Methods: Functional Abstraction

- Structured Programming
  - The flow of control in a program should be as simple as possible
  - The construction of a program should embody top-down design
- Top-Down Design
  - Repeatedly decompose a problem into smaller subproblems
    - Each decomposition is an algorithm
  - Eventually, smallest subproblems are directly solvable

Example

- Problem: Play tic-tac-toe
  1. Find the best move
  2. Make that move
  3. Wait for the other player to move
  4. Go to step 1
- Find the best move
  1. If there is a winning move, choose it
  2. If there is a blocking move, choose it
  3. If there is a move that leads to a win, choose it
  4. Etc.

Method Invocation

- A simple program contains one or more methods, including
  - main(), where program execution begins
- When program control encounters a method name followed by (), it is *called* or *invoked*
  - Program control passes to the called method
  - When the called method is finished executing, program control returns to the calling method, where program execution continues

```java
// Message.java: Simple method use
class Message {
   public static void main(String [ ] args){
      System.out.println("HELLO DEBRA!");
      printMessage();                              //method call
      System.out.println("Goodbye.");
   }

   // definition of method printMessage
   static void printMessage(){
      System.out.println("A message for you:");
      System.out.println("Have a nice day!\n");
   }
}
```

Static Method Definition

public static *<returntype>* *<Ident>* (<p*aramlist*>)<*block*>

- public static – trust me for now
- <returntype> The type of data returned by the method
  - void means nothing is returned
- <ident> - the method name
- <paramlist> - list of inputs to the method
- <block> - the code that will get executed when the method is invoked

Details

- Parameters
  - Values passed from the calling function to the called function
  - Act like variables inside the called function
- Body of the method (<block>)
  - Variable declarations and statements that are executed when the method is called

```
// Message.java: Simple method use, w/parameters
class Message {
   public static void main(String [ ] args){
      System.out.println("HELLO DEBRA!");
      printMessage("Testing");                    //method call
      System.out.println("Goodbye.");
   }

   // definition of method printMessage
   static void printMessage(String msg){
      System.out.println(msg);
      System.out.println("Have a nice day!\n");
   }
}
```

The return Statement

- Returns program control to the calling method
- May return a value of the appropriate type

```
return;
return a;
return (a + b);
return “error!”;
```

- A method can have zero or more return statements
  - Control returns to the calling method as soon as one is reached
  - If no return statement is reached, control returns

```java
// Min2.java -return expression in a method
class Min2 {

  public static void main(String [ ] args){
    int j =78, k =3 *30, m;
    System.out.println("Minimum of two integers Test:");
    m =min(j,k);
    System.out.println("The minimum of :“ +j +","+k +"is "+m);
  }

  // FInd the smaller of two integers
  static int min(int a,int b){
    if (a <b)
      return a;
    else
      return b;
  }
}
```

Scope of Variables

- The *scope* of a variable is the range of statements that can access it
- Any variable declared within a method is a *local* variable
  - Created anew each time the method is called
  - Cease to exist after the method finishes executing
  - scope: any statement after the declaration and before the end of the block in which it is declared
    - The scope of variables declared in the initialization portion of a for loop includes the boolean expression, update expression, and the loop body

```
//Min2Bad.java -doesn't work because of scope
class Min2Bad {
    public static void main(String [ ] args){
        int j =78,k =3 *30,m;

        System.out.println("Minimum of two integers Test:");
        m =min();
        System.out.println("The minimum of :“ +j +","+k +"is "+m);
    }

    static int min() {
        if (j <k)
            return j;
        else
            return k;
    }
}
```

Example of Top-Down Design

- Problem: *Find the relative areas of a unit circle and a unit square*
- One way to do this:
  - Dartboard with a square with a circle inside
  - Throw darts blindfolded and count the number that fall inside the circle and divide by the total number thrown
  - Or, by simulating the dartboard, generate random numbers representing dart locations

Algorithm

1. Find out the number of trials to execute
2. Execute the specified number of trials
3. Calculate the relative areas
4. Output the results

1. Find out the number of trials to execute

1. Ask the user how many trials to execute
2. Store the number in a local variable

2. Execute the specified number of trials

1. Set i equal to zero
2. If i is less than the number of trials
   1. Execute a trial
   2. Record the result
   3. Increment i
   4. Repeat

Execute a trial

1. Generate two random numbers x and y, between 0 and 1
2. See if (x,y) lies within the unit circle centered at (1/2,1/2)
3. If so, return true
4. Otherwise, return false

3. Calculate the relative areas

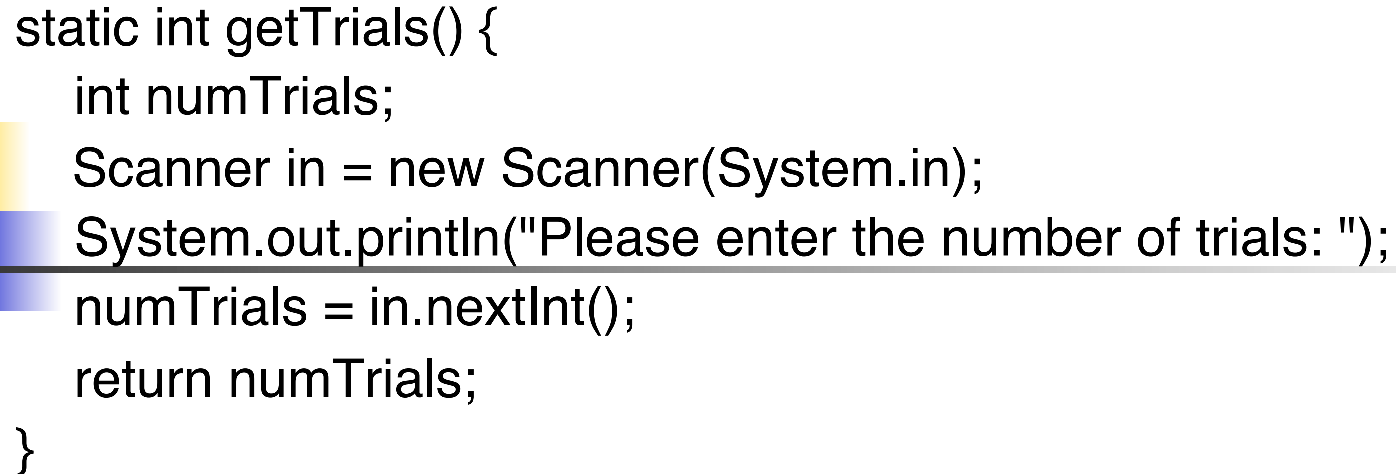
1. Divide the number of successful trials by the total number of trials
2. Return the result

```
// Calculate the percentage of a unit square taken up by a unit
    circle
class RelativeAreas {
    public static void main(String[] args) {
        int count, successful;
        double ratio;

        // Find out the number of trials to execute
        count = getTrials();

        // Execute the specified number of trials
        successful = executeTrials(count);

        // Calculate and output the relative areas
       printResults(successful, count);
}
```



```
static int getTrials() {
    int numTrials;
    Scanner in = new Scanner(System.in);
    System.out.println("Please enter the number of trials: ");
    numTrials = in.nextInt();
    return numTrials;
}

static int executeTrials(int numLoops)  {
    int count = 0;

    for(int i = 0; i < numLoops; i++) {
        if(oneTrial() ==  true)
            count++;
    }
    return count;
}
```

```
static boolean oneTrial() {
    double x, y;
    double distance;

    x = Math.random();
    y = Math.random();
    distance =  Math.sqrt( (0.5 - x)*(0.5 - x) + (0.5 - y)*(0.5 - y) );

    return (distance <= 0.5);
}

static void printResults(int successful, int count) {
    double ratio;

     ratio = (double)successful / count;
    System.out.println(“Percentage = “ + ratio * 100);
}
}
```

Invocation and Call-by-Value

- To call one method from another method in the same class
  - Write the name of the method, and
  - a list of arguments in parentheses
- The arguments have to match in number and type those listed in the method definition
- Each argument is evaluated, and its value is used to initialize the corresponding formal parameter in the method invocation
  - Changing the value of a parameter in a method does not change the value of the thing passed to it!

```
// FailedSwap.java -Call-By-Value test
class FailedSwap {
    public static void main(String [ ] args){
        int numOne =1,numTwo =2;
        swap(numOne,numTwo);
        System.out.println("numOne ="+numOne);
        System.out.println("numTwo ="+numTwo);
    }
    static void swap(int x,int y) {
        int temp;
        System.out.println("x ="+x);
        System.out.println("y ="+y);
        temp = x;
        x = y;
        y = temp;
        System.out.println("x ="+x);
        System.out.println("y ="+y);
    }
}
```

21 Pickup

- Two-player game
- Start with a pile of 21 stones
- Players take turns removing 1,2,or 3 stones from the pile
- The player that removes the last stone wins

Recall: Software Life Cycle

- Requirements analysis and definition
- Design
- Implementation
- Testing
- Maintenance

Requirements Questions

- What is the role of the computer?
  - Will it be one of the players or will it simply enforce the rules and display the progress of a game between two human players?
- What will be the interface between the human being and the computer?
  - Graphical user interface or simple text display?
- Does the program play a sequence of games, keeping track of the number of games won by the various players, or does the program play one game and then exit?

Requirements Answers

- What is the role of the computer?
  - It will be one of the players
- What will be the interface between the human being and the computer?
  - Simple text display
- Does the program play a sequence of games, keeping track of the number of games won by the various players, or does the program play one game and then exit?
  - One game at a time

Algorithm: 21 Pickup

1. Print the instructions
2. Create the initial pile of 21 stones
3. While there are stones left
   1. Ask the user or computer for their move (depending on whose turn it is)
   2. Remove their stones from the pile
   3. Print out the status

Algorithm: Have the User Move

1. Prompt the user for the user's next move
2. From the keyboard, read the number of stones to remove
3. While the number read is not a legal move
    1. Prompt the user again
    2. Read the number of stones to remove
4. Return the number of stones to remove

Algorithm: Have the Computer Move

1. Compute number of stones for the computer to remove

   Version 1: Random

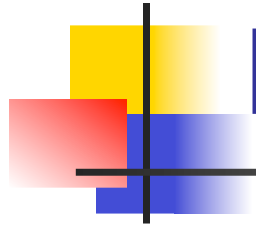
   Version 2:

   1. If three or fewer stones remain, pick them all up.
   2. If more than three stones remain, try to leave the pile with a number of stones that is a multiple of four.
   3. Otherwise, remove just one stone.

2. Print the computer's move on the screen
3. Return that number

Methods Needed

- public static void main(String[] args)
  - Play the game
- static void printInstructions()
  - Print instructions
- static void printWinner(int turn)
  - Print the winner (based on whose turn it is)
- static int getUserMove(int numberOfStones)
  - Get the user's move
- static int getComputerMove(int numberOfStones)
  - Get the computer's move



Let’s implement it!

Testing

- At a minimum you want to
  - Execute every instruction at least once
  - Take every branch at least once
  - Try every possible valid input
  - Try every possible type of invalid input
- This isn’t always possible
  - NORAD
  - Do the best you can

Recursion

- When a method calls itself, this is referred to as *recursion*
- Recursion can be confusing, but is extremely powerful
- Often used when a mathematical operation is defined in terms of other values of itself
  - Examples: factorials, fibonacci numbers, …

Recursive Methods

- Recursive methods have three parts
  - A part that does something
  - A part that calls the method
  - A part that does not call the method
    - Otherwise it would go forever
    - There is a test to decide whether or not to call the method again

Form of a Recursive Function

```
public static <type>
   recursiveMethod(<args>) {
    <whatever>
    if(<stopping condition>)
        <whatever you do at the end>
    else
        recursiveMethod(<different args>);
}
```

Example: Factorial

- n! = n * (n-1) * (n-2) * ... * 2 * 1
- n! = n * (n-1)!
- Recall: 0! = 1 and 1! = 1

```
public static int factorial(int n) {
    if(n <= 1)
        return 1;
    else
        return (n * factorial(n-1));
}
```

Example: Factorial (cont.)

- Suppose we execute factorial(4)
  - main calls factorial(4) <a>
  - <a> calls factorial(3) <b>
  - <b> calls factorial(2) <c>
  - <c> calls factorial(1) <d>
  - <d> returns 1
  - <c> returns 2 * 1 (= 2)
  - <b> returns 3 * 2 (= 6)
  - <a> returns 4 * 6 (= 24)
  - and that is the answer: 24

Example: Fibonacci numbers

- Each Fibonacci numbers is defined as the sum of the two previous fibonacci numbers
- fibonacci(n) = fibonacci(n-1) + fibonacci(n-2)
- fibonacci(0) = 1, fibonacci(1) = 1

```
public static int fibonacci(int n) {
    if(n <= 1)
        return 1;
    else
        return (fibonacci(n-1) + fibonacci(n-2));
}
```

Example: Fibonacci (cont.)

- Suppose we execute fibonacci(3)
  - main calls fibonacci(3) <a>
  - <a> calls fibonacci(2) <b> and fibonacci(1) <c>
  - <b> calls fibonacci(1) <f> and fibonacci(0) <g>
  - <f> returns 1
  - <g> returns 1
  - <c> returns 1
  - <b> returns 2
  - <a> returns 3
  - and that is the answer: 3

Recursion Wrapup

- Recursion is appropriate for any mathematical function that can be defined in terms of previous values of itself:
  - $f(x) = g(f(y))$, where $y < x$
- Examples:
  - Exponential: $x^n = x * x^{n-1}$

Example: Mathematical Functions

- Often want to know the zero crossings of a function - the values of x for which f(x) = 0
- This example doesn't illustrate any specific point having to do with methods, but does bring up lots of useful things to discuss
- We will examine two possible solutions
  - Linear search
  - Binary search

```
class SimpleFindRoot {
    public static void main(String [ ] args){
        double a = 0.0, b = 10.0, x = a, step = 0.001;

        while( f(x) != 0.0 && x < b )
            x =x +step;

        if (x < b)
            System.out.println("root is "+x);
        else
            System.out.println("root not found");
    }
    static double f(double x){return (x *x -2.0);}
}
```

```
class FindRoot {
   public static void main(String [ ] args){
double a=0.0, b=10.0, eps=0.00001, root =0.0, residual;
      while (b - a > eps ){
         root = (a + b) / 2.0;
         residual = f(root);
         if( residual > 0 )
            b = root;
         else
            a =root;
      }
      System.out.println("root is "+root);
   }
   static double f(double x){return (x *x -2.0);}
}
```

Method Overloading

- Simple idea: The method called is determined by:
  - the name of the method, and
  - the number and type of parameters in the call
- So, two methods can have the same name as long as they have different numbers and/or types of parameters

```
static int min(int s, int t) {
    if(s < t)
        return s;
    else
        return t;
}
static double min(double s, double t) {
    if(s < t)
        return s;
    else
        return t;
}
```

```
public static void main(String[] args) {
    double a,b,c;
    int w,x,y,z;
    c = min(a,b);
    z = min(x,y);
    w = min(a,y);
  }
```

Other examples of method overloading

- System.out.println()
- ...

Applets

- Graphical java programs
- Have no “main()” method
- Run inside a viewer or browser
  - appletViewer

```
appletViewer FirstApplet.java
```

  - In a web page

```
<applet code="FirstApplet.class" width=500
  height=200></applet>
```

FirstApplet.java

- paint() method instead of main()
- Parameter: Graphics object
  - Supports drawing methods (see javadoc)

AppletSum.java

DrawChairs.java