Mat 2170
Week 7

Methods – Algorithms

Spring 2014

Student Responsibilities

- Reading: Textbook, Sections 5.2 – 5.5
- Lab
- Attendance

Overview Chapter Five, Sections 2 — 5:

- 5.2 Writing your own methods
- 5.3 Mechanics of the method–calling process
- 5.4 Decomposition
- 5.5 Algorithmic methods

5.2 Writing Our Own Methods

- The general form of a method definition is:

```
scope type name (argument list)
{
        statements in the method body
}
```

- where
  - **scope**: indicates what blocks of code have access to the method choices: **public**, **private**, or **protected**
  - **type**: indicates the type of value the method returns (if any)
  - **name**: is the name of the method
  - **argument list**: is the ordered list of declarations for the variables used to hold the values of each argument

Scope and Type

```
scope type name (argument list) {
        statements in the method body
}
```

- **Scope**: what code blocks have access?
  1. The most common value for *scope* is **private**, which means that the method is available only within its own class.
  2. If other classes need access to the method, *scope* should be **public** instead.
- **Type** should be **void** if a method does **not** return a value. Such methods are sometimes called **procedures**.
- If a method has a return type other than **void**, then it **must** return a value.

Returning Values from a Method

- You can return a **single** value from a method by including a **return** statement, which is usually written as:

```
return expression;
```

  where **expression** is a Java expression that specifies the value the method is to return

- As an example, the method definition:

```
private double feetToInches (double feet) {
    return 12.0 * feet;
}
```

  converts an argument indicating a distance in feet to the equivalent number of inches, and returns this calculated value to the calling program.

Methods Involving Control Statements

- The **body** of a method can contain statements of any type, including control statements: `for`, `while`, `if`, and `switch`.
- As an example, the following method uses an **if** statement to find the larger of the two integer arguments:

```
private int MyMax (int x, int y) {
    if (x > y)
    {
      return x;
    }
    else    // x <= y
    {
      return y;
    }
}
```

- **return** statements can be used **at any point** in the method, and may **appear more than once**, although **only one** will be executed during a particular call.

The `factorial` Method

- The **factorial** of a number n (written as $n!$) is defined to be the product of the integers from 1 to n. Thus, $5!$ is $1 \times 2 \times 3 \times 4 \times 5$, or 120.
- The following method definition uses a `for` loop to compute the factorial function:

```
private int factorial (int n) {
    int result = 1;
    for (int i = 2; i <= n; i++)
    {
       result *= i;
    }
    return result;
}
```

- Note here that the accumulator **result** stores a **product** rather than a sum, so it must be initialized to `1` instead of `0`.

Non–numeric Methods

Methods in Java can return values of any type. The following method, for example, returns the English name of the day of the week, given a number between 0(Sunday) and 6(Saturday):

```
private String weekdayName (int day) {
    switch (day)
    {
      case 0:  return "Sunday";
      case 1:  return "Monday";
      case 2:  return "Tuesday";
      case 3:  return "Wednesday";
      case 4:  return "Thursday";
      case 5:  return "Friday";
      case 6:  return "Saturday";
      default:  return "Illegal weekday";
    }
}
```

(**String** is a class defined in the package `java.lang`.)
There is **no need** for a **break** statement following a **return**.

Methods Returning Graphical Objects

- Textbook has examples of these types of methods.
- The following method **creates a filled circle centered at the point** (x, y), with a **radius** of r pixels, and is filled using the color specified in the parameter list.

```
private GOval createFilledCircle (double x,
                double y, double r, Color color) {
    GOval circle = new GOval(x-r, y-r, 2*r, 2*r);
    circle.setFilled(true);
    circle.setColor(color);
    return circle;
}
```

- If you are creating a `GraphicsProgram` that requires many filled circles in different colors, the `createFilledCircle()` method turns out to save a considerable amount of code.

Predicate Methods

- Methods that return a **boolean** value play an important role in programming and are called **predicate methods**.
- As an example, the following method returns **true** if the first argument is divisible by the second, and **false** otherwise:

```
private boolean isDivisibleBy (int x, int y)
{
    return x % y == 0;
}
```

Notice that when `x` is evenly divisible by `y`, **true** is returned, otherwise **false** is returned — an `if` statement isn't required in this case.

Invoking **Predicate** Methods

- Once you have defined a predicate method, you can use it just like any other Boolean value.
- For example, you can print the integers between `low` and `high` that are divisible by 7 by running a `for` loop through the integers [`low..high`] and checking which are divisible by 7:

```
for (int i = low; i <= high; i++)
{
    if (isDivisibleBy(i, 7))
    {
       println(i);
    }
}
```

Notice that numbers which aren't divisible by 7 are simply ignored.

Using Predicate Methods Effectively

- While the following code is not incorrect, it is **inelegant**:

```
private boolean isDivisibleBy (int x, int y)
{
  if (x % y == 0)
  {
    return true;
  }
  else
  {
    return false;
  }
}
```

- A similar problem occurs when beginning programmers include an explicit comparison in an `if` statement to see if a predicate method returns `true`.

Avoid redundant tests such as this:

```
if (isDivisibleBy(i, 7) == true)
```

Method: Powers of Two

- The following method takes an integer n and returns **true** if n is a power of two, and **false** otherwise.
- The powers of 2 are: 1, 2, 4, 8, 16, 32, and so forth; numbers that are less than or equal to zero cannot be powers of two.

```
private boolean isPowerOfTwo (int n) {
    if (n < 1) return false;
    while (n > 1) {
      if (n % 2 == 1) return false;
      n /= 2;
    }
    return true;
}
```

- If **at any time** it is discovered that the value is **not** a power of 2, **false** is returned. If execution drops out of the loop, then the original number was a power of 2, and **true** is returned.

5.3 Mechanics of the Method–Calling Process

When you invoke a method the following actions occur:

- The **argument expressions** are **evaluated** (in the context of the calling method)
- Each **argument value** is **copied** into the **corresponding parameter variable**, which is allocated in a newly assigned region of memory called a **stack frame**.

  This **assignment follows the order** in which the arguments appear: the first argument is copied into the first parameter variable, and so on.

Mechanics of the Method–Calling Process, Cont.

- The statements in the **method body** are **evaluated** (using the new stack frame to look up the values of local variables).
- When a **return statement** is encountered, it **computes** the return value and **substitutes** that value in place of the original call.
- The stack frame for the called method is **discarded**, and execution is **returned** to the calling program, continuing from where it left off.

The Combinations Function

- To illustrate method calls, the text uses a function $C(n, k)$ that computes the **combinations** function — the number of ways one can select k elements from a set of n objects.
- Suppose, for example, that you have a set of five coins:

- How many ways are there to select two coins?

penny + nickel	nickel + dime	dime + quarter	quarter + dollar
penny + dime	nickel + quarter	dime + dollar	
penny + quarter	nickel + dollar		
penny + dollar			

for a total of 10 ways.

Combinations and Factorials

- Fortunately, mathematics provides an easier way to compute the combinations function than by counting out all the ways.
- The value of the combinations function is given by the formula:

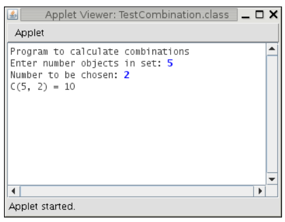
$$C(n, k) = \frac{n!}{k! \times (n-k)!}$$

- Given that we already have a `factorial()` method, it is easy to turn this formula directly into a Java method:

```
private int combinations (int n, int k)
{
    return factorial(n) /
               (factorial(k) * factorial(n-k));
}
```

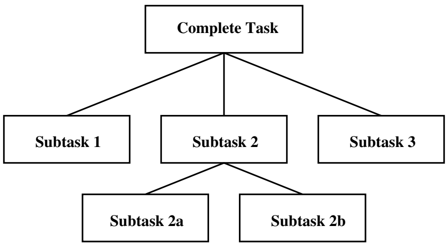

The Combinations Program

```
public void run()
{
  println("Program to calculate combinations");
  int num = readInt("Enter number objects in set: ");
  int chosen = readInt("Number to be chosen: ");
  println("C(" + num + ", " + chosen + ") = " +
                          combinations(num,chosen));
}
```



5.4 Decomposition

- One of the most important advantages of methods is that they make it possible to **break a large task down** into **successively simpler pieces**. This process is called **decomposition**.



- Once you have completed the decomposition, you can then write a method to **implement** each **subtask**.

Choosing a Decomposition Strategy

- One of the most subtle aspects of programming is the process of **deciding how to decompose** large tasks into smaller ones.
- In most cases, the best decomposition strategy for a program follows the structure of the real–world problem that program is intended to solve.
- If the problem seems to have natural **subdivisions**, those subdivisions usually provide a useful basis for designing the program decomposition.
- Each subtask in the decomposition should **perform a function** that is **easy to name and describe**.

Decomposition Goals

- One of the primary goals of decomposition is to **simplify the programming process**.
- A good decomposition strategy must **limit the spread of complexity**.
- Each level in the decomposition should **take responsibility** for **certain details**, and avoid having those details percolate up to higher levels.

  For example, in the program to calculate the combinations, the problem was broken down to utilize the `factorial()` method. Thus, the `combinations()` method was less cluttered and easier to read.

5.5 Algorithmic Methods

- **Methods** are important in programming because they provide a structure in which to express algorithms.
- **Algorithms** are abstract expressions of a solution strategy.
- **Implementing** an algorithm as a method makes that **abstract strategy concrete**.
- Algorithms for solving a particular problem can vary widely in their efficiency — it makes sense to think carefully when choosing an algorithm because making a bad choice can be extremely costly.

Greatest Common Divisor

- Section 5.5 in the text looks at two algorithms for computing the greatest common divisor of two integers.
- The GCD is defined to be the largest integer that divides evenly into both
- There is big difference in the **efficiency** of the two algorithms: **brute force** vs **Euclid's algorithm**.

Brute–Force Approach

- **Trying every possible solution** is called a **brute–force** strategy.
- For the greatest common divisor, we can count backwards from the smaller of the two numbers until we find a value that divides both numbers evenly.

```
public int gcd(int x, int y) {
   int guess = Math.min(x, y);
   while (x % guess != 0 || y % guess != 0)
   {
     guess--;
   }
   return guess;
}
```

- This `gcd()` algorithm **must terminate** for positive values of `x` and `y` because the value of **guess** will eventually reach 1 if it doesn't stop before that.
- At the point it terminates, **guess** must be the greatest common divisor because the `while` loop will have already tested all larger possibilities and discarded them.
- Note that in the worst case, when the `gcd(x, y)` is 1, the loop must iterate all the way from the smaller of the two numbers down to 1.
- Computing `gcd(1000005, 1000000)` results in **almost a million** steps to obtain the answer, **5**.

Euclid's Algorithm

- A better, more **efficient** algorithm can produce an answer more quickly.
- The mathematician Euclid of Alexandria described a more efficient algorithm 23 centuries ago:

```
public int gcd(int x, int y) {
   int r = x % y;
   while (r != 0)
   {
      x = y;
      y = r;
      r = x % y;
   }
   return y;
}
```

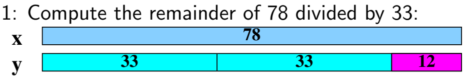
- Using Euclid's algorithm, the `gcd(1000005, 1000000)` takes **two** steps.

How Euclid's Algorithm Works

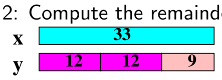
- Euclid's great insight was that the greatest common divisor of `x` and `y` must also be the greatest common divisor of `y` and the remainder when `x` is divided by `y`.
- He was able to prove this proposition in Book VII of his *Elements*
- The next slide works through the steps geometrically to illustrate the calculation when `x` is 78 and `y` is 33.

An Illustration of Euclid's Algorithm

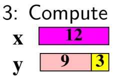
Step 1: Compute the remainder of 78 divided by 33:



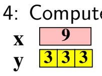
Step 2: Compute the remainder of 33 divided by 12:



Step 3: Compute the remainder of 12 divided by 9:



Step 4: Compute the remainder of 9 divided by 3:



Because there is no remainder, the answer is 3.

Graphics: Arguments *vs.* Named Constants

- In graphical programs there are **two** strategies for providing methods with size and location information:
  1. Use shared **named constants** to define the picture parameters
  2. Pass the information as **arguments** to each method
- Using named constants is easy, but relatively inflexible. If you define constants to specify the location of an object, you can only draw the object at that location.

- Using arguments is more cumbersome, but makes it easier to change such values.
- It is best to find an appropriate **trade–off** between the two approaches. The text recommends:
  - Use **arguments** when callers need to supply different values
  - Use **named constants** when there is a known satisfactory value