

# **CSE 143**

## **Lecture 9**

Recursion

reading: 12.1 - 12.2

slides adapted from Marty Stepp and Hélène Martin

<http://www.cs.washington.edu/143/>

# Recursion

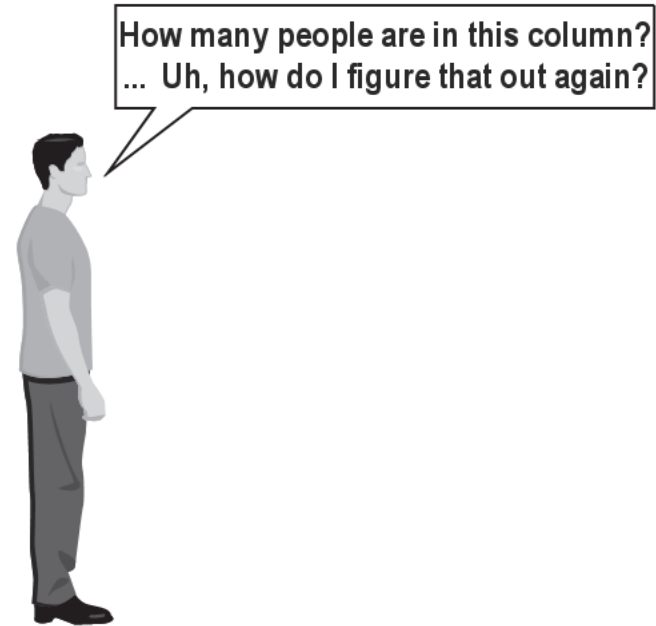
- **recursion:** The definition of an operation in terms of itself.
  - Solving a problem using recursion depends on solving smaller occurrences of the same problem.
- **recursive programming:** Writing methods that call themselves to solve problems recursively.
  - An equally powerful substitute for *iteration* (loops)
  - Particularly well-suited to solving certain types of problems

# Why learn recursion?

- "cultural experience" - A different way of thinking of problems
- Can solve some kinds of problems better than iteration
- Leads to elegant, simplistic, short code (when used well)
- Many programming languages ("functional" languages such as Scheme, ML, and Haskell) use recursion exclusively (no loops)
- A key component of the rest of our assignments in CSE 143

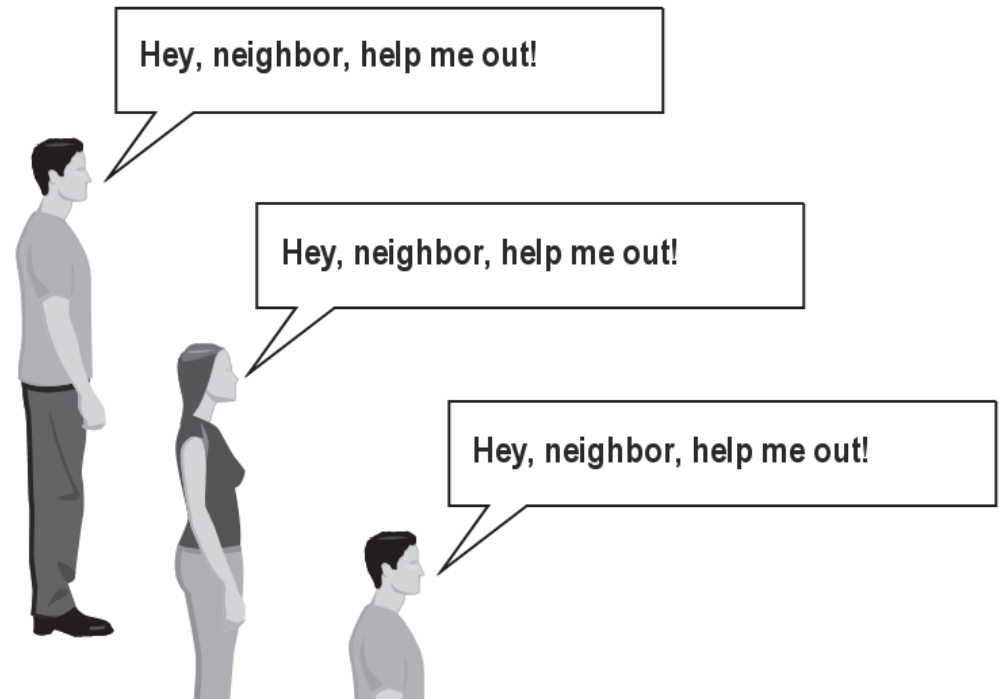
# Exercise

- (To a student in the front row)  
How many students total are directly behind you in your "column" of the classroom?
  - You have poor vision, so you can see only the people right next to you. So you can't just look back and count.
  - But you are allowed to ask questions of the person next to you.
  - How can we solve this problem? (*recursively*)



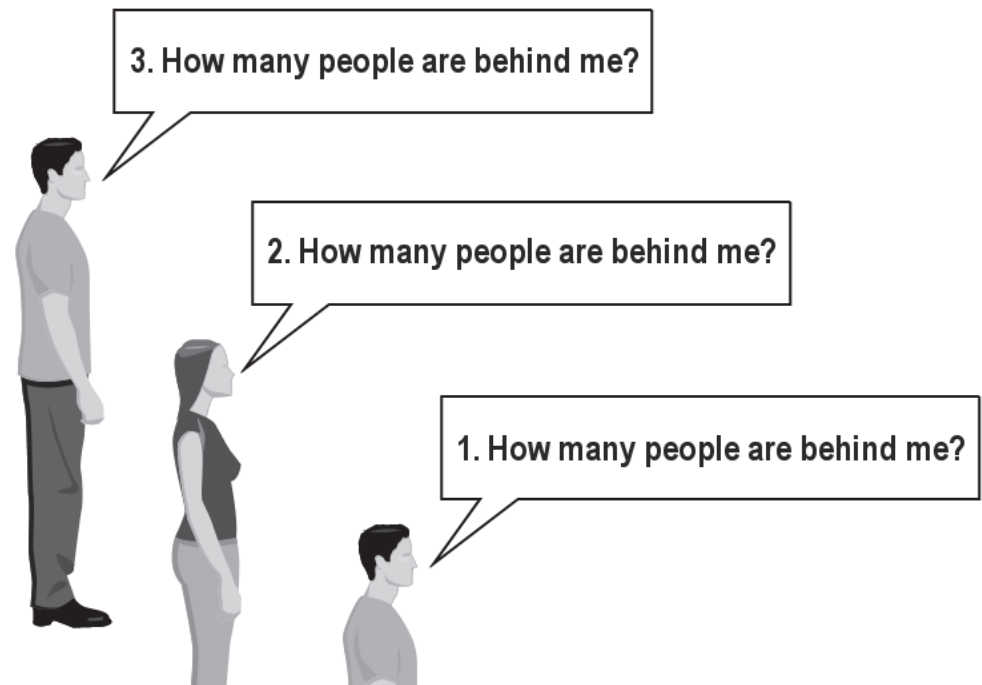
# The idea

- Recursion is all about breaking a big problem into smaller occurrences of that same problem.
  - Each person can solve a small part of the problem.
    - What is a small version of the problem that would be easy to answer?
    - What information from a neighbor might help me?



# Recursive algorithm

- Number of people behind me:
  - If there is someone behind me, ask him/her how many people are behind him/her.
    - When they respond with a value **N**, then I will answer **N + 1**.
  - If there is nobody behind me, I will answer **0**.



# Recursion and cases

- Every recursive algorithm involves at least 2 cases:
  - **base case:** A simple occurrence that can be answered directly.
  - **recursive case:** A 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.

# Another recursive task

- How can we remove exactly half of the M&M's in a large bowl, without dumping them all out or being able to count them?
  - What if multiple people help out with solving the problem?  
Can each person do a small part of the work?



# Recursion in Java

- Consider the following method to print a line of \* characters:

```
// Prints a line containing the given number of stars.  
// Precondition: n >= 0  
public static void printStars(int n) {  
    for (int i = 0; i < n; i++) {  
        System.out.print("*");  
    }  
    System.out.println();    // end the line of output  
}
```

- Write a recursive version of this method (that calls itself).
  - Solve the problem without using any loops.
  - Hint: Your solution should print just one star at a time.

# A basic case

- What are the cases to consider?
  - What is a very easy number of stars to print without a loop?

```
public static void printStars(int n) {  
    if (n == 1) {  
        // base case; just print one star  
        System.out.println("*");  
    } else {  
        ...  
    }  
}
```

# Handling more cases

- Handling additional cases, with no loops (in a bad way):

```
public static void printStars(int n) {  
    if (n == 1) {  
        // base case; just print one star  
        System.out.println("*");  
    } else if (n == 2) {  
        System.out.print("*");  
        System.out.println("*");  
    } else if (n == 3) {  
        System.out.print("*");  
        System.out.print("*");  
        System.out.println("*");  
    } else if (n == 4) {  
        System.out.print("*");  
        System.out.print("*");  
        System.out.print("*");  
        System.out.println("*");  
    } else ...  
}
```

# Handling more cases 2

- Taking advantage of the repeated pattern (somewhat better):

```
public static void printStars(int n) {  
    if (n == 1) {  
        // base case; just print one star  
        System.out.println("*");  
    } else if (n == 2) {  
        System.out.print("*");  
        printStars(1);        // prints "*"   
    } else if (n == 3) {  
        System.out.print("*");  
        printStars(2);        // prints "***"   
    } else if (n == 4) {  
        System.out.print("*");  
        printStars(3);        // prints "****"   
    } else ...  
}
```

# Using recursion properly

- Condensing the recursive cases into a single case:

```
public static void printStars(int n) {  
    if (n == 1) {  
        // base case; just print one star  
        System.out.println("*");  
    } else {  
        // recursive case; print one more star  
        System.out.print("*");  
        printStars(n - 1);  
    }  
}
```

# "Recursion Zen"

- The real, even simpler, base case is an  $n$  of 0, not 1:

```
public static void printStars(int n) {  
    if (n == 0) {  
        // base case; just end the line of output  
        System.out.println();  
    } else {  
        // recursive case; print one more star  
        System.out.print("*");  
        printStars(n - 1);  
    }  
}
```

- **Recursion Zen:** The art of properly identifying the best set of cases for a recursive algorithm and expressing them elegantly.  
(A CSE 143 informal term)

# Recursive tracing

- Consider the following recursive method:

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

- What is the result of the following call?

`mystery(648)`

# A recursive trace

mystery(648) :

- `int a = 648 / 10;`                    `// 64`
- `int b = 648 % 10;`                `// 8`
- `return mystery(a + b);`           `// mystery(72)`

mystery(72) :

- `int a = 72 / 10;`                   `// 7`
- `int b = 72 % 10;`                `// 2`
- `return mystery(a + b);`           `// mystery(9)`

mystery(9) :

- `return 9;`

# Recursive tracing 2

- Consider the following recursive method:

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

- What is the result of the following call?

`mystery(348)`

# A recursive trace 2

mystery(348)

- `int a = mystery(34);`

- `int a = mystery(3);`

- `return (10 * 3) + 3;     // 33`

- `int b = mystery(4);`

- `return (10 * 4) + 4;     // 44`

- `return (100 * 33) + 44;     // 3344`

- `int b = mystery(8);`

- `return (10 * 8) + 8;     // 88`

- `– return (100 * 3344) + 88;     // 334488`

– What is this method really doing?