Methods

CSE160, Computer Science A: Honors
Stony Brook University

http://www.cs.stonybrook.edu/~cse160
Opening Problem

Find multiple sums of integers:
- from 1 to 10,
- from 20 to 30,
- from 35 to 45,
...

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Opening Problem

- Repeat code:

```java
int sum = 0;
for (int i = 1; i <= 10; i++)
    sum += i;
System.out.println("Sum from 1 to 10 is " + sum);

sum = 0;
for (int i = 20; i <= 30; i++)
    sum += i;
System.out.println("Sum from 20 to 30 is " + sum);

sum = 0;
for (int i = 35; i <= 45; i++)
    sum += i;
System.out.println("Sum from 35 to 45 is " + sum);
```
Opening Problem Solution

- Use a method!

```java
public static int sum(int i1, int i2) {
    int sum = 0;
    for (int i = i1; i <= i2; i++)
        sum += i;
    return sum;
}

public static void main(String[] args) {
    System.out.println("Sum from 1 to 10 is " + sum(1, 10));
    System.out.println("Sum from 20 to 30 is " + sum(20, 30));
    System.out.println("Sum from 35 to 45 is " + sum(35, 45));
}
```
Why write methods?

- To shorten your programs
  - avoid writing identical code twice or more
- To modularize your programs
  - fully tested methods can be trusted
- To make your programs more:
  - readable
  - reusable
  - testable
  - debuggable
  - extensible
  - adaptable
Rule of thumb

• If you have to perform some operation in more than one place inside your program, make a new method to implement this operation and have other parts of the program use it.
Defining Methods

- A *method* is a collection of statements that are grouped together to perform an operation.

```java
public static int max(int num1, int num2) {
    int result;
    if (num1 > num2) {
        result = num1;
    } else {
        result = num2;
    }
    return result;
}
```

**Define a method**

**Invoke a method**

```java
int z = max(x, y);
```
Method Signature

- **Method signature** is the combination of the method name and the parameter list.

```java
public static int max(int num1, int num2) {
    int result;
    if (num1 > num2) {
        result = num1;
    } else {
        result = num2;
    }
    return result;
}
```

```
int z = max(x, y);
```

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Formal Parameters

- The variables defined in the method header are known as *formal parameters*.
Actual Parameters

• When a method is invoked, you pass a value to the parameter: *actual parameter or argument*.
Return Value Type

• A method may return a value.

• The \textit{returnValueType} is the data type of the value the method returns
  • If the method does not return a value, the \textit{returnValueType} is the keyword \texttt{void}.

```
public static int \texttt{max}(int \texttt{num1}, int \texttt{num2}) {
  int \texttt{result};
  if (\texttt{num1} > \texttt{num2})
    \texttt{result} = \texttt{num1};
  else
    \texttt{result} = \texttt{num2};
  \texttt{return} \texttt{result};
}
```

Invoke a method

```
\texttt{int} \texttt{z} = \texttt{max}(x, y);
```

actual parameters (arguments)

(modifier \texttt{public static} \texttt{int} \texttt{max}(\texttt{int} \texttt{num1}, \texttt{int} \texttt{num2}) \{ \texttt{int} \texttt{result}; \texttt{if} (\texttt{num1} > \texttt{num2}) \texttt{result} = \texttt{num1}; \texttt{else} \texttt{result} = \texttt{num2}; \texttt{return} \texttt{result}; \})
Calling Methods

```java
public static void main(String[] args) {
    int i = 5;
    int j = 2;
    int k = max(i, j);

    System.out.println("The maximum between " + i + " and " + j + " is " + k);
}
```

```java
public static int max(int num1, int num2) {
    int result;
    if (num1 > num2)
        result = num1;
    else
        result = num2;

    return result;
}
```

pass the value of i
pass the value of j

public static void main(String[] args) {
    int i = 5;
    int i = 2;
    int k = max(i, i);

    System.out.println(
        "The maximum between " + i + " and " + i + " is " + k);
}

public static int max(int num1, int num2) {
    int result;

    if (num1 > num2)
        result = num1;
    else
        result = num2;

    return result;
}
j is now 2

```java
public static void main(String[] args) {
    int i = 5;
    int j = 2;
    int k = max(i, j);
    System.out.println("The maximum between " + i + " and " + j + " is " + k);
}

public static int max(int num1, int num2) {
    int result;
    if (num1 > num2)
        result = num1;
    else
        result = num2;
    return result;
}
```
Trace Method Invocation

```
public static void main(String[] args) {
    int i = 5;
    int j = 2;
    int k = max(i, j);

    System.out.println("The maximum between " + i + " and " + i + " is " + k);
}
```

```
public static int max(int num1, int num2) {
    int result;
    if (num1 > num2)
        result = num1;
    else
        result = num2;

    return result;
}
```
Trace Method Invocation

invoke max(i, j)
Pass the value of i to num1
Pass the value of j to num2

public static void main(String[] args) {
    int i = 5;
    int i = 2;
    int k = max(i, i);
    System.out.println("The maximum between " + i + " and " + i + " is " + k);
}

public static int max(int num1, int num2) {
    int result:
    if (num1 > num2)
        result = num1;
    else
        result = num2:
    return result:
}
Trace Method Invocation

declare variable result

```java
public static void main(String[] args) {
    int i = 5;
    int j = 2;
    int k = max(i, j);
    System.out.println("The maximum between " + i + " and " + j + " is " + k);
}
```

```java
public static int max(int num1, int num2) {
    int result;
    if (num1 > num2)
        result = num1;
    else
        result = num2;
    return result;
}
```
Trace Method Invocation

(num1 > num2) is true since num1 is 5 and num2 is 2

public static void main(String[] args) {
    int i = 5;
    int j = 2;
    int k = max(i, j);

    System.out.println(
        "The maximum between " + i + " and " + j + " is " + k);
}

public static int max(int num1, int num2) {
    int result;
    if (num1 > num2)
        result = num1;
    else
        result = num2;

    return result;
}
Trace Method Invocation

```java
public static void main(String[] args) {
    int i = 5;
    int j = 2;
    int k = max(i, j);

    System.out.println("The maximum between " + i + " and " + j + " is " + k);
}

public static int max(int num1, int num2) {
    int result;
    if (num1 > num2) {
        result = num1;
    } else {
        result = num2;
    }
    return result;
}
```

result is now 5
public static void main(String[] args) {
    int i = 5;
    int i = 2;
    int k = max(i, i);

    System.out.println("The maximum between " + i + " and " + i + " is " + k);
}

public static int max(int num1, int num2) {
    int result;
    if (num1 > num2) {
        result = num1;
    } else {
        result = num2;
    }

    return result;
}
return max(i, j) and assign the return value to k

```java
public static void main(String[] args) {
    int i = 5;
    int j = 2;
    int k = max(i, j);
    System.out.println("The maximum between " + i + " and " + i + " is " + k);
}
```

```java
public static int max(int num1, int num2) {
    int result;
    if (num1 > num2)
        result = num1;
    else
        result = num2;
    return result;
}
```
**Trace Method Invocation**

Execute the print statement

```java
public static void main(String[] args) {
    int i = 5;
    int j = 2;
    int k = max(i, j);

    System.out.println("The maximum between \" + i + \" and \" + j + \" is \" + k);
}
```

```java
public static int max(int num1, int num2) {
    int result:
    if (num1 > num2)
        result = num1;
    else
        result = num2;
    return result;
}
```
Benefits of Methods

- Write a method once and reuse it anywhere
- Information hiding:
  - Hide the implementation from the user
  - Reduces complexity of the whole program
Method Abstraction

API = the method body is a black box that contains the detailed implementation for the method

Diagram:
- Method Header
- Method body (black box)
- Optional arguments for input
- Optional return value

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Javadoc

• Generate Javadoc for your project in Eclipse with:

1. Project -> Generate Javadoc
2. In the "Javadoc command" field - browse to find javadoc.exe
   • On the computers in the lab that is C:\Program Files\Java\jdk1.8.0\bin\javadoc.exe
   • On other computers it would be <path_to_jdk_directory>\bin\javadoc.exe
3. Check the box next to the project/package/file for which you are creating the javadoc
4. In the "Destination" field browse to find the desired destination (for example, the doc directory of the current project).
5. Leave everything else as it is.
6. Click "Finish" and open "index.html"
Class pattern

java.lang.Object

public class pattern
extends java.lang.Object
CAUTION: all execution paths

- A return statement is required for a value-returning method
- The method shown below has a compilation error because the Java compiler thinks it possible that this method does not return any value

```
public static int sign(int n) {
    if (n > 0)
        return 1;
    else if (n == 0)
        return 0;
    else if (n < 0)
        return -1;
}
```

To fix this problem, delete `if (n < 0)` in (a), so that the compiler will see a return statement to be reached regardless of how the if statement is evaluated.
Call Stacks

Methods are executed using a stack data structure

(a) The main method is invoked.

(b) The max method is invoked.

(c) The max method is being executed.

(d) The max method is finished and the return value is sent to k.

(e) The main method is finished.
public static void main(String[] args) {
    int i = 5;
    int i = 2;
    int k = max(i, i);
    System.out.println("The maximum between " + i + ", " + i + " is " + k);
}

public static int max(int num1, int num2) {
    int result;
    if (num1 > num2)
        result = num1;
    else
        result = num2;
    return result;
}
Trace Call Stack

j is declared and initialized

```java
public static void main(String[] args) {
    int i = 5;
    int j = 2;
    int k = max(i, j);

    System.out.println(
        "The maximum between " + i + " and " + j + " is " + k);
}

public static int max(int num1, int num2) {
    int result:
    if (num1 > num2)
        result = num1:
    else
        result = num2:

    return result:
}
```

The main method is invoked.
Trace Call Stack

```
public static void main(String[] args) {
    int i = 5;
    int j = 2;
    int k = max(i, i);

    System.out.println(
        "The maximum between " + i + 
        " and " + i + " is " + k);
}
```

```
public static int max(int num1, int num2) {
    int result:
    if (num1 > num2)
        result = num1:
    else
        result = num2:
    return result:
}
```
Trace Call Stack

The main method is invoked.
Space required for the main method
k: 
j: 2
i: 5

```
public static void main(String[] args) {
    int i = 5;
    int j = 2;
    int k = max(i, i);

    System.out.println("The maximum between " + i + " and " + i + " is " + k);
}

public static int max(int num1, int num2) {
    int result:
    if (num1 > num2)
        result = num1:
    else
        result = num2:
    return result:
}
```

Invoke max(i, j)
Trace Call Stack

```java
public static void main(String[] args) {
    int i = 5;
    int j = 2;
    int k = max(i, j);
    System.out.println(
        "The maximum between " + i + 
        " and " + i + " is " + k);
}
```

```java
public static int max(int num1, int num2) {
    int result:
    if (num1 > num2)
        result = num1:
    else
        result = num2:
    return result;
}
```

pass the values of i and j to num1 and num2

The max method is invoked.

Space required for the main method
```
num1: 5
num2: 2
```

k: 
j: 2
i: 5
public static void main(String[] args) {
    int i = 5;
    int j = 2;
    int k = max(i, j);

    System.out.println("The maximum between " + i + " and " + j + " is " + k);
}

public static int max(int num1, int num2) {
    int result:
    if (num1 > num2)
        result = num1:
    else
        result = num2:
    return result:
}
Trace Call Stack

```
public static void main(String[] args) {
    int i = 5;
    int j = 2;
    int k = max(i, j);

    System.out.println("The maximum between " + i + " and " + j + " is " + k);
}

public static int max(int num1, int num2) {
    int result:
    if (num1 > num2)
        result = num1:
    else
        result = num2:
    return result:
}
```

(num1 > num2) is true

Space required for the main method
- k: 2
- j: 2
- i: 5

The max method is invoked.

result:
- num2: 2
- num1: 5
public static void main(String[] args) {
    int i = 5;
    int j = 2;
    int k = max(i, j):

    System.out.println(
        "The maximum between " + i + 
        " and " + i + " is " + k):
    }

public static int max(int num1, int num2) {
    int result:

    if (num1 > num2)
        result = num1;
    else
        result = num2;

    return result:
}
public static void main(String[] args) {
    int i = 5;
    int j = 2;
    int k = max(i, j);

    System.out.println("The maximum between "+ i + " and "+ j + " is "+ k);
}

public static int max(int num1, int num2) {
    int result;

    if (num1 > num2)
        result = num1;
    else
        result = num2;

    return result;
}
The main method is invoked. Space required for the main method:

- k: 5
- j: 2
- i: 5

Trace Call Stack

```java
public static void main(String[] args) {
    int i = 5;
    int j = 2;
    int k = max(i, i);

    System.out.println("The maximum between " + i + " and " + i + " is " + k);
}

public static int max(int num1, int num2) {
    int result:

    if (num1 > num2)
        result = num1;
    else
        result = num2;

    return result;
}
```
Call-by-value

• Method formal arguments are *copies of the original data*.

• Consequence?
  *methods cannot assign ("=") new values to primitive type formal arguments and affect the original passed variables.*

• Why?
  *changing argument values changes the copy, not the original.*
The main method

is invoked

The swap method

is invoked

The swap method

is finished

The main method

is finished

public static void main(String[] args) {
    int n1 = 1;
    int n2 = 2;
    faulty_swap(n1, n2);
    System.out.println("n1=" + n1); // still 1
    System.out.println("n2=" + n2); // still 2
}

public static void faulty_swap(int num1, int num2) {
    int temp = num1;
    num1 = num2;
    num2 = temp;
}

The values of num1 and num2 are passed to n1 and n2. Executing swap does not affect num1 and num2.
Overloading

• Same method name, but with different type or number of parameters:

```java
public static int plus(int i, int j) {
    return i + j;
}
public static double plus(double x, double y) {
    return x + y;
}
public static String plus(String s1, String s2) {
    return s1 + s2;
}
public static void main(String[] args) {
    System.out.println(plus(1,2));  // 3
    System.out.println(plus(1.0,2.0));  // 3.0
    System.out.println(plus("a","b"));  // "ab"
}
```
Overloading

• Example 2:

```java
public static int plus(int i, int j, int k) {
    return i + j + k;
}
public static int plus(int i, int j) {
    return i + j;
}
public static void main(String[] args) {
    System.out.println(plus(1,2,3));  // 6
    System.out.println(plus(1,2));    // 3
}
```

• The correct method is found using the type and number of the input parameters (a process called *method matching*)
Overloading & Ambiguous Invocation

- Sometimes there may be two or more possible matches for an invocation of a method, but the compiler cannot determine the most specific match - this is referred to as *ambiguous invocation*

- Ambiguous invocation is a compilation error

```java
public static void main(String[] args) {
    System.out.println(max(1, 2)); // Compiler Error
}
public static double max(int num1, double num2) {
    if (num1 > num2)
        return num1;
    else
        return num2;
}
public static double max(double num1, int num2) {
    if (num1 > num2)
        return num1;
    else
        return num2;
}
```
Scope of Local Variables

- A **local variable**: a variable defined inside a method
- **Scope**: the part of the program where the variable can be referenced
  - In Java, the scope of a local variable starts from its declaration and continues to the end of the block that contains the variable
- A nested block cannot redefine a local variable:

```java
public static void correctMethod() {
    int x = 1;
    int y = 1;
    for (int i = 1; i < 10; i++) {
        int x = 0; // error
        x += i;
    }
}
```
Stepwise Refinement

- The concept of method abstraction can be applied to the process of developing programs.
  - When writing a large program, you can use the “divide and conquer” strategy, also known as *stepwise refinement*, to decompose it into sub-problems.
  - The sub-problems can be further decomposed into smaller, more manageable problems.
- For example, consider a `PrintCalendar` program:

![PrintCalendar Output](image)
Design Diagram

printCalendar
(main)

readInput

printMonth

printMonthTitle

printMonthBody

getNumOfDaysInMonth

getMonthName

isLeapYear

getTotalNumOfDays

gerStartDay

printMonthTitle

printMonthBody

Design Diagram
Design Diagram

printCalendar
(main)

readInput

printMonth

printMonthTitle

getMonthName

printMonthBody

getStartDay

getNumOfDaysInMonth

getMonthName

isLeapYear
Implementation: Top-Down

- The **top-down** approach is to implement one method in the structure chart at a time **from the top to the bottom**
  - A **stub** is a simple but incomplete version of a method. Stubs can be used for the methods waiting to be implemented.

```java
/** A stub for getStartDay may look like this */
public static int getStartDay(int year, int month) {
    return 1; // A dummy value
}
```

- The use of stubs enables you to test invoking the method from a caller.
- Implement the main method first and then use a stub for the `printMonth` method
  - Then implement the complete methods
Implementation: Bottom-Up

• **Bottom-up** approach is to implement one method in the structure chart at a time **from the bottom to the top**
  • For each method implemented, write a test program to test only that method

• Both top-down and bottom-up methods are fine.
  • Both approaches implement the methods incrementally and help to isolate programming errors and makes debugging easy.
  • Most of the time, they are used together
Benefits of Stepwise Refinement

• Simpler Program
• Reusing Methods
• Easier Developing, Debugging, and Testing
• Better Facilitating Teamwork