

Chapter 2

Control Statements (Part I)

TAO Yida

taoyd@sustech.edu.cn

Agenda

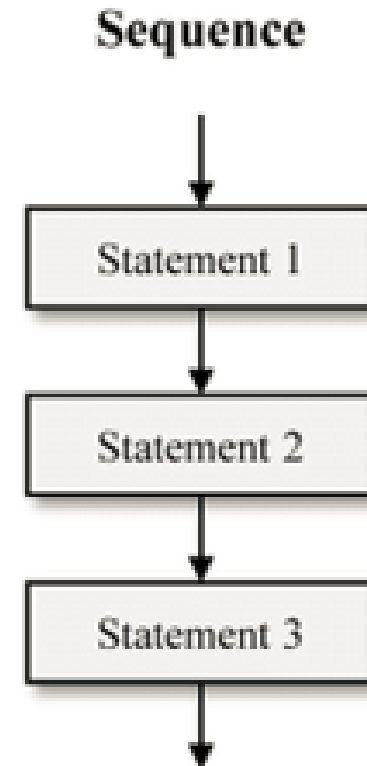
- ▶ Types of control structures
- ▶ Selection statements: `if`, `if...else` (选择/条件语句)
- ▶ Repetition statements: `while` (循环语句)
- ▶ Case Study

Control Structures

Control structures specify the flow of control in programs

Sequential Flow (顺序执行)

Actions are executed one after the other in the order in which they are specified. Unless directed otherwise, computers execute Java statements one after the other in the order in which they're written.



Control Structures

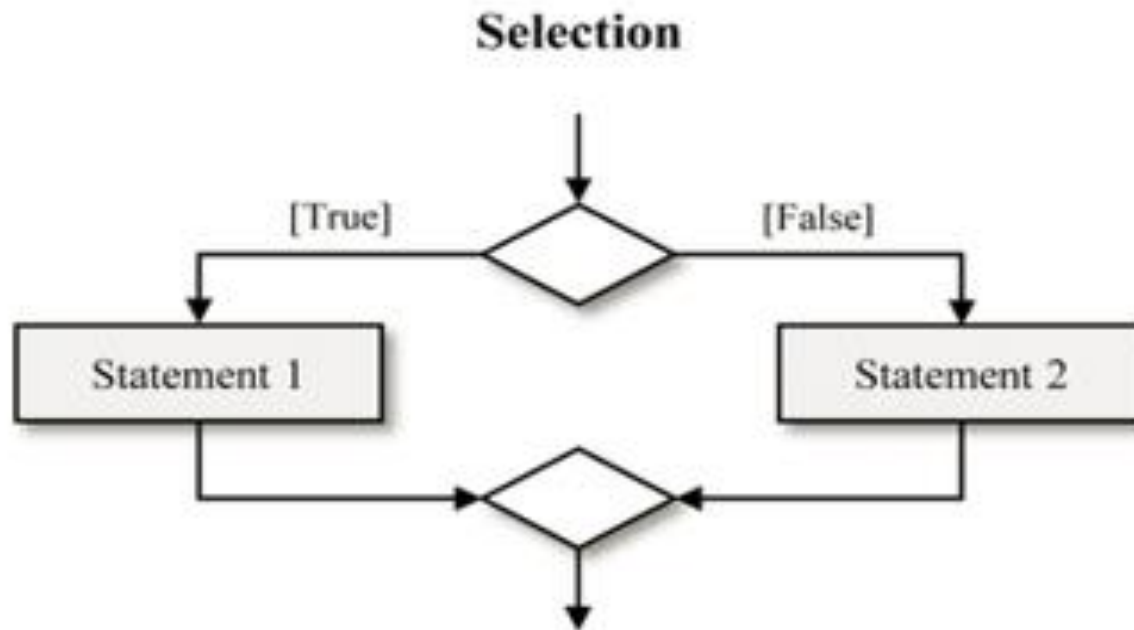
What if we need to make selections?



Control Structures

Conditional Flow (Selection Structure)

Execute one or more statements when certain condition(s) are met

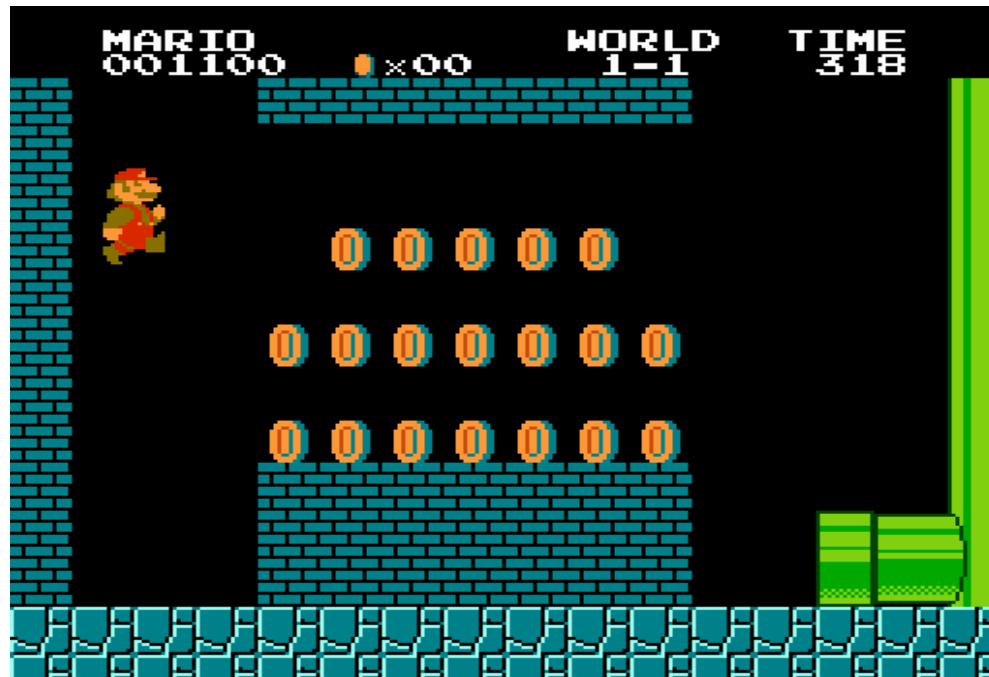


Selection Structure (选择)

- ▶ Three types of selection statements:
 - if statement (单路选择)
 - if...else statement (双路选择)
 - switch statement (多路选择)

Control Structures

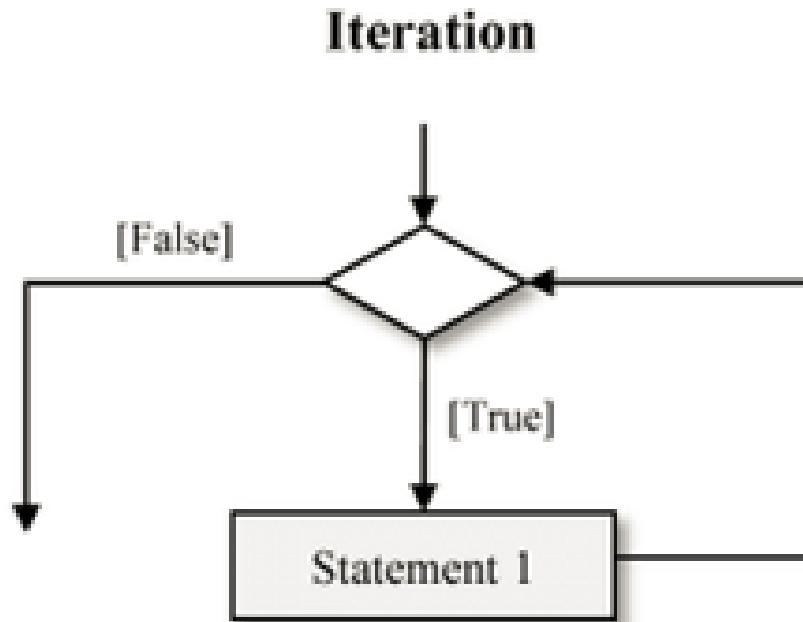
What if we need to repeat an action?



Control Structures

Repetitive Flow (Repetition Structure)

Repeat a statement a certain number of times or while a condition is fulfilled.



Repetition Structure (循环)

- ▶ Three **repetition statements** (a.k.a., **looping statements**).
Perform statements repeatedly while a **loop-continuation condition** remains true.
 - **while** statement
 - **for** statement
 - **do...while** statement

Agenda

- ▶ Types of control structures
- ▶ Selection statements: **if, if...else** (选择/条件语句)
- ▶ Repetition statements: **while** (循环语句)
- ▶ Case Study

if Single-Selection Statement

- ▶ If the condition is TRUE, execute the statement; if the condition is FALSE, nothing happens (i.e., one choice)

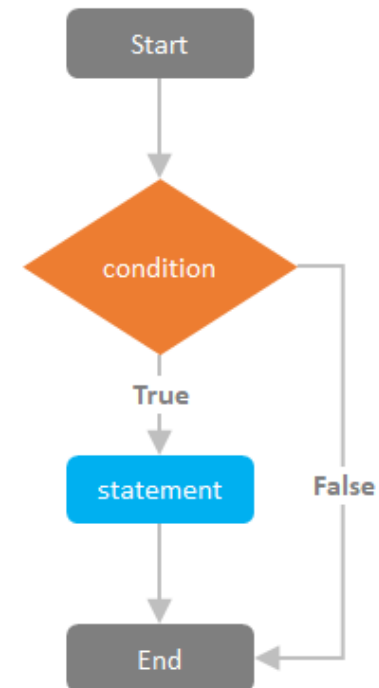
- ▶ Pseudocode (伪代码)

If student's grade is greater than or equal to 60

Print "Passed"

- ▶ Java code

```
if ( grade >= 60 ) {  
    System.out.println( "Passed" );  
}
```



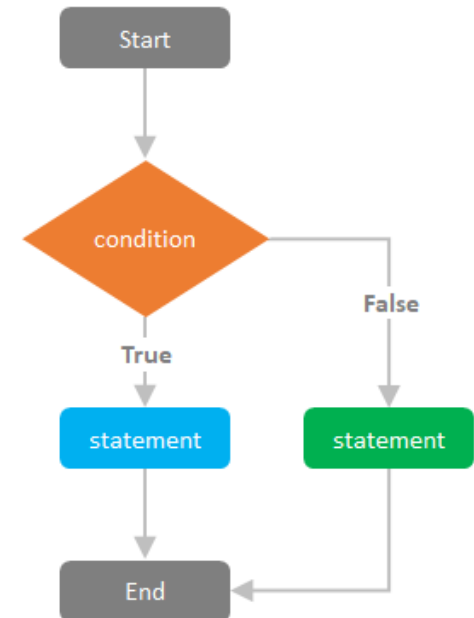
if...else Double-Selection Statement

- ▶ If the condition is TRUE, execute the statement; if the condition is FALSE, execute another statement (i.e., two choices)
- ▶ Pseudocode:

If student's grade is greater than or equal to 60
Print "Passed"
Else
Print "Failed"

- ▶ Java code:

```
if ( grade >= 60 )  
    System.out.println( "Passed" );  
else  
    System.out.println( "Failed" );
```



Conditional operator ?:

```
String result = studentGrade >= 60 ? "Passed" : "Failed"
```

The operands ? and : form a conditional expression.

Shorthand of if...else

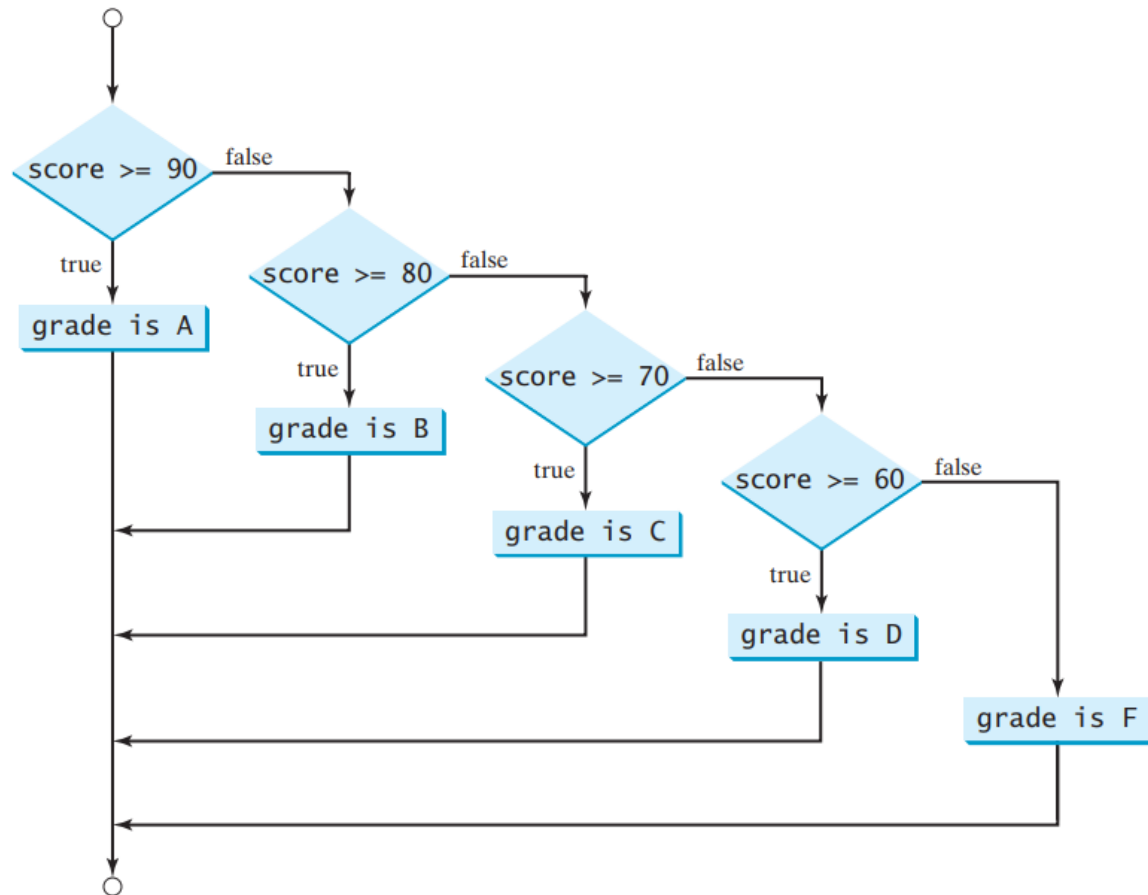
Ternary operator (三元操作符): We need to specify 3 parts.

Equivalent to

```
String result;  
if ( studentGrade >= 60 )  
    result = "Passed";  
else  
    result = "Failed";
```

Nested if Statements (嵌套)

```
if (score >= 90.0)
    System.out.print("A");
else
    if (score >= 80.0)
        System.out.print("B");
    else
        if (score >= 70.0)
            System.out.print("C");
        else
            if (score >= 60.0)
                System.out.print("D");
            else
                System.out.print("F");
```



A More Elegant Version

- ▶ Use *multi-way if...else statements* (多分支if-else语句) to specify a new condition to test, if the first condition is false

```
if (score >= 90.0)
    System.out.print("A");
else
    if (score >= 80.0)
        System.out.print("B");
    else
        if (score >= 70.0)
            System.out.print("C");
        else
            if (score >= 60.0)
                System.out.print("D");
            else
                System.out.print("F");
```

Equivalent

This is better

```
if (score >= 90.0)
    System.out.print("A");
else if (score >= 80.0)
    System.out.print("B");
else if (score >= 70.0)
    System.out.print("C");
else if (score >= 60.0)
    System.out.print("D");
else
    System.out.print("F");
```

Common Error 1: Condition for else

```
String level = "";
if(grade>=90) {
    level = "A";
}
else if(grade>=75) {
    level = "B";
}
else if(grade>=60) {
    level = "C";
}
else (grade < 60) {
    level = "F";
}
System.out.println(level);
```

Can the code even compile?

```
17 String level = "";
18 if(grade>=90) {
19     level = "A";
20 }
21 else if(grade>=75) {
22     level = "B";
23 }
24 else if(grade>=60) {
25     level = "C";
26 }
27 else (grade<60) {
28     level = "F";
29 }
30 System.out.println(level);
31
```


Common Error 2: Forgetting necessary braces

```
if (radius >= 0)
    area = radius * radius * PI;
    System.out.println("The area "
        + " is " + area);
```

(a) Wrong

```
if (radius >= 0) {
    area = radius * radius * PI;
    System.out.println("The area "
        + " is " + area);
}
```

(b) Correct

Common Error 3: Dangling else ambiguity

```
int i = 1, j = 2, k = 3;
if (i > j)
    if (i > k)
        System.out.println("A");
    else
        System.out.println("B");
```

(a)

if-else matching rule

- Extra spaces are irrelevant in Java (only for formatting).
- The Java compiler always associates an **else** with the immediately preceding **if** unless told to do otherwise by the placement of braces (**{** and **}**)

Common Error 3: Dangling else ambiguity

```
int i = 1, j = 2, k = 3;
if (i > j)
    if (i > k)
        System.out.println("A");
    else
        System.out.println("B");
```

(a)

Equivalent

This is better
with correct
indentation

```
int i = 1, j = 2, k = 3;
if (i > j)
    if (i > k)
        System.out.println("A");
    else
        System.out.println("B");
```

(b)

```
int i = 1, j = 2, k = 3;

if (i > j) {
    if (i > k)
        System.out.println("A");
}
else
    System.out.println("B");
```

Common Error 4: Wrong semicolon at the if line

- ▶ Just as a block (代码块) can be placed anywhere a single statement can be placed, it's also possible to have an empty statement (空语句)
- ▶ The empty statement is represented by placing a semicolon (;) where a statement would normally be

Logic error

```
if (radius >= 0);  
{  
    area = radius * radius * PI;  
    System.out.println("The area "  
        + " is " + area);  
}
```

(a)

Agenda

- ▶ Types of control structures
- ▶ Selection statements: **if, if...else** (选择/条件语句)
- ▶ Repetition statements: **while** (循环语句)
- ▶ Case Study

while Repetition Statement

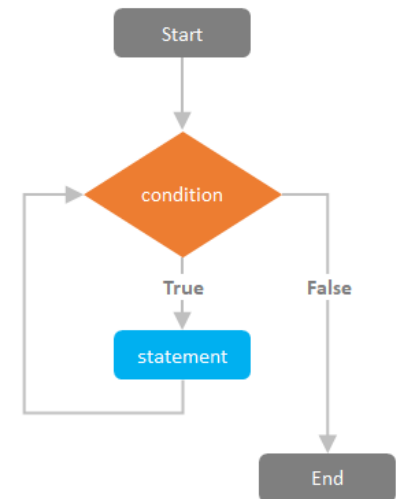
- ▶ Repeat an action while a condition remains true
- ▶ Pseudocode

While there are more items on my shopping list

Purchase next item and cross it off my list

Exit the shop

- ▶ The repetition statement's body may be a **single statement** or a **block**.
- ▶ Eventually, the condition should become false, and the repetition **terminates**, and the first statement after the repetition statement executes



Example

- ▶ Example of Java's **while repetition statement**: find the first power of 3 larger than 100

```
int product = 3;  
while ( product <= 100 ) {  
    product = 3 * product;  
}  
// other statements
```



The body of the while loop

Example

- ▶ Example of Java's **while repetition statement**: find the first power of 3 larger than 100

```
→ int product = 3;  
   while ( product <= 100 ) {  
       product = 3 * product;  
   }  
   // other statements
```

product value

Example

- ▶ Example of Java's **while repetition statement**: find the first power of 3 larger than 100

```
int product = 3;  
→ while ( product <= 100 ) {  
    product = 3 * product;  
}  
// other statements
```

product value
3

Condition true
Enter loop body

Example

- ▶ Example of Java's **while repetition statement**: find the first power of 3 larger than 100

```
int product = 3;  
while ( product <= 100 ) {  
→   product = 3 * product;  
}  
// other statements
```

product value
3
9

Example

- ▶ Example of Java's **while repetition statement**: find the first power of 3 larger than 100

```
int product = 3;  
→ while ( product <= 100 ) {  
    product = 3 * product;  
}  
// other statements
```

product value
3
9

Condition true
Enter loop body

Example

- ▶ Example of Java's **while repetition statement**: find the first power of 3 larger than 100

```
int product = 3;  
while ( product <= 100 ) {  
→   product = 3 * product;  
}  
// other statements
```

product value
3
9
27

Example

- ▶ Example of Java's **while repetition statement**: find the first power of 3 larger than 100

```
int product = 3;  
→ while ( product <= 100 ) {  
    product = 3 * product;  
}  
// other statements
```

product value
3
9
27

Condition true
Enter loop body

Example

- ▶ Example of Java's **while repetition statement**: find the first power of 3 larger than 100

```
int product = 3;  
while ( product <= 100 ) {  
→   product = 3 * product;  
}  
// other statements
```

product value
3
9
27
81

Example

- ▶ Example of Java's **while repetition statement**: find the first power of 3 larger than 100

```
int product = 3;  
→ while ( product <= 100 ) {  
    product = 3 * product;  
}  
// other statements
```

product value
3
9
27
81

Condition true
Enter loop body

Example

- ▶ Example of Java's **while repetition statement**: find the first power of 3 larger than 100

```
int product = 3;  
while ( product <= 100 ) {  
→   product = 3 * product;  
}  
// other statements
```

product value
3
9
27
81
243

Example

- ▶ Example of Java's **while repetition statement**: find the first power of 3 larger than 100

```
int product = 3;  
→ while ( product <= 100 ) {  
    product = 3 * product;  
}  
// other statements
```

product value
3
9
27
81
243

Condition false
Exit loop

Example

- ▶ Example of Java's **while repetition statement**: find the first power of 3 larger than 100

```
int product = 3;  
  
while ( product <= 100 ) {  
    product = 3 * product;  
}
```

→ // other statements

The first statement after the while
statement will be executed

product value
3
9
27
81
243

Will This Program Terminate?

(下面程序的循环会终止吗?)

```
int product = 3;

while ( product <= 100 ) {
    int x = 3 * product;
}

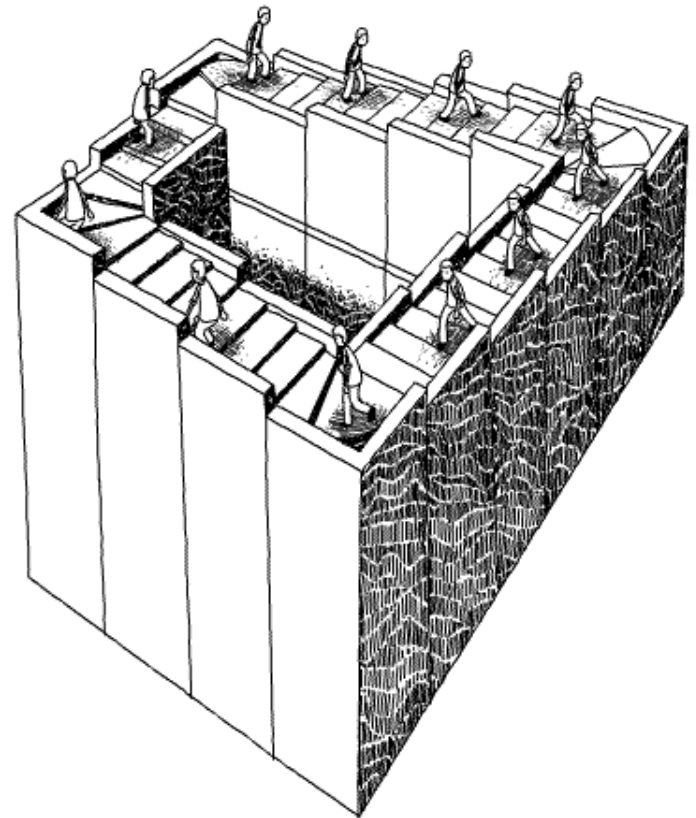
// other statements
```

Endless Loop

- ▶ The condition remains TRUE and the loop never terminates

```
int product = 3;  
while ( product <= 100 ) {  
    int x = 3 * product;  
}  
// other statements
```

The value of product never change and the condition remains to be TRUE!



Agenda

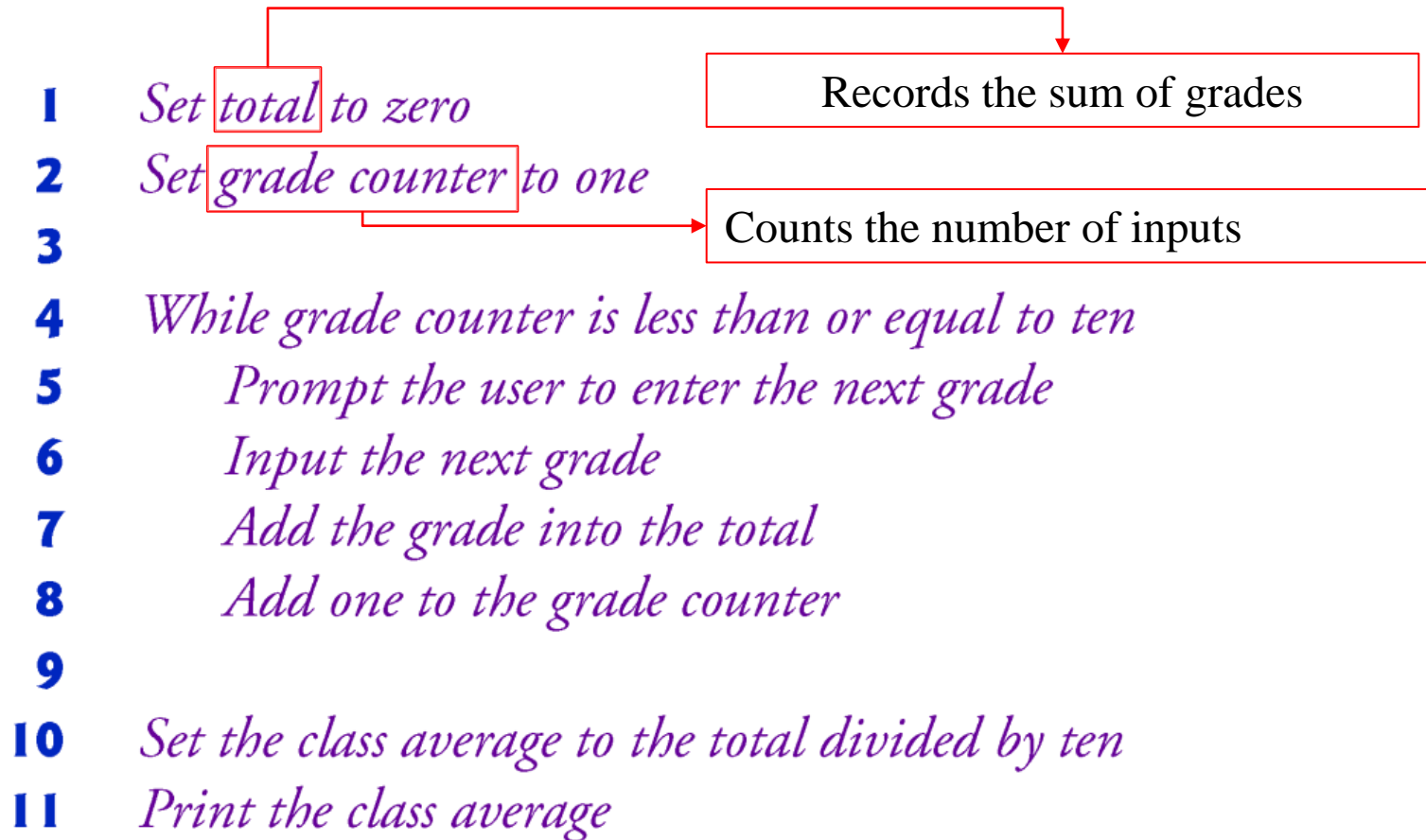
- ▶ Types of control structures
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Counter-Controlled Repetition

(计数器控制的循环)

- ▶ **Class-Average Problem:** *A class of ten students took a quiz. The grades (integers in the range 0 to 100) for this quiz are available to you. Determine the class average on the quiz*
- ▶ **Analysis:** The algorithm for solving this problem on a computer must input each grade, keep track of the total of all grades input, perform the averaging calculation and print the result
- ▶ **Solution:** Use **counter-controlled repetition** to input the grades one at a time. A variable called a **counter** (or **control variable**) controls the number of times a set of statements will execute.

The Pseudo Code



Translate to Java Code

```
// Counter-controlled repetition: Class-average problem
import java.util.Scanner;
public class ClassAverage {

    public static void main(String[] args) {

        // create Scanner to obtain input from command window
        Scanner input = new Scanner(System.in);

        int total; // sum of grades entered by user
        int gradeCounter; // number of the grade to be entered next
        int grade; // grade value entered by user
        int average; // average of grades

        // initialization phase
        total = 0; // initialize total
        gradeCounter = 1; // initialize loop counter
```


Translate to Java Code

```
// processing phase
while(gradeCounter <= 10) { // loop 10 times
    System.out.print("Enter grade: "); // prompt
    grade = input.nextInt(); // input next grade
    total = total + grade; // add grade to total
    gradeCounter = gradeCounter + 1; // increment counter by 1
} // end while

// termination phase
average = total / 10; // integer division yields integer result

// display total and average of grades
System.out.printf("\nTotal of all 10 grades is %d\n", total);
System.out.printf("Class average is %d\n", average);

} // end main
} // end class ClassAverage
```

A Sample Run

```
Enter grade: 67
Enter grade: 78
Enter grade: 89
Enter grade: 67
Enter grade: 87
Enter grade: 98
Enter grade: 93
Enter grade: 85
Enter grade: 82
Enter grade: 100
```

```
Total of all 10 grades is 846
Class average is 84
```

Sentinel-Controlled Repetition

(边界值控制的循环)

- ▶ **A new class-average problem:** *Develop a program that processes grades for an arbitrary number of students and output the average grade.*
- ▶ **Analysis:** In the earlier problem, the number of students was known in advance, but here how can the program determine when to stop the input of grades?

Sentinel-Controlled Repetition



We can use **a special value** called a **sentinel value** can be used to indicate “end of data entry”.

Marking the end of inputs

92, 77, 68, 84, 35, 72, 95, 79, 88, 84, **-1**

Pseudo Code

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17

Initialize total to zero

Initialize counter to zero

total stores the sum of grades

counter stores the number grades

Prompt the user to enter the first grade

Input the first grade (possibly the sentinel)

Try to take an input

While the user has not yet entered the sentinel

Add this grade into the running total

Add one to the grade counter

Prompt the user to enter the next grade

Input the next grade (possibly the sentinel)

If no sentinel value seen,
repeat the process

If the counter is not equal to zero

Set the average to the total divided by the counter

Print the average

else

Print "No grades were entered"

Compute and print average
(avoid division by 0)

Java Code

```
// Sentinel-controlled repetition: Class-average problem
import java.util.Scanner;
public class ClassAverage2 {
    public static void main(String[] args) {
        // create Scanner to obtain input from command window
        Scanner input = new Scanner(System.in);

        int total; // sum of grades
        int gradeCounter; // number of grades entered
        int grade; // grade value
        double average; // number with decimal point for average

        // initialization phase
        total = 0; // initialize total
        gradeCounter = 0; // initialize loop counter

        // processing phase
        // prompt for input and read grade from user
        System.out.print("Enter grade or -1 to quit: ");
        grade = input.nextInt();
```

Sentinel value

```

// loop until sentinel value read from user
while(grade != -1) {

    total = total + grade; // add grade to total
    gradeCounter = gradeCounter + 1; // increment counter
    // prompt for input and read next grade from user
    System.out.print("Enter grade or -1 to quit: ");
    grade = input.nextInt();

} // end while

// termination phase
if(gradeCounter != 0) { // if user entered at least one grade

    // calculate average of all grades entered
    average = (double) total / gradeCounter;
    // display total and average (with two digits of precision)
    System.out.printf("\nTotal of the %d grades entered is %d\n", gradeCounter, total);
    System.out.printf("Class average is %.2f\n", average);

} else { // no grades were entered, output appropriate message

    System.out.println("No grades were entered");

} // end if

} // end main

} // end class ClassAverage2

```

Enter grade or -1 to quit: 97

Enter grade or -1 to quit: 88

Enter grade or -1 to quit: 72

Enter grade or -1 to quit: -1

Total of the 3 grades entered is 257

Class average is 85.67

Type Cast (类型转换)

```
int total;          average = (double) total / gradeCounter;  
int gradeCounter;  
double average;
```

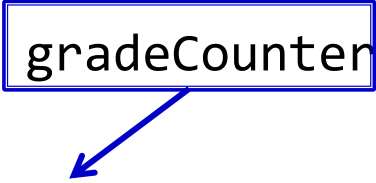
The unary cast operator creates a temporary floating-point copy of its operand

- ▶ Cast operator performs **explicit conversion** (or **type cast**). It has a higher precedence than the binary arithmetic operators (e.g., /).
- ▶ The value stored in the operand is unchanged (e.g., `total`'s value is not changed, `total`'s type is also not changed).

Type Promotion (类型提升)

```
int total;           average = (double) total / gradeCounter;  
int gradeCounter;  
double average;
```

Type promotion from **int** to **double**



- ▶ Java evaluates only arithmetic expressions in which the operands' types are identical.
- ▶ In the above expression, the `int` value of `gradeCounter` will be **implicitly promoted** (**widening**) to a `double` value for computation.



Why it is called promotion? Why it is implicit?

Variables: Declaration, Assignment, and Usage

- ▶ A variable must be **declared** before it can be **assigned** a value

```
public static void main(String[] args) {
```

```
    int a = 3;
```

```
    b = a + 4;  b must be declared before assigned a value
```

```
}
```

Variables: Declaration, Assignment, and Usage

- ▶ A variable must be **declared** before it can be **assigned** a value
- ▶ A variable declared in a method must be **assigned** a value before it can be **used**.


```
public static void main(String[] args) {  
    int a;  
    System.out.println(a);  
}
```



a must be initialized before being used

Variables: Declaration, Assignment, and Usage

- ▶ A variable must be **declared** before it can be **assigned** a value
- ▶ A variable declared in a method must be **assigned** a value before it can be **used**.
- ▶ A variable can be **declared only once** inside its **scope** (more on this later)

```
public static void main(String[] args) {  
    int a = 3;  
    int a = 5;   
}
```

a cannot be defined twice because the first a has a method-level scope

Block Scope (块作用域)

- ▶ A variable declared inside a pair of braces “{” and “}” in a method has a scope within the braces only

```
// generates a random number in [0, 1)
```

```
double a = Math.random();
```

```
System.out.println(a);
```

```
if(a > 0.5) {
```

```
    double b = 2 * a;
```

```
}
```

```
System.out.println(b);
```



b can be used only in the if block

Block Scope (块作用域)

- ▶ Due to the rule of variable scope, we often define counters before repetition statements

```
int counter = 0;
while(counter < 10) {
    // do something and increase counter
    // ...
    counter = counter + 1;
}
System.out.printf("repeated %d times\n", counter);
```

Recall case study I

```
int total; // sum of grades entered by user
int gradeCounter; // number of the grade to be entered next
int grade; // grade value entered by user
int average; // average of grades

// initialization phase
total = 0; // initialize total
gradeCounter = 1; // initialize loop counter

// processing phase
while(gradeCounter <= 10) { // loop 10 times
    System.out.print("Enter grade: "); // prompt
    grade = input.nextInt(); // input next grade
    total = total + grade; // add grade to total
    gradeCounter = gradeCounter + 1; // increment counter by 1
} // end while

// termination phase
average = total / 10; // integer division yields integer result

// display total and average of grades
System.out.printf("\nTotal of all 10 grades is %d\n", total);
System.out.printf("Class average is %d\n", average);
```

Can grade be declared inside of the while loop?

Compound Assignment Operators

(组合赋值操作符)

- ▶ Compound assignment operators simplify assignment expressions.
- ▶ *variable = variable operator expression;* where operator is one of +, -, *, / or % can be written in the form
*variable **operator**= expression;*
- ▶ `C = C + 3;` can be written as `C += 3;`

Compound Assignment Operators

(组合赋值操作符)

Assignment operator	Sample expression	Explanation	Assigns
<i>Assume: int c = 3, d = 5, e = 4, f = 6, g = 12;</i>			
+=	c += 7	c = c + 7	10 to c
-=	d -= 4	d = d - 4	1 to d
*=	e *= 5	e = e * 5	20 to e
/=	f /= 3	f = f / 3	2 to f
%=	g %= 9	g = g % 9	3 to g

Recall case study I

```
int total; // sum of grades entered by user
int gradeCounter; // number of the grade to be entered next
int grade; // grade value entered by user
int average; // average of grades

// initialization phase
total = 0; // initialize total
gradeCounter = 1; // initialize loop counter

// processing phase
while(gradeCounter <= 10) { // loop 10 times
    System.out.print("Enter grade: "); // prompt
    grade = input.nextInt(); // input next grade
    total = total + grade; // add grade to total
    gradeCounter = gradeCounter + 1; // increment counter by 1
} // end while

// termination phase
average = total / 10; // integer division yields integer result

// display total and average of grades
System.out.printf("\nTotal of all 10 grades is %d\n", total);
System.out.printf("Class average is %d\n", average);
```

Where can we apply the compound assignment operators?

Increment and Decrement Operators

(自增、自减运算符)

- ▶ Unary **increment operator**, **++**, adds one to its operand
- ▶ Unary **decrement operator**, **--**, subtracts one from its operand
- ▶ An increment or decrement operator placed before a variable is called **prefix increment** or **prefix decrement operator** (前缀自增自减操作符).
- ▶ An increment or decrement operator placed after a variable is called **postfix increment** or **postfix decrement operator** (后缀自增自减操作符).

```
int a = 6;   int b = ++a;   int c = a--;
```

Preincrementing/Predecrementing

(前綴自增/自減)

- ▶ Using the prefix increment (or decrement) operator to add (or subtract) 1 from a variable is known as **preincrementing** (or **predecrementing**) the variable.
- ▶ Preincrementing (or predecrementing) a variable causes the variable to be incremented (decremented) by 1; then the new value is used in the expression in which it appears.

```
int a = 6;
```

```
int b = ++a; // a, b gets the value 7
```

Postincrementing/Postdecrementing

(后綴自增/自減)

- ▶ Using the postfix increment (or decrement) operator to add (or subtract) 1 from a variable is known as **postincrementing** (or **postdecrementing**) the variable.
- ▶ This causes the current value of the variable to be used in the expression in which it appears; then the variable's value is incremented (decremented) by 1.

```
int a = 6;
```

```
int b = a++; // b gets the value 6, a gets the value 7
```

Note the Difference

```
int a = 6;  
int b = a++; // b gets the value 6
```

```
int a = 6;  
int b = ++a; // b gets the value 7
```

```
int b = a++;
```

Equivalent to:

```
int b = a;  
a = a + 1;
```

```
int b = ++a;
```

Equivalent to:

```
a = a + 1;  
int b = a;
```

In both cases, a becomes 7 after execution, but b gets different values. Be careful when programming.

Recall case study

```
int total; // sum of grades entered by user
int gradeCounter; // number of the grade to be entered next
int grade; // grade value entered by user
int average; // average of grades

// initialization phase
total = 0; // initialize total
gradeCounter = 1; // initialize loop counter

// processing phase
while(gradeCounter <= 10) { // loop 10 times
    System.out.print("Enter grade: "); // prompt
    grade = input.nextInt(); // input next grade
    total = total + grade; // add grade to total
    gradeCounter = gradeCounter + 1; // increment counter by 1
} // end while

// termination phase
average = total / 10; // integer division yields integer result

// display total and average of grades
System.out.printf("\nTotal of all 10 grades is %d\n", total);
System.out.printf("Class average is %d\n", average);
```

Where can we apply the increment operators?