Loops

CSE160: Computer Science A: Honors
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Motivation

Suppose that you need to print a string (e.g., "Welcome to Java!") a user-entered times N:

```java
Scanner input = new Scanner(System.in);
System.out.print("Enter N: ");
int N = input.nextInt();
```

```
N?
{ 
System.out.println("Welcome to Java!");
...
System.out.println("Welcome to Java!");
}
```
Motivation

• Without iteration (or recursion) this would be impractical
  • We do not know N, when we are about to write the program
  • So, we need a cascade of if statements to check all cases for the value of N.
Without iteration or recursion

Scanner input = new Scanner(System.in);
System.out.print("Enter N: ");
int N = input.nextInt();
if(N == 1)
    System.out.println("Welcome to Java!");
else if(N == 2){
    System.out.println("Welcome to Java!");
    System.out.println("Welcome to Java!");
    System.out.println("Welcome to Java!");
}else if(N == 3){
    System.out.println("Welcome to Java!");
    System.out.println("Welcome to Java!");
    System.out.println("Welcome to Java!");
}...

Inefficient coding (repetition)!
Loops Solution

• While loop:

```java
Scanner input = new Scanner(System.in);
System.out.print("Enter N: ");
int N = input.nextInt();
int count = 0;
while (count < N) {
    System.out.println("Welcome to Java");
    count++;
}
```
How would we write code to print N! (factorial), where N is a number entered by the user?
Without iteration or recursion

Scanner input = new Scanner(System.in);
System.out.print("Enter N: ");
int N = input.nextInt();
int factorial = 1;
if ((N == 1) || (N == 0)) factorial = 1;
else if (N == 2) factorial = 2 * 1;
else if (N == 3) factorial = 3 * 2 * 1;
else if (N == 4) factorial = 4 * 3 * 2 * 1;
else if (N == 5) factorial = 5 * 4 * 3 * 2 * 1;
...
System.out.println(factorial);

Inefficient coding (repetition)!
With iteration/loops

Scanner input = new Scanner(System.in);
System.out.print("Enter N: ");
int N = input.nextInt();
int factorial = 1;
int i = 1;
while(i <= N)
    factorial *= i++;
System.out.println(factorial);
What is Iteration?

- Repeating a set of instructions a specified number of times or until a specific result is achieved.

- How do we repeat steps?
  - Imagine 3 instructions A, B, & C:
    - Instruction A
    - Instruction B
    - Instruction C can be conditional jump to A (meaning go back to A)

- Iteration might result in:
  - Execute A
  - Execute B
  - Execute C
  - Execute A
  - Execute B
  - ...
  - ...
Java and iteration

- We have 3 types of iterative statements
  - a while loop
  - a do ... while loop
  - a for loop
- All 3 can be used to do similar things
- Which one should you use?
  - a matter of individual preference/convenience
- Note: When we will learn arrays, we will see a 4th kind of loop: for-each loop
while (loop-continuation-condition) {
  // loop-body;
  Statement(s);
}

int count = 0;
while (count < 100) {
  System.out.println("Welcome to Java!");
  count++;
}
Trace while Loop

```
int count = 0;

while (count < 2) {
    System.out.println("Welcome to Java!");
    count++;
}
```
int count = 0;
while (count < 2) {
    System.out.println("Welcome to Java!");
    count++;
}
int count = 0;
while (count < 2) {
    System.out.println("Welcome to Java!");
    count++;
}

Welcome to Java!
int count = 0;
while (count < 2) {
    System.out.println("Welcome to Java!");
    count++;
}

Welcome to Java!
Trace while Loop

```java
int count = 0;
while (count < 2) {
    System.out.println("Welcome to Java!");
    count++;
}
```

(count < 2) is still true since count is 1

Welcome to Java!
int count = 0;
while (count < 2) {
    System.out.println("Welcome to Java!");
    count++;
}

Welcome to Java!
Welcome to Java!
int count = 0;
while (count < 2) {
    System.out.println("Welcome to Java!");
    count++;
}

Welcome to Java!
Welcome to Java!
int count = 0;
while (count < 2) {
    System.out.println("Welcome to Java!");
    count++;
}

Welcome to Java!
Welcome to Java!

(count < 2) is false since count is 2 now
The loop exits. Execute the next statement after the loop.

```java
int count = 0;
while (count < 2) {
    System.out.println("Welcome to Java!");
    count++;
}
```

Welcome to Java!
Welcome to Java!
Caution: don't use equality for reals

- Don’t use floating-point values for equality checking in a loop control - because floating-point values are approximations for some values
  
  ```java
  System.out.print(1 - 0.1 - 0.1 - 0.1);
  prints 0.7000000000000001
  ```

- Loop example: the following code for computing $1 + 0.9 + 0.8 + \ldots + 0.1$:
  
  ```java
  double item = 1, sum = 0;
  while (item != 0) { // No guarantee item will be 0 or 0.0
    sum += item;     // change the condition: item > 0
    item -= 0.1;
  }
  System.out.printf("%.1f",sum);
  ```

- It is actually an infinite loop!
  
  - Variable item starts with 1 and is reduced by 0.1 every time the loop body is executed
  - The loop should terminate when item becomes 0
    - However, there is no guarantee that item will be exactly 0, because the floating-point arithmetic is approximated
    - So, it continues running forever
do-while Loop

```c
do {
// Loop body;
Statement(s);
} while (loop-continuation-condition);
```
Why use do ... while?

- For when you have a loop body that must execute at least once.
- Example: a program menu

```java
Scanner in = new Scanner(System.in);
String selection;
int counter = 0;

do{
    System.out.println("Choose a Menu Option: ");
    System.out.println("P) Print Counter");
    System.out.println("Q) Quit");
    System.out.print("ENTER: ");
    selection = in.nextLine();
    if (selection.toUpperCase().equals("P"))
        System.out.println("Counter: "+counter++);
}while(!selection.toUpperCase().equals("Q"));
System.out.println("Goodbye!");
```
• An Example Session

Choose a Menu Option:
P) Print Counter
Q) Quit
ENTER: P
Counter: 0
Choose a Menu Option:
P) Print Counter
Q) Quit
ENTER: A
Choose a Menu Option:
P) Print Counter
Q) Quit
ENTER: P
Counter: 1
Choose a Menu Option:
P) Print Counter
Q) Quit
ENTER: Q
Goodbye!
for (initial-action;
   loop-continuation-condition;
   action-after-each-iteration) {
   // loop body;
   Statement(s);
}

int i;
for (i = 0; i < N; i++){
   System.out.println("Welcome to Java!");
}

(A) i = 0

(i < 100)?
   true
   System.out.println("Welcome to Java");
   i++
   false

(B) (i < 100)?
   true
   System.out.println("Welcome to Java");
   i++
   false
for loops and counting

• for loops are popular for counting loops
  • through the indices of a string
  • through the indices of an array (later)
  • through iterations of an algorithm
• Good for algorithms that require a known number of iterations
  • counter-controlled loops
Trace for Loop

```java
int i;
for (i = 0; i < 2; i++) {
    System.out.println(
        "Welcome to Java!";
}
```
int i;
for (i = 0; i < 2; i++) {
    System.out.println("Welcome to Java!");
}
int i;
for (i = 0; i < 2; i++) {
    System.out.println("Welcome to Java!");
}
Trace for Loop

int i;
for (i = 0; i < 2; i++) {
    System.out.println("Welcome to Java!");
}

Welcome to Java!
int i;
for (i = 0; i < 2; i++) {
    System.out.println(
        "Welcome to Java!";
}

Welcome to Java!
int i;
for (i = 0; i < 2; i++) {
    System.out.println("Welcome to Java!");
}

Welcome to Java!
int i;
for (i = 0; i < 2; i++) {
    System.out.println("Welcome to Java!");
}

Welcome to Java!
Welcome to Java!
int i;
for (i = 0; i < 2; i++) {
    System.out.println("Welcome to Java!");
}

Welcome to Java!
Welcome to Java!

Execute adjustment statement
i now is 2
int i;
for (i = 0; i < 2; i++) {
    System.out.println("Welcome to Java!");
}

Welcome to Java!
Welcome to Java!

(i < 2) is false since i is 2
int i;
for (i = 0; i < 2; i++) {
    System.out.println("Welcome to Java.");
}
Welcome to Java!
Welcome to Java!

Exit the loop. Execute the next statement after the loop.
for loops

The initial-action in a for loop can be a list of zero or more comma-separated expressions.

The action-after-each-iteration in a for loop can be a list of zero or more comma-separated statements.

```java
for (int i = 0, j = 0; (i + j < 10); i++, j++){
    // Do something
}
```

The loop body can be the no-op statement:

```java
for (int i = 0; i < 100; System.out.println(i++)) ;
```
Caution;

Adding a semicolon at the end of the for clause before the loop body is a common mistake:

```java
for (int i=0; i<10; i++)
{
    System.out.println("i is " + i);
}
// i does not exist anymore
// it is a syntax error
```
Adding a semicolon at the end of the `while` clause before the loop body is a common mistake:

```java
int i=0;
while (i < 10);
{
    System.out.println("i is " + i);
    i++;
}
```

this will cause an infinite loop
Infinite loops

If the loop-continuation-condition in a for loop is omitted, it is implicitly true.

```plaintext
for ( ; ; ) {
  // Do something
}
```

Equivalent

```plaintext
while (true) {
  // Do something
}
```

(a) 
(b)
Which Loop to Use?

while, do-while, and for loops are expressively equivalent

while (loop-continuation-condition) {
    // Loop body
}

(a)

Equivalent

for (; loop-continuation-condition; ) {
    // Loop body
}

(b)

for (initial-action;
    loop-continuation-condition;
    action-after-each-iteration) {
    // Loop body;
}

(a)

Equivalent

initial-action;
while (loop-continuation-condition) {
    // Loop body;
    action-after-each-iteration;
}

(b)
Caution: Loop variables

```c
int sum = 0;
for (int j=1; j<=4; j++) {
    sum = sum + j;
    j++;  // Be careful not to double the update of your counting variable
}
```

Sums

int sum = 0;
for (int i=1; i<=4; i++)
    sum = sum + i;

<table>
<thead>
<tr>
<th>sum</th>
<th>i</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>10</td>
<td>5</td>
</tr>
</tbody>
</table>
Product

```java
int product = 1;
for (int i=1; i<=4; i++)
    product = product * i;
```
Nested Loops

```java
for (int i = 1; i <= 10; i++){
    for (int j = 1; j <= 10; j++){
        int product = i*j;
        System.out.print(product + " ");
    }
    System.out.println();
}
```

```
1 2 3 4 5 6 7 8 9 10
2 4 6 8 10 12 14 16 18 20
3 6 9 12 15 18 21 24 27 30
...
10 20 30 40 50 60 70 80 90 100
```
Local Variables and Blocks

• A variable declared inside a block is known only inside that block
  • it is *local* to the block, therefore it is called a *local variable*
    • when the block finishes executing, local variables disappear
      • references to it outside the block cause a compiler error

• That includes *Init field* of for loops:

```java
for(int i=0; i < 10; i++){
    ...
}
System.out.print(i);
```

// Compile Error: i is garbage collected
Do not declare variables inside loops it takes time during execution to create and destroy variables, so it is better to do it just once for loops)

```java
for(int i=1; i<=10; i++) {
    double x = 10;
    //...
}
```

```java
double x;
for(int i=1; i<=10; i++) {
    x = 10;
    //...
}
```
Keywords break and continue

- You can also use `break` in a loop to immediately terminate the loop:

```java
public static void main(String[] args) {
    int sum = 0;
    int number = 0;
    while (number < 20) {
        number++;
        sum += number;
        if (sum >= 100) // increments until the sum is greater than 100
            break;
    }
    System.out.println("The number is " + number);
    System.out.println("The sum is " + sum);
}
```

The number is 14
The sum is 105
Keywords break and continue

- You can also use `continue` in a loop to end the current iteration and program control goes to the end of the loop body (and continues the loop):

```java
public static void main(String[] args) {
    int sum = 0;
    int number = 0;
    while (number < 20) { // adds integers from 1 to 20
        number++;
        // except 10 and 11 to sum
        if (number ==10 || number == 11)
            continue;
        sum += number;
    }
    System.out.println("The number is " + number);
    System.out.println("The sum is " + sum);
}
```

The number is 20
The sum is 189