CSE 143
Lecture 12 (B)

Recursion

reading: 12.1 - 12.2

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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

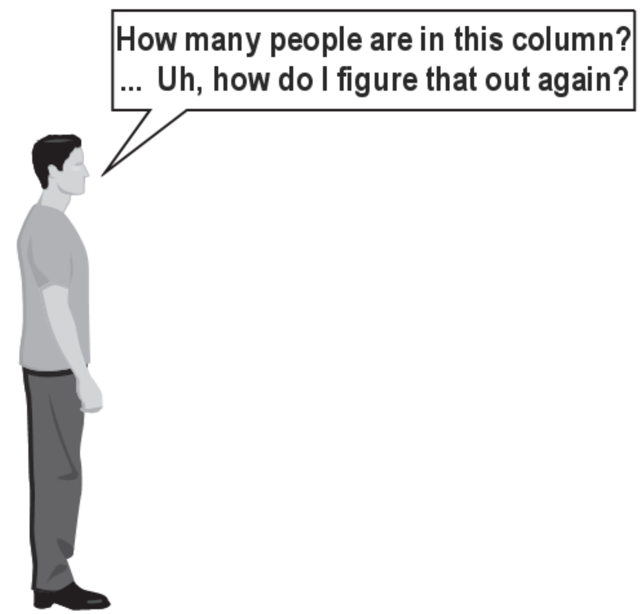
Exercise

- (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.

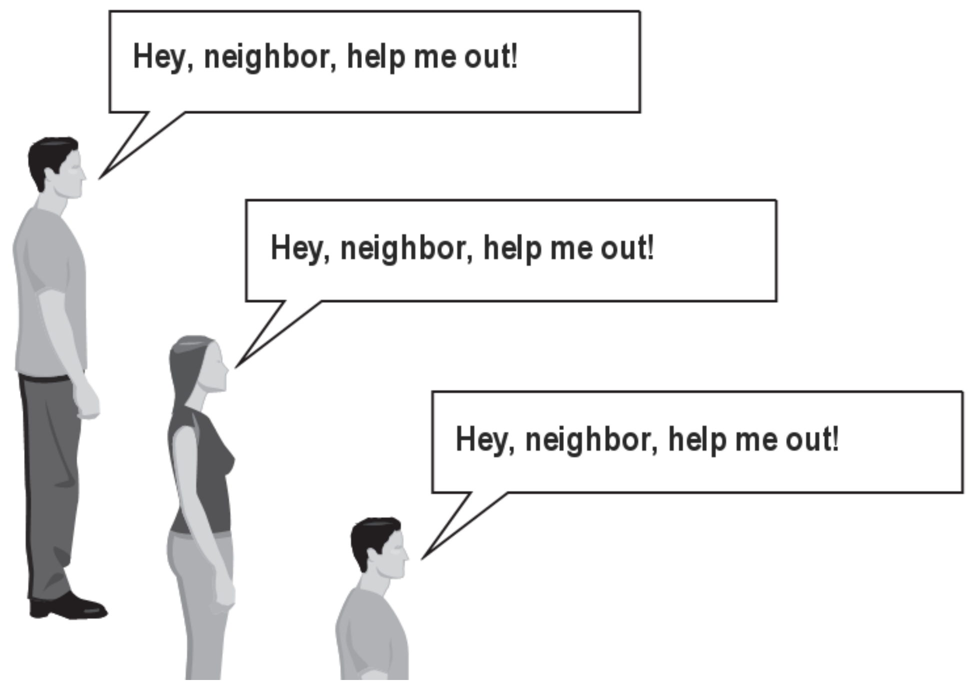
  – But you are allowed to ask questions of the person next to you.

  – How can we solve this problem? (*recursively*)



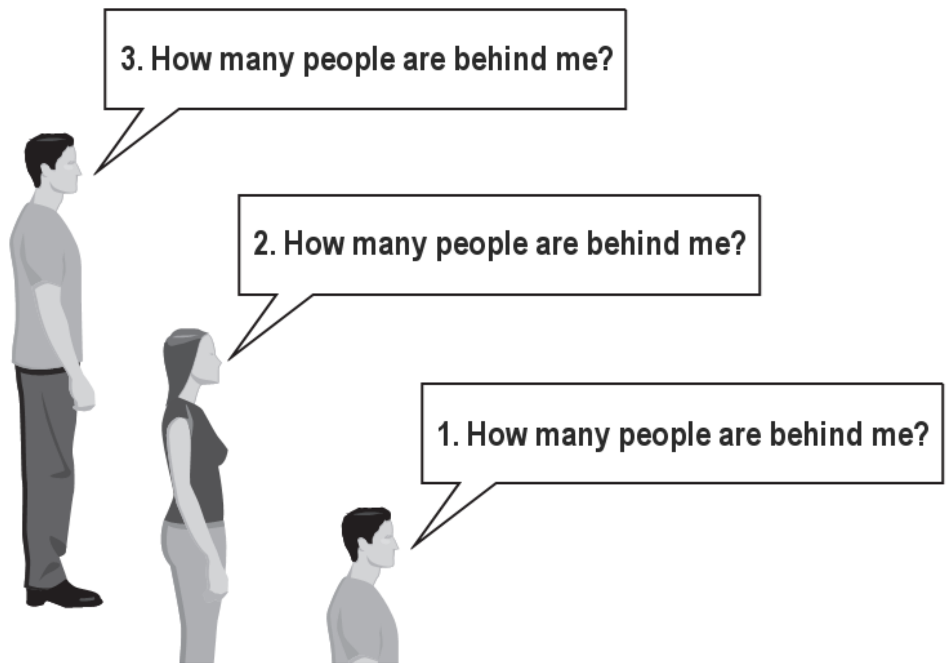
The idea

- 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?
  - What is a number of M&M's that it is easy to double, even if you can't count?

    (What is a "base case"?)

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 <u>without using any loops</u>.
  - 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?