CSCI 136:
Data Structures
and
Advanced Programming

Lecture 9

Recursion

Instructor: Dan Barowy

Williams

Topics

- Pre/post conditions
- Recursion

Your to-dos

1. Lab 3, **due Tuesday 3/1 by 10pm** ([random] partner lab!)
2. Read **before Fri**: Bailey, Ch 7.1–7.2.

Announcements

- Colloquium today: **Senior thesis proposals #2**, 2:35pm in Wege Auditorium with **cookies**.
- Survey: masking…

Pre/post conditions

Example

```
x + 1
```

What does this operation do?
(i.e., what is our desired post-condition?)

Example

```
x + 1
```

Are you sure?

(code)

Example

These examples may seem contrived but trust me, they are not.

What **should have been true** about `x`?

1. `x` is an `int`
2. `x < Integer.MAX_VALUE`

Pre-condition

A **pre-condition** is a **true/false statement** (a “predicate”) that must always be true **prior to a code segment (e.g., a function) being called**. If a pre-condition is false, the result of executing the code is **undefined**.

Post-condition

A **post-condition** is a **true/false statement** (a “predicate”) that must always be true after a code segment (e.g., a function) is called **assuming that the pre-condition was true**.

Post-condition implications

If a **pre-condition is false**, there is **no guarantee that the post-condition will be true**.

Conversely, if a **post-condition is false**, then if the pre-condition is valid, **the pre-condition must have been false**.

Example, with conditions

```
public static int addOne(int x) {
  Assert.pre(
    x < Integer.MAX_VALUE,
    "x must be an integer less than MAX_VALUE.");
  int z = x + 1;
  Assert.post(z > x, "z must be greater than x.");
  return z;
}
```

Pre/post in comments

- It's a good idea to put pre- and post-conditions in comments before your methods

```
/* @pre  0 ≤ index < length
 * @post returns char at position index
 */
 public char charAt(int index) { … }
```

Pre/post conditions

- Pre and post conditions form a contract.
- *Principle: post-condition is satisfied if pre-condition is satisfied.*
- Examples:
  - `s.charAt(s.length() - 1)`: index < length, so valid
  - `s.charAt(s.length() + 1)`: index > length, so not valid
- These conditions document requirements that user of method should satisfy.
- As comments, they are not enforced.

`Assert` class

- Pre- and post-condition comments are **useful to a human**, but it would be really helpful to know as soon as a pre-condition is violated (and return an error)
- The `Assert` class (in `structure5` package) allows us to **programmatically check** for pre- and post-conditions

Remember: "Assume your code will fail."

`Assert` class

The `Assert` class contains the `static` methods

```
public static void pre(boolean test, String message);
public static void post(boolean test, String message);
public static void condition(boolean test, String message);
public static void fail(String message);
```

If the boolean test is NOT satisfied, an exception is raised, the message is printed and the program halts.

General guidelines

1. State pre/post conditions in **comments**
2. **Check** conditions in code using `Assert`
3. Use `Fail` in **unexpected cases** (such as the default block of a switch statement)

- Any questions?
- You should use `Assert` in Lab 3

Recursion

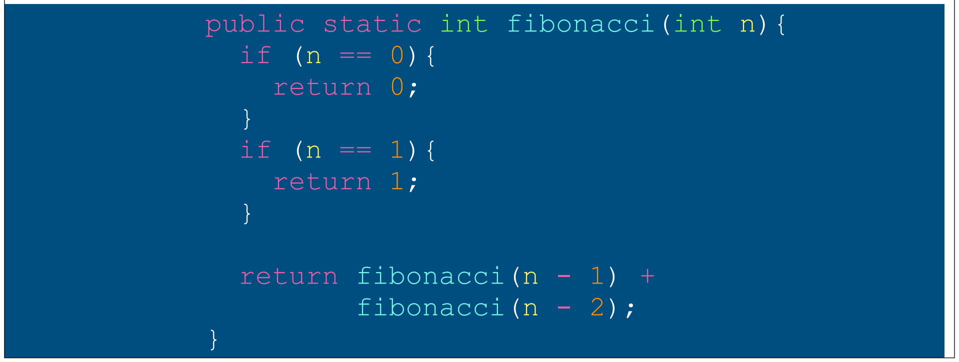
Recursion

General problem solving strategy:

- Split **big problem** into **smaller sub-problems**.
- Sub-problems may look a lot like original; are often **smaller versions of same problem**!

Recursion

Recursion is when a thing is **defined in terms of itself**. The most concrete application of recursion in computer science is **when a function is called within its own definition**.



```
public static int fibonacci(int n){
  if (n == 0){
    return 0;
  }
  if (n == 1){
    return 1;
  }

  return fibonacci(n - 1) +
         fibonacci(n - 2);
}
```

Recursion

- **Many** algorithms are recursive
  - Often **easier to understand** (and prove correctness/state efficiency of) than non-recursive versions!

Recursion: formal structure

- Recursion is a good solution when a problem fits a **basic pattern**:
- It has at least one “terminating” rule that **does not** use recursion, called the **base case**.
- It has at least one rule that **does** use recursion, called the **recursive case**. The recursive case should **reduce the problem toward the base case**.

We will talk about formal (i.e., “inductive”) proofs for recursion this week.

Passing a note (recursively)

What are our base/recursive cases?

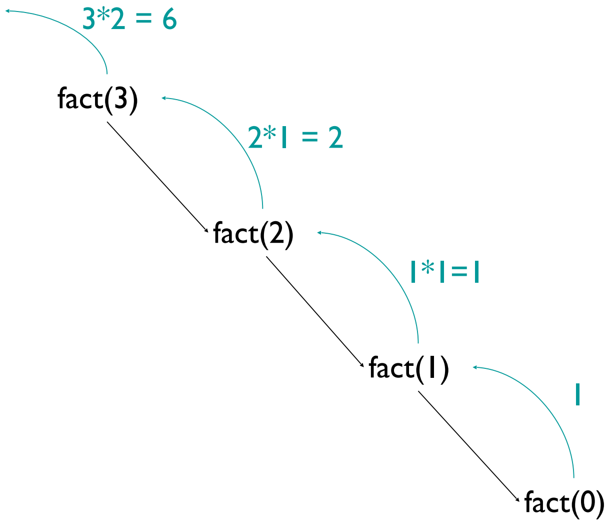
Recursion

- `n! = n × (n-1) × (n-2) × … × 1`
- How can we implement this?
  - We could use a `for` loop…

```
int product = 1;
for(int i = 1;i <= n; i++)
     product *= i;
```

- But we could also write it recursively….

Graphically…



3*2 = 6

fact(3)

2*1 = 2

fact(2)

1*1=1

fact(1)

1

fact(0)

Activity: Factorial

- `n! = n × (n-1) × (n-2) × … × 1`
- Work with a partner and see if you can come up with a recursive solution.

Recap & Next Class

Today:

- Pre/post conditions
- Recursion

Next class:

- Mathematical induction