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Slides for the Methods Lecture

Methods

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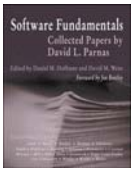

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Parnas's most influential contribution to software engineering is his groundbreaking 1972 paper "On the criteria to be used in decomposing systems into modules," which laid the foundation for modern structured programming. This paper appears in many anthologies and is available on the web at

`http://portal.acm.org/citation.cfm?id=361623`

A Quick Overview of Methods

- You have been working with methods ever since you wrote your first Java program in Chapter 2. The **`run`** method in every program is just one example. Most of the programs you have seen have used other methods as well, such as **`println`** and **`setColor`**.
- At the most basic level, a ***method*** is a sequence of statements that has been collected together and given a name. The name makes it possible to execute the statements much more easily; instead of copying out the entire list of statements, you can just provide the method name.
- The following terms are useful when learning about methods:
  - Invoking a method using its name is known as ***calling*** that method.
  - The caller can pass information to a method by using ***arguments***.
  - When a method completes its operation, it ***returns*** to its caller.
  - A method can pass information to the caller by ***returning a result***.

Methods and Information Hiding

- One of the most important advantages of methods is that they make it possible for callers to ignore the inner workings of complex operations.
- When you use a method, it is more important to know what the method does than to understand exactly how it works. The underlying details are of interest only to the programmer who implements a method. Programmers who use a method as a tool can usually ignore the implementation altogether.
- The idea that callers should be insulated from the details of method operation is the principle of ***information hiding***, which is one of the cornerstones of software engineering.

Methods as Tools for Programmers

- Particularly when you are first learning about programming, it is important to keep in mind that methods are not the same as application programs, even though both provide a service that hides the underlying complexity involved in computation.
- The key difference is that an application program provides a service to a *user*, who is typically not a programmer but rather someone who happens to be sitting in front of the computer. By contrast, a method provides a service to a *programmer*, who is typically creating some kind of application.
- This distinction is particularly important when you are trying to understand how the applications-level concepts of input and output differ from the programmer-level concepts of arguments and results. Methods like **`readInt`** and **`println`** are used to communicate with the user and play no role in communicating information from one part of a program to another.

Method Calls as Expressions

- Syntactically, method calls in Java are part of the expression framework. Methods that return a value can be used as terms in an expression just like variables and constants.
- The **`Math`** class in the **`java.lang`** package defines several methods that are useful in writing mathematical expressions. Suppose, for example, that you need to compute the distance from the origin to the point (x, y), which is given by

$$\sqrt{x^2 + y^2}$$

  You can apply the square root function by calling the **`sqrt`** method in the **`Math`** class like this:

```
double distance = Math.sqrt(x * x + y * y);
```

- Note that you need to include the name of the class along with the method name. Methods like **`Math.sqrt`** that belong to a class are called ***static methods***.

Useful Methods in the `Math` Class

`Math.abs(`*x*`)`	Returns the absolute value of *x*
`Math.min(`*x*`, `*y*`)`	Returns the smaller of *x* and *y*
`Math.max(`*x*`, `*y*`)`	Returns the larger of *x* and *y*
`Math.sqrt(`*x*`)`	Returns the square root of *x*
`Math.log(`*x*`)`	Returns the natural logarithm of *x* ($\log_e x$)
`Math.exp(`*x*`)`	Returns the inverse logarithm of *x* (e^x)
`Math.pow(`*x*`, `*y*`)`	Returns the value of *x* raised to the *y* power (x^y)
`Math.sin(`*theta*`)`	Returns the sine of *theta*, measured in radians
`Math.cos(`*theta*`)`	Returns the cosine of *theta*
`Math.tan(`*theta*`)`	Returns the tangent of *theta*
`Math.asin(`*x*`)`	Returns the angle whose sine is *x*
`Math.acos(`*x*`)`	Returns the angle whose cosine is *x*
`Math.atan(`*x*`)`	Returns the angle whose tangent is *x*
`Math.toRadians(`*degrees*`)`	Converts an angle from degrees to radians
`Math.toDegrees(`*radians*`)`	Converts an angle from radians to degrees

Method Calls as Messages

- In object-oriented languages like Java, the act of calling a method is often described in terms of ***sending a message*** to an object. For example, the method call

```
rect.setColor(Color.RED);
```

  is regarded metaphorically as sending a message to the `rect` object asking it to change its color.

- The object to which a message is sent is called the ***receiver***.
- The general pattern for sending a message to an object is

```
receiver.name(arguments);
```

Writing Your Own Methods

- The general form of a method definition is

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

  where *visibility* indicates who has access to the method, *type* indicates what type of value the method returns, *name* is the name of the method, and *argument list* is a list of declarations for the variables used to hold the values of each argument.
- The usual setting for *visibility* is `private`, which means that the method is available only within its own class. If other classes need access to it, *visibility* should be `public` instead.
- If a method does not return a value, *type* should be `void`. Such methods are sometimes called ***procedures***.

Returning Values from a Method

- You can return a 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 you want to return.
- As an example, the method definition

```
private double feetToInches(double feet) {
   return 12 * feet;
}
```

  converts an argument indicating a distance in feet to the equivalent number of inches, relying on the fact that there are 12 inches in a foot.

Methods Involving Control Statements

- The body of a method can contain statements of any type, including control statements. As an example, the following method uses an `if` statement to find the larger of two values:

```
private int max(int x, int y) {
   if (x > y) {
      return x;
   } else {
      return y;
   }
}
```

- As this example makes clear, `return` statements can be used at any point in the method and may appear more than once.

The `factorial` Method

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

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

Nonnumeric 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";
   }
}
```

Methods Returning Graphical Objects

- The text includes examples of methods that return graphical objects. The following method creates a filled circle centered at the point (**x**, **y**), with a radius of **r** pixels, which is filled using the specified color:

```
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 Boolean values 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;
}
```

- 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 1 and 100 that are divisible by 7 as follows:

```
for (int i = 1; i <= 100; i++) {
   if (isDivisibleBy(i, 7)) {
      println(i);
   }
}
```

Using Predicate Methods Effectively

- New programmers often seem uncomfortable with Boolean values and end up writing ungainly code. For example, a beginner might write **isDivisibleBy** like this:

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

While this code is not technically incorrect, it is inelegant enough to deserve the bug symbol.

Using Predicate Methods Effectively

- A similar problem occurs when novices explicitly check to see if a predicate method returns **true**. You should be careful to avoid such redundant tests in your own programs.

```
for (int i = 1; i <= 100; i++) {
   if (isDivisibleBy(i, 7) == true) {
      println(i);
   }
}
```

Mechanics of the Method-Calling Process

When you invoke a method, the following actions occur:

1. Java evaluates the argument expressions in the context of the calling method.
2. Java then copies each argument value 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.
3. Java then evaluates the statements in the method body, using the new stack frame to look up the values of local variables.
4. When Java encounters a **return** statement, it computes the return value and substitutes that value in place of the call.
5. Java then discards the stack frame for the called method and returns to the caller, 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, which is 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: a penny, a nickel, a dime, a quarter, and a dollar:

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 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 you already have a **`factorial`** method, is easy to turn this formula directly into a Java method, as follows:

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

- The next slide simulates the operation of **`combinations`** and **`factorial`** in the context of a simple **`run`** method.

The `Combinations` Program

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

120 2 6

n	k
5	2

```
Combinations
Enter number of objects in the set (n): 5
Enter number to be chosen (k): 2
C(5, 2) = 10
```

Exercise: Finding Perfect Numbers

- Greek mathematicians took a special interest in numbers that are equal to the sum of their proper divisors (a proper divisor of n is any divisor less than n itself). They called such numbers ***perfect numbers***. For example, 6 is a perfect number because it is the sum of 1, 2, and 3, which are the integers less than 6 that divide evenly into 6. Similarly, 28 is a perfect number because it is the sum of 1, 2, 4, 7, and 14.
- For the rest of this class, we're going to design and implement a Java program that finds all the perfect numbers between two limits. For example, if the limits are 1 and 10000, the output should look like this:

```
FindPerfect
The perfect numbers between 1 and 10000 are:
6
28
496
8128
```