CSE 143

Computer Programming II

Recursive Programming

```
public static void solveProblem() {
    solveProblem();
}
```

Outline

1 Writing Recursive Functions

hasX

Implement a function

```
public static boolean hasX(String s)
```

which returns true if there is an `'x'` in `s`, and false otherwise. You may not use `contains` or loops.

For example:

- `hasX("hello")` → `false`
- `hasX("xylophone")` → `true`
- `hasX("abcdx")` → `true`
- `hasX("qrst")` → `false`

Solving Recursion Problems

Procedure For Solving Recursion Problems

1. Figure out what the base case is. To do this, look at the type of the argument and think of the simplest thing of that type.
2. Now that you know the base case(s), figure out what the answer for the base case is.
3. Now, we have to figure out the recursive step. First, write down what the function we are writing does.
4. Then, ask the question: "What is the smallest piece of the problem I can break off?"
5. Figure out the answer to the question for the tiny problem.
6. Use a recursive call to solve whatever is left.

1. Figure out what the base case is. To do this, look at the type of the argument and think of the simplest thing of that type:
   The argument is a `String`. The simplest `String` is the empty String.

2. Now that you know the base case(s), figure out what the answer for the base case is:

```
1 if (s.length() == 0) {
2    // The empty string doesn't have any x's
3    return false;
4 }
```

3. Now, we have to figure out the recursive step. First, write down what the function we are writing does:

   `hasX(s)` returns true when `s` contains an `'x'`

5. Ask the question: "What is the smallest piece of the problem I can break off?"

   A `String` is made up of `char`s. We can break off a single `char`:

```
1 else {
2    // Break off the first character
3    char c = s.charAt(0);
4    ...
```

6. Figure out the answer to the question for the tiny problem:

```
1    // Answer the question for that character
2    if (c == 'x') {
3       return true;
4    }
5    ...
```

7. Use a recursive call to solve whatever is left.

```
1    // Ask someone else to solve the rest of the problem
2    return hasX(s.substring(1));
3 }
```

hasX Solution

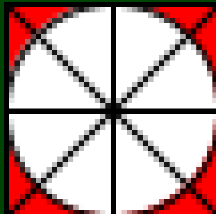
```
1  public static boolean hasX(String s) {
2     if (s.length() == 0) {
3        // The empty string doesn’t have any x’s
4        return false;
5     }
6     else {
7        // Break off the first character
8        char c = s.charAt(0);
9
10       // Answer the question for that character
11       return c == ’x’ || hasX(s.substring(1));
12    }
13 }
```

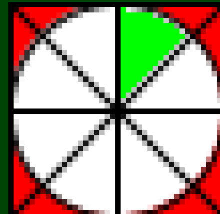
paintbucket

Implement a function

```
public static void paintbucket(int x, int y, Color toFill)
```

which fills an area with `Color.GREEN` when the `DrawingPanel` is clicked.





The algorithm to fill in the space is called "floodfill." To see it working with `DrawingPanel`, download the code. Here it is more generally:

floodfill

```
1  public static final ThingToFill drawing;
2  public static final int SIZE = ...;
3  public static void floodfill(int x, int y, Color toFill) {
4     if (x >= 0 && y >= 0 && x < SIZE && y < SIZE &&
5          drawing.getColor(x, y).equals(toFill)) {
6        drawing.setColor(x, y, Color.GREEN);
7        floodfill(x - 1, y, toFill);
8        floodfill(x, y - 1, toFill);
9        floodfill(x + 1, y, toFill);
10       floodfill(x, y + 1, toFill);
11       /* Include the following four lines to also fill diagonals... */
12       //floodfill(x - 1, y - 1, toFill);
13       //floodfill(x + 1, y + 1, toFill);
14       //floodfill(x + 1, y - 1, toFill);
15       //floodfill(x - 1, y + 1, toFill);
16    }
17 }
```

Back to Making Change

canMakeChange

Implement a function

```
public static boolean canMakeChange(int n)
```

which returns true if it is possible to make n spirals by combining 2's and 5's and false otherwise.

canMakeChange Solution

```
1 public static boolean canMakeChange(int n) {
2    if (n < 0) {
3       return false;
4    }
5    else if (n == 0) {
6       return true;
7    }
8    return canMakeChange(n - 2) || canMakeChange(n - 5);
9 }
```

isPalindrome

Implement a function

```
public static boolean isPalindrome(int[] arr, int begin, int end)
```

which returns true if the elements between begin and end (inclusive) of arr are the same forwards and backwards.

For example:

- isPalindrome({1, 1, 1, 1}, 0, 2) → true
- isPalindrome({1, 1, 1, 1}, 0, 3) → true
- isPalindrome({1, 1, 1, 1}, 1, 2) → true
- isPalindrome({1, 2, 3, 4}, 1, 1) → true
- isPalindrome({1, 2, 3, 4}, 1, 2) → false
- isPalindrome({1, 2, 3, 2, 1}, 1, 3) → true
- isPalindrome({1, 2, 3, 2, 1}, 0, 1) → false

isPalindrome

```
1 public static boolean isPalindrome(int[] arr, int begin, int end) {
2    if (begin >= end) {
3       return true;
4    }
5    else {
6       return arr[begin] == arr[end]) &&
7             isPalindrome(arr, begin + 1, end - 1);
8    }
9 }
```

Okay, but wait. Are we ever going to ask for partial arrays being palindromes? We'd rather a function:

```
public static boolean isPalindrome(int[] arr)
```

How can we write this using our previous function?

```
1 public static boolean isPalindrome(int[] arr) {
2    return isPalindrome(arr, 0, arr.length - 1);
3 }
```

Note that, now, we should make our original function **PRIVATE**, because we don't want a user to ever actually call it.

In general, to solve some recursive problems, we will need to make **public-private** pairs. The private method will have extra arguments we can use and the public method will call the private one.

```
1  public static boolean isPalindrome(int[] arr) {
2     return isPalindrome(0, arr.length - 1);
3  }
4
5  private static boolean isPalindrome(int[] arr, int begin, int end) {
6     if (begin >= end) {
7        return true;
8     }
9     else {
10       return arr[begin] == arr[end]) &&
11             isPalindrome(arr, begin + 1, end - 1);
12    }
13 }
```

crawl

Write a method

```
public static void crawl(File f)
```

that prints out the names of the files we reach by looking inside any folders starting at `f`. The names should be indented as many times as the number of folders it is inside.
So, for instance, an output might look like:

OUTPUT

```
>> folder1
>>     file.txt
>>     IAmInsideFolder1
>>         insideinside.html
>>         lecture.pdf
>>     oops.jpg
```

Crawling The Filesystem: public/private pair again!

Because we need to keep track of how far we are supposed to indent, our recursive function will need to have a second argument `indent`:

```
public static void crawl(File f, String indent)
```

`crawl` Solution

```
1  public static void crawl(File f) {
2     return crawl(f, "");
3  }
4  private static void crawl(File f, String indent) {
5     System.out.println(indent + f.getName());
6     if (f.isDirectory()) {
7        List<File> filesInDir = f.listFiles();
8        for (int i = 0; i < filesInDir.size(); i++) {
9           crawl(filesInDir.get(i), indent + " ");
10       }
11    }
12 }
```

Some Recursion Tips!

- See earlier starred slide with approach to recursion problems.
- Practice writing recursive functions **a lot**. Looking at an answer does not count as practicing.
- Always identify **how many** base cases (e.g. the special, weird ones) you will need.

Non-negative numbers	$\longrightarrow$	0
`int`	$\longrightarrow$	negative, 0
`String`	$\longrightarrow$	“”
File System	$\longrightarrow$	non-folder

- If the problem doesn’t seem like you can break it down easily, think about what arguments you could add to help (and use a public-private pair).
  Generally, you need arguments to **“keep track of”** something.
  - Saving the `start` and `end` bounds of an `int[]`
  - Saving the number of times we’ve recursed into a folder (to print them indented)