: x=y VS x==y

```
int x = 0, y = 4, z = 8;

cout << x=y << endl;     // This line will print 4, because:
                         // x=y is an assignment expression!
                         // It copies the value of y to x.
                         // The value of an assignment expression equals to
                         // the value of the right operand,
                         // i.e., 4 in this example

cout << y==z << endl;    // This line will print 0 because:
                         // y==z is a logical expression!
                         // and y doesn't equal to z
```

DO NOT MIX: a<x<b VS a<x && x<b

```
double a = 0.5;

cout << 0<a && a<1 << endl;




cout << 0<a<1 << endl;
```

DO NOT MIX: a<x<b VS a<x && x<b

```
double a = 0.5;

cout << 0<a && a<1 << endl; // will print 1, because:
                            // the value of 0 < a is true (0<0.5)
                            // the value of a < 1 is true (0.5<1)
                            // the operator && combines the two values
                            // and creates a new value
                            // which is true (printed as 1) in this example

cout << 0<a<1 << endl;
```

DO NOT MIX: a<x<b VS a<x && x<b

```
double a = 0.5;

bool b = 0<a && a<1;

cout << b << endl;

bool c = 0<a<1;

cout << c << endl;
```

// will print 1, because:
// the value of 0 < a is true (0<0.5)
// the value of a < 1 is true (0.5<1)
// the operator && combines the two values
// and creates a new value
// which is true (printed as 1) in this example

// will print 0, because:
// 0 < a < 1 is equivalent to (0 < a) < 1
// in this example, it's equivalent to (0<0.5) < 1
// i.e., true < 1, which equals to false
// and printed as 0

Short Circuit Evaluation

- Evaluation of logical expressions containing && and || stops as soon as the outcome *true* or *false* is known

For &&: the value of x&&y is `false` as long as x is false

in this case, the value of y doesn't matter and *is NOT evaluated*

For ||: the value of x||y is `true` as long as x is true

in this case, the value of y doesn't matter and *is NOT evaluated*

Short Circuit Evaluation

- Example I:

```
int x = 0, y = 2;
bool a = (x==0 || y==1);   // we know that a must equal to true after
                           // evaluating x==0 (which is true), it doesn't
                           // matter if y equals to 1 or not

bool b = (x!=0 && y==2);   // we know that b must equals to false after
                           // evaluating x!=0  (which is false), it doesn't
                           // matter if y equals to 2 or not
```

Short Circuit Evaluation

- Example II:

```
int a = 0, b = 0;

bool x = (a==0 || b=1);
cout << b << endl;
cout << x << endl;


bool y = (a==0 && b=1);
cout << b << endl;
cout << y << endl;
```

Short Circuit Evaluation

- Example II:

```
int a = 0, b = 0;

bool x = (a==0 || b=1);    // we know that x must equal to true after
cout << b << endl;         // evaluating a==0 (which is true)
cout << x << endl;         // in this case b=1 is not evaluated
                           // therefore, the value of b is still 0

bool y = (a==0 && b=1);
cout << b << endl;
cout << y << endl;
```

Short Circuit Evaluation

- Example II:

```
int a = 0, b = 0;

bool x = (a==0 || b=1);    // we know that x must equal to true after
cout << b << endl;         // evaluating a==0 (which is true)
cout << x << endl;         // in this case b=1 is not evaluated
                           // therefore, the value of b is still 0

bool y = (a==0 && b=1);
cout << b << endl;         // what value will be printed and why?
cout << y << endl;
```

Short Circuit Evaluation

- Example III:

```
int a = 0, b = 0;

bool x = (a!=0 && b=1);
cout << b << endl;          // what value will be printed and why?
cout << x << endl;


bool y = (a!=0 || b=1);
cout << b << endl;          // what value will be printed and why?
cout << y << endl;
```

Quick Summary

- Comparative operators

  less than < not less than <=

  greater than > not greater than >=

  equal to == not equal to !=

- Logical operators

  logical AND && logical OR && watch out to SHORT CIRCUIT!

  logical NOT !

- The value of a logical expression is bool
  - i.,e, true or false

Today’s Outline

- Logical data type, operators and expressions
- If statement
  - Simple
  - Nested
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Conditional Statements

- In decision making process, logical value can be used to determine the actions to take

- Examples: if AC2 canteen is too crowded, then go to AC1/AC3 for lunch

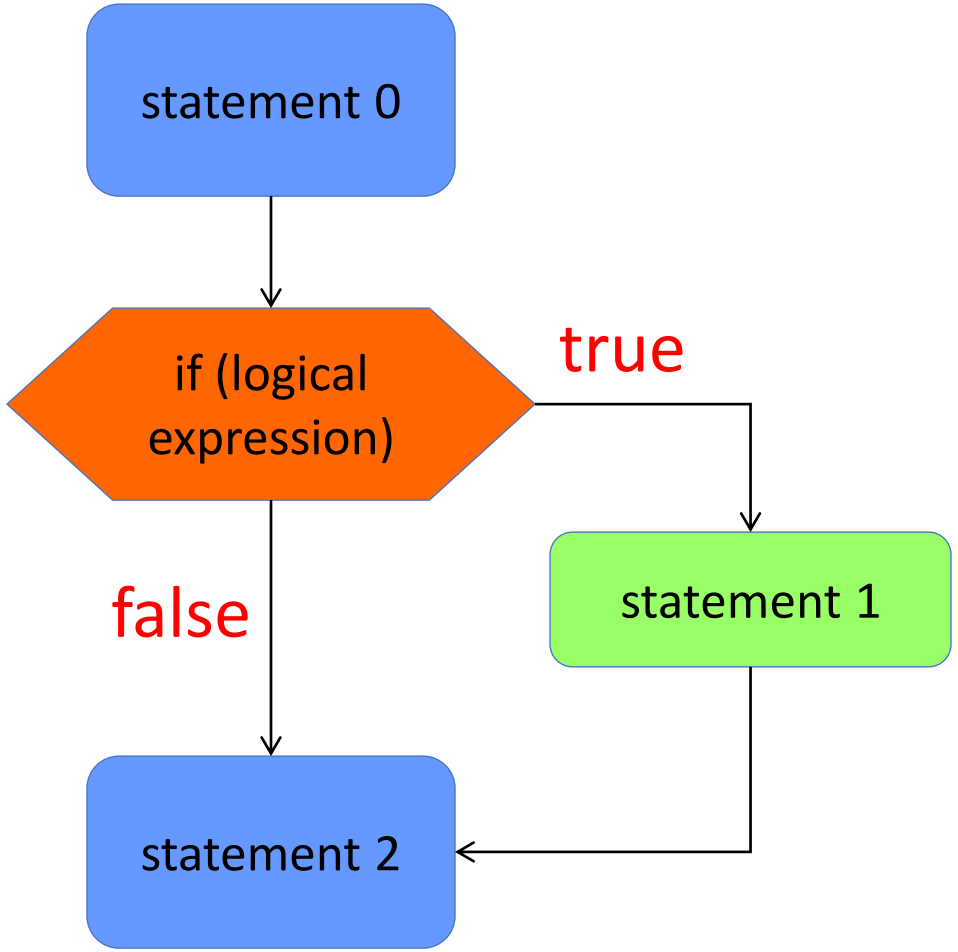
- In programming, certain statements will only be executed when certain condition is fulfilled. We call them *conditional statements*

if Statement: Basic Syntax

```
statement 0;
if (logical expression)
    statement 1;
statement 2;
```

- statement 1 will be executed if logical expression is evaluated to true, for example

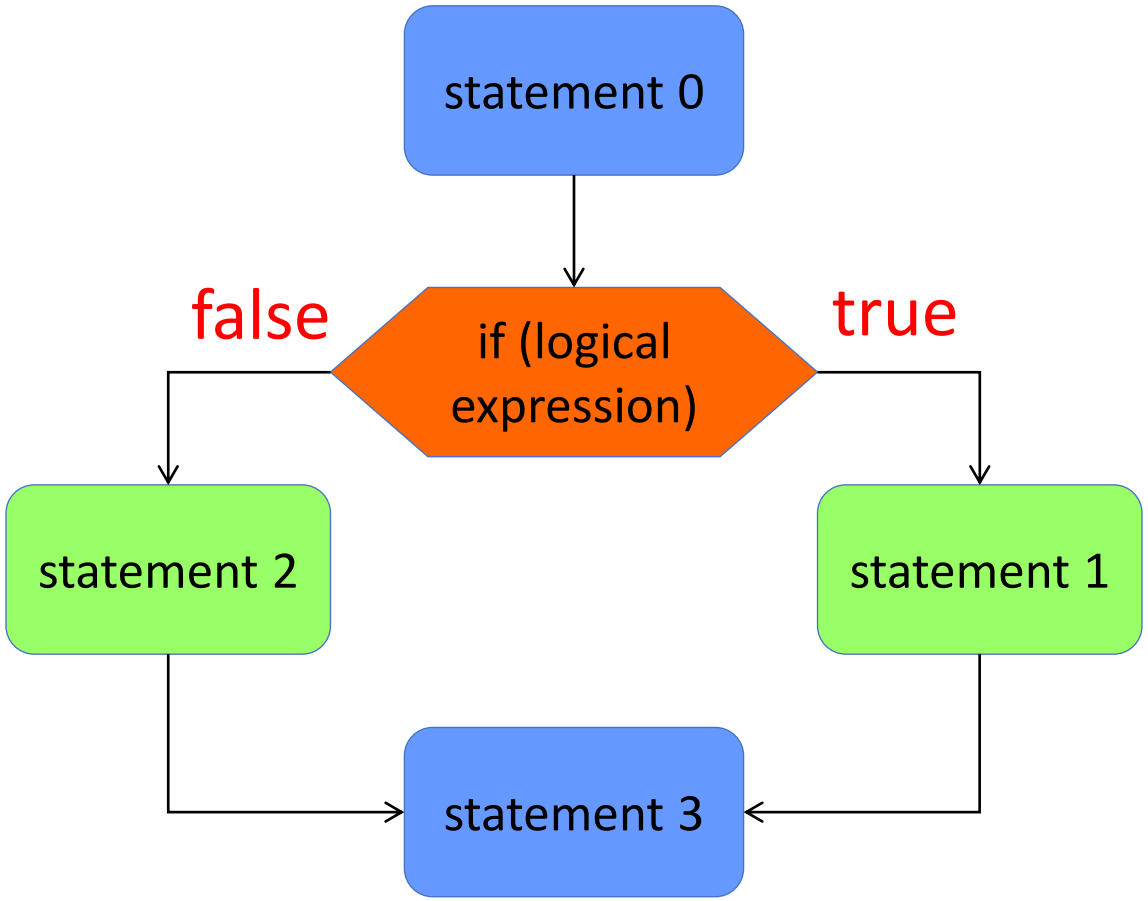
```
cin >> x;
if (x < 0)
    x = -x;
cout << x;
```



if Statement: Two-way Condition

```
statement 0;
if (logical expression)
    statement 1;
else
    statement 2;
statement 3;
```

- if logical expression is true, statement 1 will be executed
- If logical expression is false, statement 2 will be exected



if Statement: Some Syntax Notes

The logical expression should be enclosed with parenthesis ()

No semi-colon after if or else

```
if (i == 3)
    a ++;
else
    a --;
```

The semi-colons belong to the statements, not to the if else

if Statement: Some Syntax Notes

- Watch out to *empty statements*!

```
int x=5;
if (x!=5);
  x=3;
cout << x;
/*output is 3*/
```

```
int x=5;
if (x!=5)
  x=3;
cout << x;
/*output is 5*/
```

- An empty statement can be specified by a semi-colon ';'. Empty statement specifies that no action should be performed.
- For program on the right, x=3 statement will NOT be executed if x equals to 5.
- For the program on the left, x=3 statement will be always executed.

if Statement: Inline Ternary

- Also known as *inline* if-then-else constructs

- Syntax
  - expr1 ? expr2 : expr3 ;

- Semantics
  - expr1 is evaluated as the condition
  - if the value of expr1 is non-zero/true, then execute expr2;
  - else execute expr3

```
int a, b, c;
cin >> a;
cin >> b;
a>=b ? c=a : c=b;
cout << c;
```

if Statement: Inline Ternary

- The value of the whole inline ternary expression equals to the expression evaluated *at the end*
- For example

```
int a, b, c;
cin >> a;
cin >> b;
c = a>=b ? a : b;
cout << c;
```

Precedence & Associativity

Operator precedence (high to low)	Associativity
::	none
() ++ (post) -- (post)	Left to right
~ ! ++ (prefix)	Right to left
* / %	Left to right
+ -	Left to right
< <= > >=	Left to right
== !=	Left to right
&&	Left to right
||	Left to right
?: = +=	**Right to left**

Precedence & Associativity

Expression	Fully-Parenthesized Expression
a + b + c	((a + b) + c)
a = b = c	(a = (b = c))
c = a + b	(c = (a + b))
a + b * c / d % - g	(a + (((b * c) / d) % (-g)))
++i++	(++(i++))
a += b += c += d	(a += (b += (c += d)))
d = a && !b || c	(d = ((a && (!b)) || c))
z = a == b ? ++c : --d	(z = ((a == b) ? (++c) : (--d)))

Compound if

- Group multiple statements into one block using {} to be executed for one branch

```
if (logical expression) {
      statement 1;
      …
      statement n;
} else {
      statement n+1;
      …
      statement n+m;
}
```

We may group **multiple statements** to form a **compound statement** using a pair of braces {}

```
if (j!=3){
   b++;
   cout << b;
}
else
   cout << j;
```

Compound statements are treated as if it were a **single statement**

```
if (j!=5&&d==2) {
   j++;
   d--;
   cout<<j<<d;
} else {
   j--;
   d++;
   cout<<j<<d;
}
```

Compound if: Example 1

```
int mark;
cout << "What is your exam mark?\n";
cin >> mark;
if (mark >= 30)
    cout << "You passed the exam of CS2311!\n";
```

- If the input mark is greater than or equal to 34, the yellow statement is executed.

Compound if: Example 2

```
int mark;
cout << "What is your exam mark?\n";
cin >> mark;
if (mark >= 30) {
    cout << "You passed the exam of CS2311!\n";
    cout << “Congratulations!\n”;
} else
    cout << “You failed CS2311 … \n”;
```

- If more than 1 statements are specified within an if branch, group the statements in a pair of braces { }
- The else statement is executed when the `mark>=30` is false

Compound if: Example 3

```
int mark;
cout << "What is your exam mark?\n";
cin >> mark;
if (mark >= 30) {
    cout << "You passed the exam of CS2311!\n";
    cout << "Congratulations!\n";
} else
    cout << "You failed CS2311 … \n";
    cout << "You need to retake CS2311.\n";
```

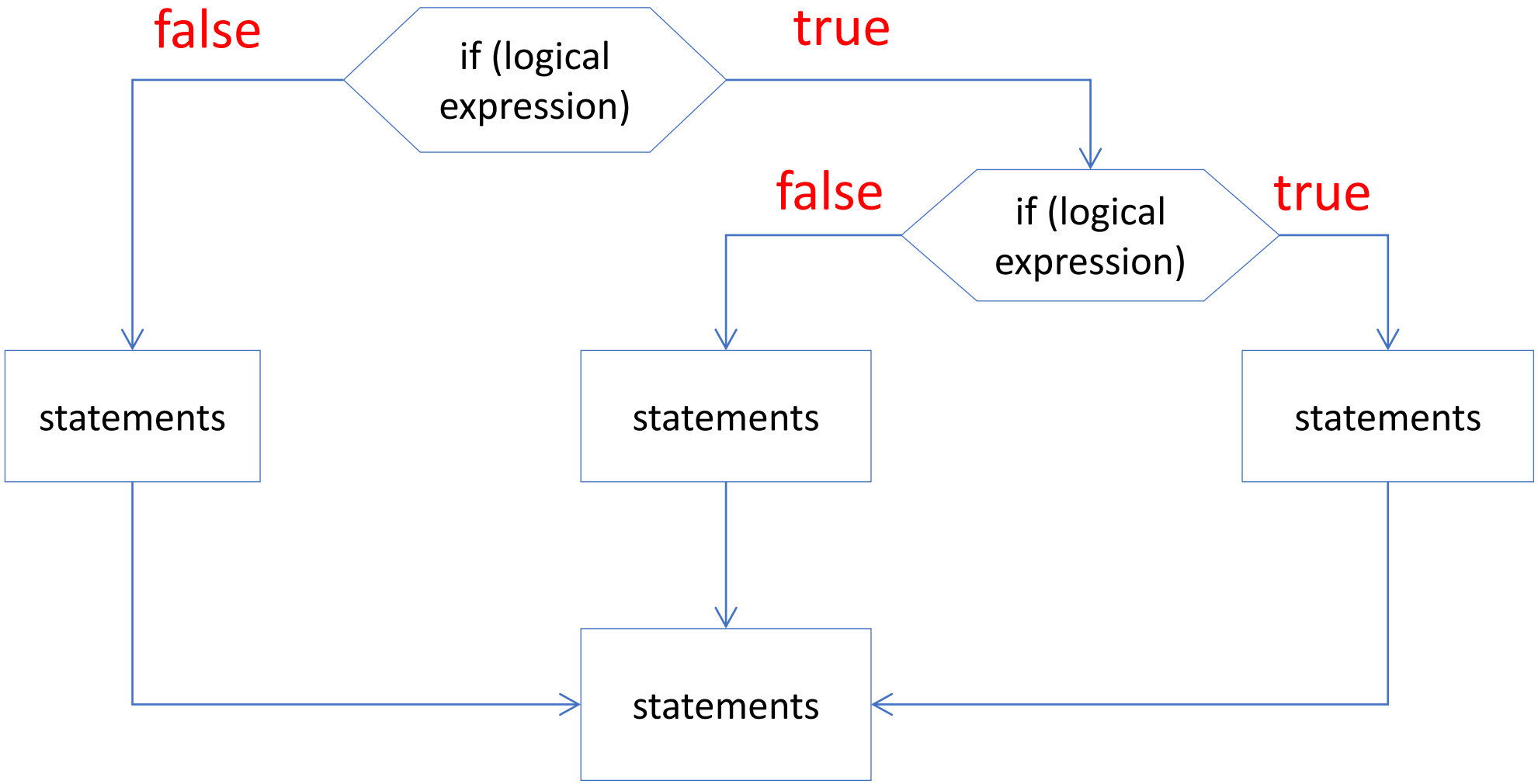
- Suppose the user inputs 40, what will be printed and why?

Compound if: Example 3

```
int mark;
cout << "What is your exam mark?\n";
cin >> mark;
if (mark >= 30) {
    cout << "You passed the exam of CS2311!\n";
    cout << “Congratulations!\n”;
} else {
    cout << “You failed CS2311 … \n”;
    cout << “You need to retake CS2311.\n”;
}
```

- Don’t forget to use { } to enclose the statements in the else branch

Beyond Two-way Condition



Multi-way Condition: Construct

- In C++, multi-way condition can be constructed as,

```
if (logical expression 1) {
   statements when expression 1 is true
}
else if (logical expression 2) {
   statements when expression 1 is false and expression 2 is true
}
else {
   statements when both logical expression 1 and 2 are false
}
```

Multi-way Condition: An Example

- Input a mark, display grade according to
- A: [90, 100], B: [75, 90), C: [55, 75), D: [0, 55)

Multi-way Condition: An Example

- Input a mark, display grade according to
- A: [90, 100], B: [75, 90), C: [55, 75), D: [0, 55)

```
if (mark < 0 || mark > 100)
   cout << "invalid mark \n";
if (mark >= 90 && mark <= 100)
   grade = 'A';
if (mark < 90 && mark >= 75)
   grade = 'B';
if (mark < 75 && mark >= 55)
   grade = 'C';
if (mark < 55 && mark >= 0)
   grade = 'D';
```

Multi-way Condition: An Example

- Input a mark, display grade according to
- A: [90, 100], B: [75, 90), C: [55, 75), D: [0, 55)

```
if (mark < 0 || mark > 100)
   cout << "invalid mark \n";
if (mark >= 90 && mark <= 100)
   grade = 'A';
if (mark < 90 && mark >= 75)
   grade = 'B';
if (mark < 75 && mark >= 55)
   grade = 'C';
if (mark < 55 && mark >= 0)
   grade = 'D';
```

```
if (mark < 0 || mark > 100)
   cout << "invalid mark \n";
else if (mark >= 90)
   grade = 'A';
else if (mark >= 75)
   grade = 'B';
else if (mark >= 55)
   grade = 'C';
else
   grade = 'D';
```

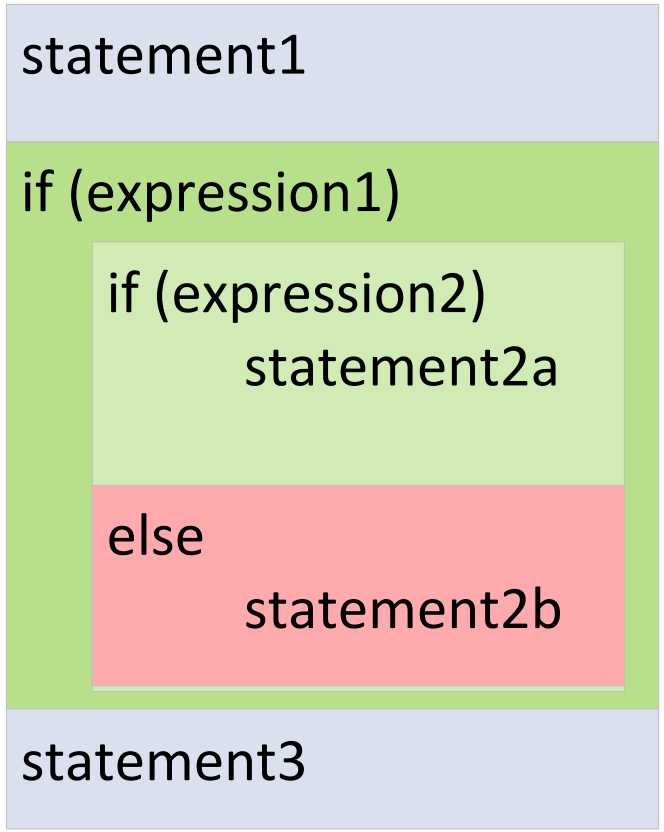
Nested if

- An if-else statement is included within another if or else statement

```
statement1

if (expression1)
    if (expression2)
        statement2a

    else
        statement2b

statement3
```

Nested if

- An if-else statement is included within another if or else statement




```
if (mark>=90 && mark<=100) {
  // divide A into can be A-, A or A+
  if (mark>97)
      cout << "You get grade A+\n";
  else if (mark>93)
      cout << "You get grade A \n";
  else
      cout << "You get grade A-\n";
}
```

Nested if (cont'd)

- Consider the two indentation formats of the same program

```
if (a==1)
    if (b==2)
        cout << "***\n";
else
    cout << "###\n";
```

```
if (a==1)
    if (b==2)
        cout << "***\n";
    else
        cout << "###\n";
```

- With which "if" the else statement is associated?

Nested if (cont'd)

- Consider the two indentation formats of the same program

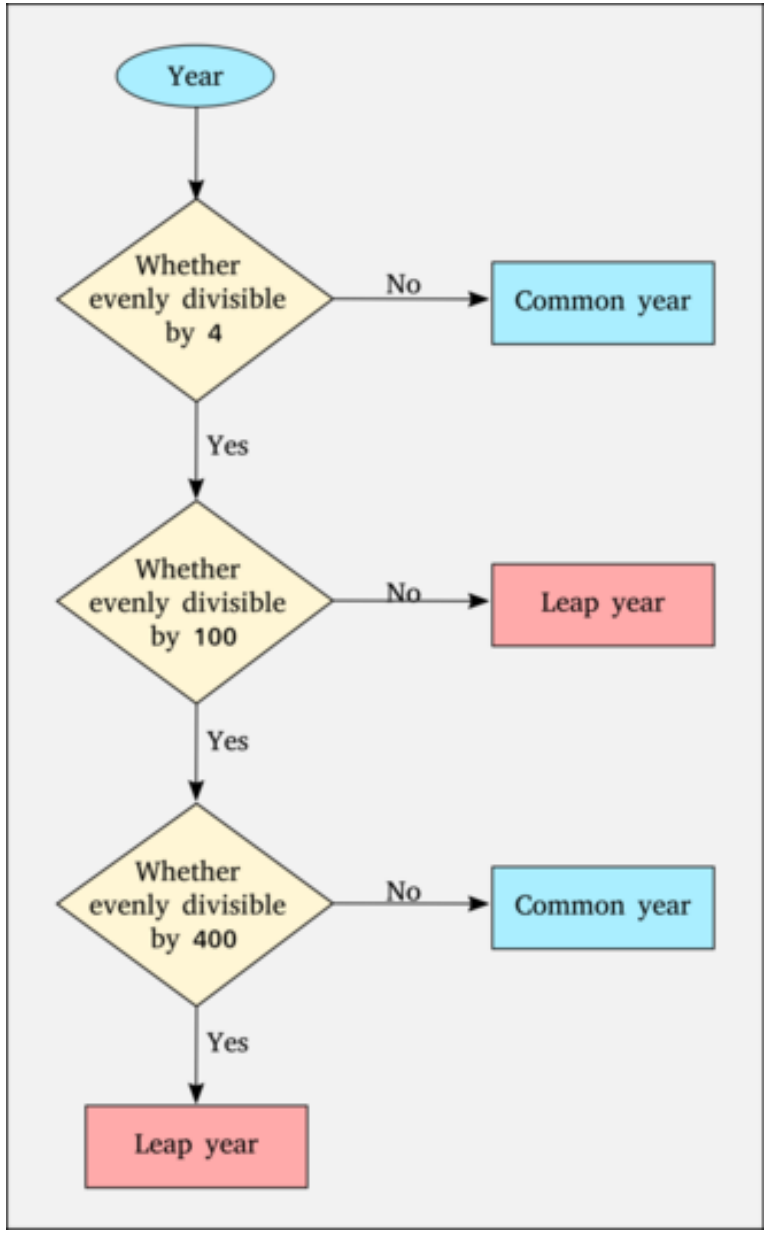
```
if (a==1)
    if (b==2)
        cout << "***\n";
else
    cout << "###\n";
```

```
if (a==1)
    if (b==2)
        cout << "***\n";
    else
        cout << "###\n";
```

- With which "if" the else statement is associated?
- An else is attached to the nearest if

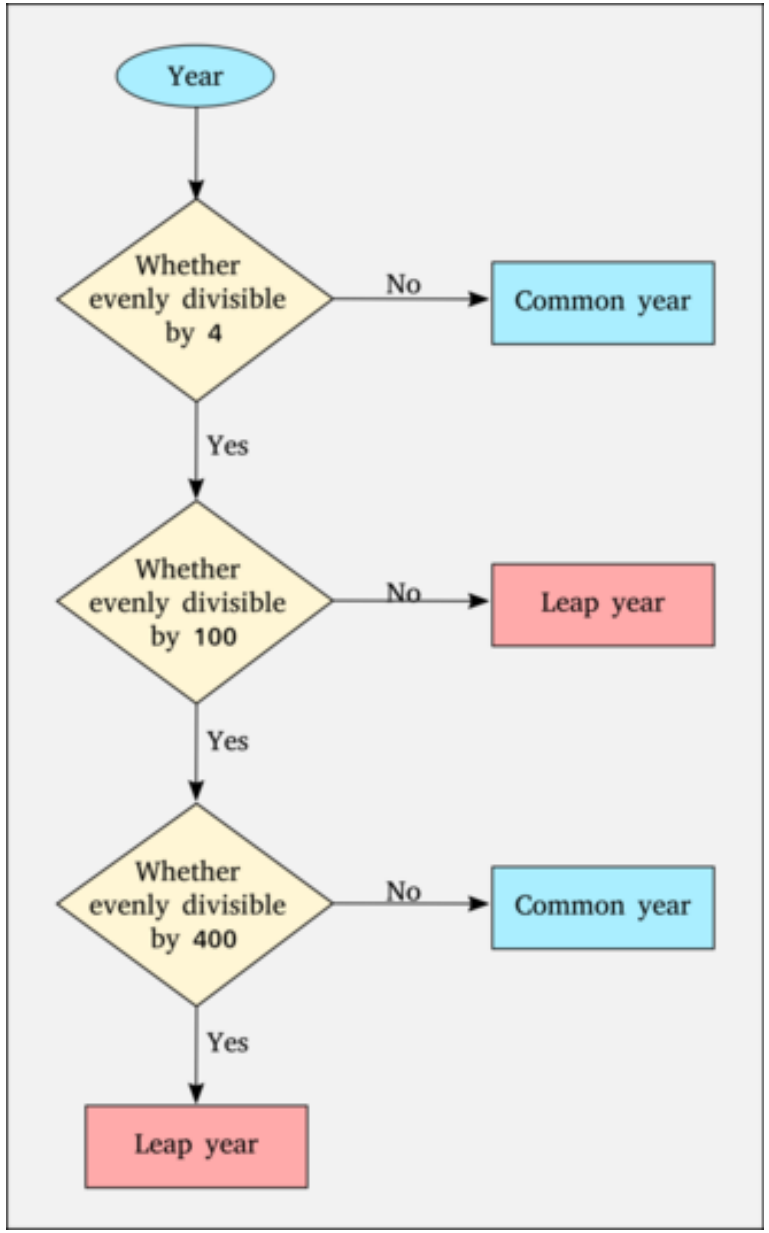
Nested if: An Example

- Check if a year is leap year
- A leap year is a calendar year that contains an additional day added to February to keep the calendar year synchronized with the astronomical year or seasonal year
- These extra days occur in each year that is an integer multiple of 4, except for years evenly divisible by 100, but not by 400



Nested if: An Example

```
4   void main() {
5
6       int year;
7       cout << "Please input year: ";
8       cin >> year;
9       if (year % 4 == 0) {
10          if (year % 100 == 0) {
11              if (year % 400 == 0)
12                  cout << "It is a leap year" << endl;
13              else
14                  cout << "It is not a leap year" << endl;
15          }
16          else
17              cout << "It is a leap year" << endl;
18      }
19      else
20          cout << "It is not a leap year" << endl;
21
22  }
```



Today’s Outline

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  - Simple
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- Switch statement

Motivation

- Is there a better way to organize the following code?

```
int day_of_week;
cin >> day_of_week;
if (day_of_week < 1 || day_of_week )
      cout << "invalid day\n";
if (day_of_week == 1) cout << "its Monday\n";
if (day_of_week == 2) cout << "its Tuesday\n";
if (day_of_week == 3) cout << "its Wednesday\n";
if (day_of_week == 4) cout << "its Thursday\n";
if (day_of_week == 5) cout << "its Friday\n";
if (day_of_week == 6) cout << "its Saturday\n";
if (day_of_week == 7) cout << "its Sunday\n";
```

switch: Syntax and Semantic

- Syntax

```
switch (expression) {
    case constant-expr1:
      statements
      break;     // optional
    ...
    case constant-exprN:
       statements
       break;    // optional
    default:     // optional
       statements
       break;    // optional
}
```

- Semantic
  - Evaluate the expression which results in an integer type (`int`, `long`, `short`, `char`)
  - Go to the case label having a constant value that matches the value of expression;
  - when a break statement is encountered, terminate the switch
  - If there is no break statement, execution falls through to the next statement
  - if a match is not found, go to the default label;
  - if default label does not exist, terminate the switch

switch: Example 1

```
int day_of_week;
cin >> day_of_week;
switch (day_of_week) {
    case 1:  cout << "Monday\n";    break;
    case 2:  cout << "Tuesday\n";   break;
    case 3:  cout << "Wednesday\n"; break;
    case 4:  cout << "Thursday\n";  break;
    case 5:  cout << "Friday\n";    break;
    case 6:  cout << "Saturday\n";  break;
    case 7:  cout << "Sunday\n";    break;
    default: cout << "Invalid\n";   break;
}  // end switch
```

switch: Example 1

```
// What happens there is no break ??
int day_of_week;
cin >> day_of_week;
switch (day_of_week) {
    case 1:  cout << "Monday\n";
    case 2:  cout << "Tuesday\n";
    case 3:  cout << "Wednesday\n";
    case 4:  cout << "Thursday\n";
    case 5:  cout << "Friday\n";
    case 6:  cout << "Saturday\n";
    case 7:  cout << "Sunday\n";
    default: cout << "Invalid\n";
}  // end switch
```

switch: Example 1

```
// What happens there is no break ??
int day_of_week;
cin >> day_of_week;
switch (day_of_week) {
    case 1:  cout << "Monday\n";
    case 2:  cout << "Tuesday\n";
    case 3:  cout << "Wednesday\n";
    case 4:  cout << "Thursday\n";
    case 5:  cout << "Friday\n";
    case 6:  cout << "Saturday\n";
    case 7:  cout << "Sunday\n";
    default: cout << "Invalid\n";
}  // end switch
```

- Semantic
  - Evaluate the expression which results in an integer type (`int`, `long`, `short`, `char`)
  - Go to the case label having a constant value that matches the value of expression;
  - when a break statement is encountered, terminate the switch
  - If there is no break statement, execution falls through to the next statement
  - if a match is not found, go to the default label;
  - if default label does not exist, terminate the switch

switch: Example 2

```
while ((c=getchar()) != EOF) { // get a char
    switch (c) {
        case '0': case '1': case '2': case '3':
        case '4': case '5': case '6': case '7':
        case '8': case '9':
            digit_count++;
            break;
        case ' ': case '\n': case '\t':
            white_character_count++;
            break;
        default:
            other_character_count++;
            break;
    }
}
```

Summary

- Boolean logic has two values only; true or false.

- Conditional statements are the statements that only execute under certain conditions.

- In C++, there are two approaches to construct conditional statement
  - if (…){…}else{…}
  - switch(…){case:break…}

Exercise

Police captured four suspects, among whom one is a thief

Consider the following statement of the suspects

- A: I am not a thief.
- B: C is a thief
- C: The thief must've been D.
- D: C is lying

If we know that there is only one liar, then who is the thief?