Building Java Programs

Chapter 12
recursive programming

reading: 12.2 - 12.4

Poll Everywhere

Warm Up: pollev.com/cse143

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

What is the value returned by `method(5)`?

Recursion and cases

- Every recursive algorithm involves at least 2 cases:
  - **base case**: simple problem that can be solved directly.
  - **recursive case**: more complex occurrence of the problem that cannot be directly answered, but can instead be described in terms of smaller occurrences of the same problem.
  - Some recursive algorithms have more than one base or recursive case, but all have at least one of each.
  - A crucial part of recursive programming is identifying these cases.

Tracing our algorithm

- **call stack**: The method invocations currently running

```
reverseLines(new Scanner("poem.txt"));
```

```
public static void reverseLines(Scanner input) {
    if (input.hasNextLine()) {
        String line = input.nextLine();   // "I have eaten"
public static void reverseLines(Scanner input) {
    if (input.hasNextLine()) {
        String line = input.nextLine();   // "the plums"
public static void reverseLines(Scanner input) {
    if (input.hasNextLine()) {
        String line = input.nextLine();   // "that were in"
public static void reverseLines(Scanner input) {
    if (input.hasNextLine()) {
        String line = input.nextLine();   // "the icebox"
public static void reverseLines(Scanner input) {
    if (input.hasNextLine()) {   // false
        ...
    }
}
```

```
I have eaten
the plums
that were in
the icebox
```

```
the icebox
that were in
the plums
I have eaten
```

Exercise

- Write a recursive method `pow` accepts an integer base and exponent and returns the base raised to that exponent.
  - Example: `pow(3, 4)` returns 81
  - Solve the problem recursively and without using loops.

An optimization

- Notice the following mathematical property:

$3^{12} = 531441 = 9^6$

$= (3^2)^6$

$531441 = (9^2)^3$

$= ((3^2)^2)^3$

  - When does this "trick" work?
  - How can we incorporate this optimization into our `pow` method?
  - What is the benefit of this trick if the method already works?

Exercise

- Write a recursive method `printBinary` that accepts an integer and prints that number's representation in binary (base 2).
  - Example: `printBinary(7)` prints 111
  - Example: `printBinary(12)` prints 1100
  - Example: `printBinary(42)` prints 101010

place	10	1
value	**4**	**2**

32	16	8	4	2	1
1	**0**	**1**	**0**	**1**	**0**

  - Write the method recursively and without using any loops.

Repeat Digits

- How did we break the number apart?

```
public static int repeatDigits(int n) {
    if (n < 10) {
        return (10 * n) + n;
    } else {
        int a = repeatDigits(n / 10);
        int b = repeatDigits(n % 10);
        return (100 * a) + b;
    }
}
```

Case analysis

- Recursion is about solving a small piece of a large problem.
  - What is 69743 in binary?
    - Do we know *anything* about its representation in binary?
  - Case analysis:
    - What is/are easy numbers to print in binary?
    - Can we express a larger number in terms of a smaller number(s)?

printBinary solution

```
// Prints the given integer's binary representation.
// Precondition: n >= 0
public static void printBinary(int n) {
    if (n < 2) {
        // base case; same as base 10
        System.out.println(n);
    } else {
        // recursive case; break number apart
        printBinary(n / 2);
        printBinary(n % 2);
    }
}
```

- Can we eliminate the precondition and deal with negatives?

Exercise

- Write a recursive method `isPalindrome` accepts a `String` and returns `true` if it reads the same forwards as backwards.
  - `isPalindrome("madam")` → `true`
  - `isPalindrome("racecar")` → `true`
  - `isPalindrome("step on no pets")` → `true`
  - `isPalindrome("able was I ere I saw elba")` → `true`
  - `isPalindrome("Java")` → `false`
  - `isPalindrome("rotater")` → `false`
  - `isPalindrome("byebye")` → `false`
  - `isPalindrome("notion")` → `false`

Exercise solution

```
// Returns true if the given string reads the same
// forwards as backwards.
// Trivially true for empty or 1-letter strings.
public static boolean isPalindrome(String s) {
    if (s.length() < 2) {
        return true;   // base case
    } else {
        char first = s.charAt(0);
        char last  = s.charAt(s.length() - 1);
        if (first != last) {
            return false;
        }                  // recursive case
        String middle = s.substring(1, s.length() -
  1);
        return isPalindrome(middle);
    }
}
```

Exercise solution 2

```
// Returns true if the given string reads the same
// forwards as backwards.
// Trivially true for empty or 1-letter strings.
public static boolean isPalindrome(String s) {
    if (s.length() < 2) {
        return true;   // base case
    } else {
        return s.charAt(0) == s.charAt(s.length() - 1)
            && isPalindrome(s.substring(1, s.length() -
  1));
    }
}
```

Exercise

- Write a method `print` accepts a `File` parameter and prints information about that file.
  - If the `File` object represents a normal file, just print its name.
  - If the `File` object represents a directory, print its name and information about every file/directory inside it, indented.

```
cse143
    handouts
        syllabus.doc
        lecture_schedule.xls
    homework
        1-tiles
            TileMain.java
            TileManager.java
            index.html
            style.css
```

  - **recursive data**: A directory can contain other directories.

Recursive Data

- A file is one of
  - A simple file
  - A directory containing files
- Directories can be nested to an arbitrary depth

`File` objects

- A `File` object (from the `java.io` package) represents a file or directory on the disk.

Constructor/method	Description
`File(`**String**`)`	creates `File` object representing file with given name
`canRead()`	returns whether file is able to be read
`delete()`	removes file from disk
`exists()`	whether this file exists on disk
`getName()`	returns file's name
`isDirectory()`	returns whether this object represents a directory
`length()`	returns number of bytes in file
`listFiles()`	returns a `File[]` representing files in this directory
`renameTo(`**File**`)`	changes name of file

Public/private pairs

- We cannot vary the indentation without an extra parameter:

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

- Often the parameters we need for our recursion do not match those the client will want to pass.

  In these cases, we instead write a pair of methods:

  1) a public, non-recursive one with parameters the client wants
  2) a private, recursive one with the parameters we really need

Exercise solution 2

```
// Prints information about this file,
// and (if it is a directory) any files inside it.
public static void crawl(File f) {
    crawl(f, "");   // call private recursive helper
}

// Recursive helper to implement crawl/indent
  behavior.
private static void crawl(File f, String indent) {
    System.out.println(indent + f.getName());
    if (f.isDirectory()) {
        // recursive case; print contained files/dirs
        File[] subFiles = f.listFiles();
        for (int i = 0; i < subFiles.length; i++) {
            crawl(subFiles[i], indent + "    ");
        }
    }
}
```

Recursion Challenges

- Forgetting a base case
  - Infinite recursion resulting in `StackOverflowError`
- Working away from the base case
  - The recursive case must make progress towards the base case
  - Infinite recursion resulting in `StackOverflowError`
- Running out of memory
  - Even when making progress to the base case, some inputs may require too many recursive calls: `StackOverflowError`
- Recomputing the same subproblem over and over again
  - Refining the algorithm could save significant time