CS1110

Lecture 11: **Intro to Recursion**

Prelim preparation/upcoming schedule
This week (Feb 25 – Mar 1)

Today: lecture (recursion) as usual, plus:
- **Prelim conflicts (makeup requests) at *midnight* on CMS**
- **A3 out today**; short, designed to help prepare you for the exam

Labs today and tomorrow:
- Lab 5 (lists) due
- **pick up your graded A2s** – feedback will help you for prelim
- Lab 6 (recursion) out – not optional, but that material is *not on the prelim*. Due at beginning of lab session *after the prelim*.

Thursday: lecture (recursion II) as usual

Next week (Mar 4 – Mar 8)

Monday Mar 4: A3 due

Tuesday Mar 5: review session instead of regular lecture

Labs Mar 5/6:
- pick up your graded A2s (if you haven't already)
- No new lab activity, optional attendance: treat as office hours, or opportunity to work more on Lab 6 (due in lab the week after)

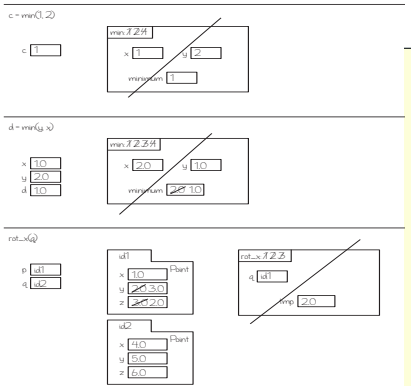
Thursday Mar 7:
- "lecture" = office hours with profs (location TBA)
- **Prelim: 7:30-9pm, 116 Kennedy Hall/Call Auditorium**

A2

We provided feedback as written comments, not grades*.
So:
- Please pick up your A2 in lab this week; the A2 material *will be on the prelim*. (If it's missing, your partner might have it.)
- Make sure you can reproduce every single bit of the solutions on your own *exactly*.**

*Everyone who submitted received the same "participation" grade, which enabled us to finish the grading faster.
**Except we don't care whether you wrote "end" to indicate the end of execution or not.

A2 solutions



New In-Lab Collaboration Policy

To get your questions answered in lab faster:

We (now) encourage you to talk to your table-mate or other students in lab to solve the problems you are given. You *may* look at each other's lab code *while in lab*.

"Submission petitions": new policy

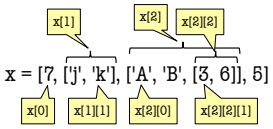
Need an extension/missed a submission deadline? Please email head TA Qin Jia (qj34@cornell.edu), not the instructor(s).

(You can cc: (both) of us profs on such email, but coordination will be handled by Qin. We (profs Marschner and Lee) need to devote more time to content creation and helping students with questions.)

Nested Lists (appear in A3)

- Lists can hold any objects
- Lists are objects
- Therefore lists can hold other lists!

```
a = ['j', 'k']
b = [3, 6]
c = ['A', 'B', b]
x = [7, a, c, 5]
```



A *Recursive* Function

```
def num_es(s):
    """Returns: number of 'e's in s. Precond: s a string"""
    if s == '':  # case: s is empty string
        return 0

    # case: <s> has at least one char
    return ((1 if s[0] == 'e'
               else 0) +
            num_es(s[1:]))
```

Indeed, if s has at least one character, the number of 'e's in s is the number of 'e's in s[0] + the number of 'e's in s[1:].

How to Think About Recursive Functions

1. **Have a precise function specification.**
2. **Base case(s):**
   - When the argument values are as "small" as possible
   - When the answer is determined with little calculation.
3. **Recursive case(s):**
   - Verify recursive cases with the specification
4. **Termination:**
   - Arguments of calls must somehow get "smaller", so each recursive call gets closer to a base case

Understanding the String Example

- **Step 1:** Have a precise specification

```
def num_es(s):
    """Returns: number of 'e's in s. Precond: s a string"""
    # case: s is empty string
    if s == '':
        return 0

    # case: s has at least one char
    # return # of 'e's in s[0]+# of 'e's in s[1:]
    return (1 if s[0] == 'e' else 0) +  num_es(s[1:])
```

Base case

"Write" your return statement using the **specification**

Recursive case

- **Step 2:** Check the base case
  - When s is the empty string, 0 is returned. Good.

Understanding the String Example

- **Step 3:** Recursive calls make progress toward termination

```
def num_es(s):
    """Returns: # of 'e's in s"""
    # {s is empty}
    if s == '':
        return 0

    # { s at least one char }
    # return # of 'e's in s[0]+# of 'e's in s[1:]
    return (1 if s[0] == 'e' else 0) +  num_es(s[1:])
```

parameter s

argument s[1:] is smaller than parameter s, so there is progress toward reaching base case 0

argument s[1:]

- **Step 4:** Recursive case is correct
  - Just check the specification

Example: Remove Blanks from a String

```
def deblank(s):
    """Returns: s with blanks removed"""
    if s == '':
        return s

    # case: s is not empty
    if s[0] in string.whitespace:
        return deblank(s[1:])

    # case: s not empty and s[0] not blank
    return (s[0] +
            deblank(s[1:]))
```

- Check the four points:
  1. Precise specification?
  2. Base case: correct?
  3. Recursive case: progress toward termination?
  4. Recursive case: correct?

Expression: x in thelist returns True if x is a member of list thelist (and False if it is not)