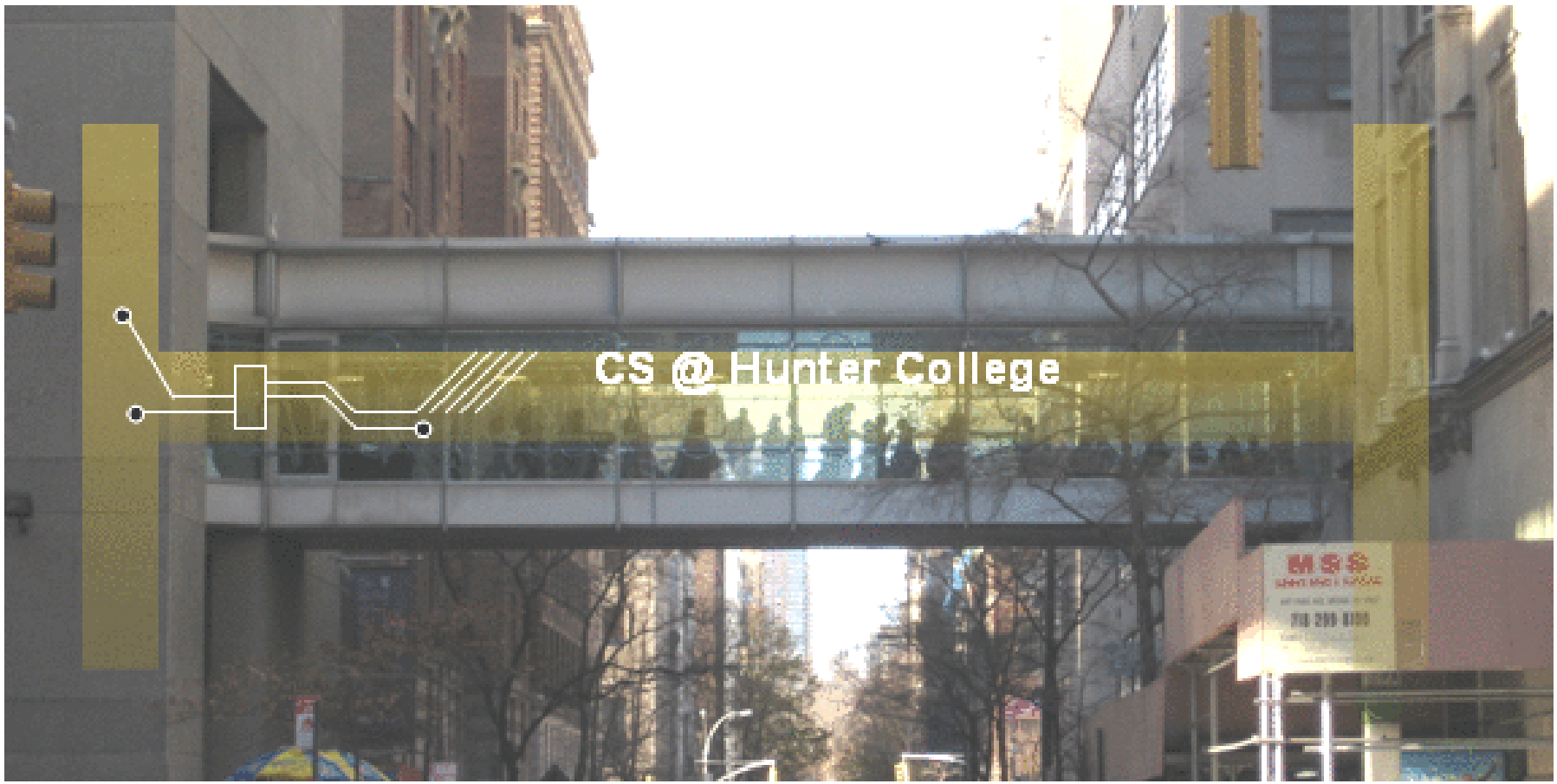
CSci 127: Introduction to Computer Science



hunter.cuny.edu/csci

Announcements

- Grades have been updated on Blackboard. Let us know if you see anything missing, so we can fix it (we found duplicate accounts and typos in EmpID's).
- Each lecture includes a survey of computing research and tech in NYC.

  Today: Prof. Anita Raja
  Artificial Intelligence

Today's Topics

- Recap: Functions & Top Down Design
- Mapping GIS Data
- Random Numbers
- Indefinite Loops
- CS Survey

Today's Topics

- **Recap: Functions & Top Down Design**
- Mapping GIS Data
- Random Numbers
- Indefinite Loops
- CS Survey

In Pairs or Triples:

```
def prob4(amy, beth):
    if amy > 4:
        print("Easy case")
        kate = -1
    else:
        print("Complex case")
        kate = helper(amy,beth)
    return(kate)
```

```
def helper(meg,jo):
    s = ""
    for j in range(meg):
        print(j, ": ", jo[j])
        if j % 2 == 0:
            s = s + jo[j]
            print("Building s:", s)
    return(s)
```

- What are the formal parameters for the functions?
- What is the output of:

```
r = prob4(4,"city")
print("Return:  ", r)
```

- What is the output of:

```
r = prob4(2,"university")
print("Return:  ", r)
```

In Pairs or Triples:

```
def prob4(amy, beth):
    if amy > 4:
        print("Easy case")
        kate = -1
    else:
        print("Complex case")
        kate = helper(amy,beth)
    return(kate)
```

```
def helper(meg,jo):
    s = ""
    for j in range(meg):
        print(j, ": ", jo[j])
        if j % 2 == 0:
            s = s + jo[j]
            print("Building s:", s)
    return(s)
```

- What are the formal parameters for the functions?

In Pairs or Triples:

```
def prob4(amy, beth):
    if amy > 4:
        print("Easy case")
        kate = -1
    else:
        print("Complex case")
        kate = helper(amy,beth)
    return(kate)
```

```
def helper(meg,jo):
    s = ""
    for j in range(meg):
        print(j, ": ", jo[j])
        if j % 2 == 0:
            s = s + jo[j]
            print("Building s:", s)
    return(s)
```

- What are the formal parameters for the functions?

In Pairs or Triples:

```
def prob4(amy, beth):
    if amy > 4:
        print("Easy case")
        kate = -1
    else:
        print("Complex case")
        kate = helper(amy,beth)
    return(kate)
```

```
def helper(meg,jo):
    s = ""
    for j in range(meg):
        print(j, ": ", jo[j])
        if j % 2 == 0:
            s = s + jo[j]
            print("Building s:", s)
    return(s)
```

- What is the output of:

```
r = prob4(4,"city")
print("Return:  ", r)
```

- What is the output of:

```
r = prob4(2,"university")
print("Return:  ", r)
```

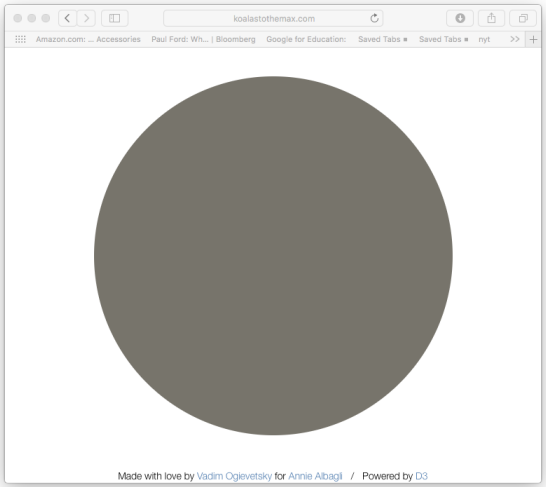
Python Tutor

```
def prob4(amy, beth):
    if amy > 4:
        print("Easy case")
        kate = -1
    else:
        print("Complex case")
        kate = helper(amy,beth)
    return(kate)
```

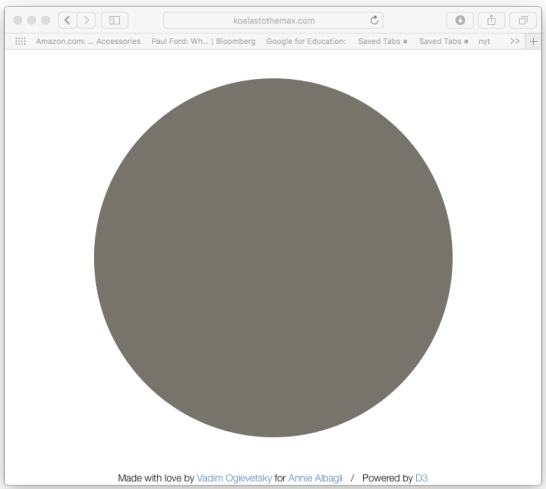
```
def helper(meg,jo):
    s = ""
    for j in range(meg):
        print(j, ": ", jo[j])
        if j % 2 == 0:
            s = s + jo[j]
            print("Building s:", s)
    return(s)
```

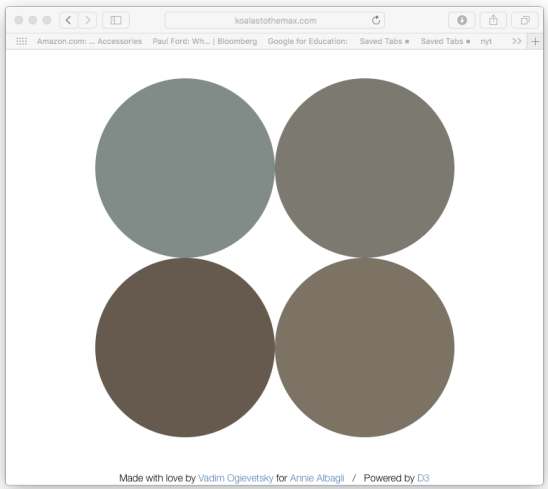
(Demo with pythonTutor)

From Last Time: koalas

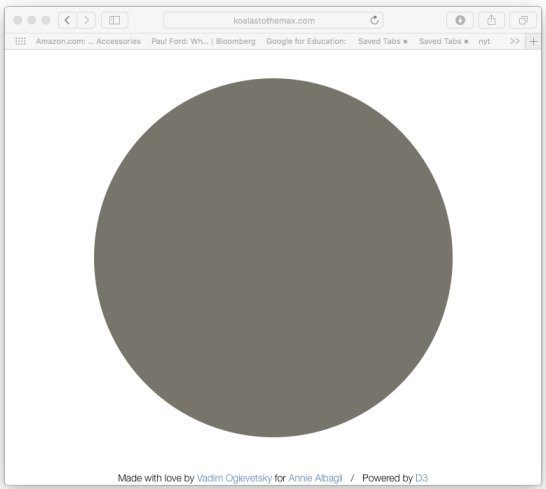


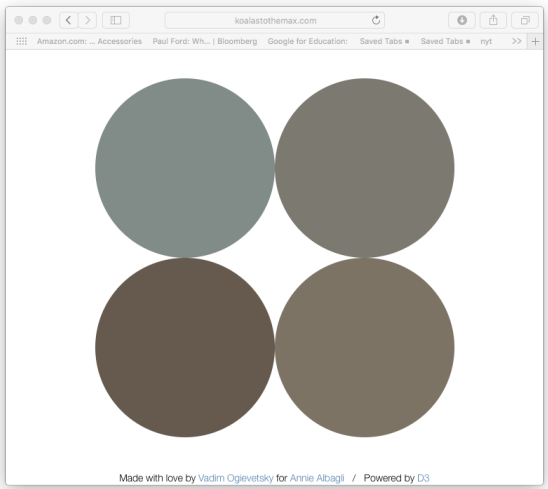
From Last Time: koalas

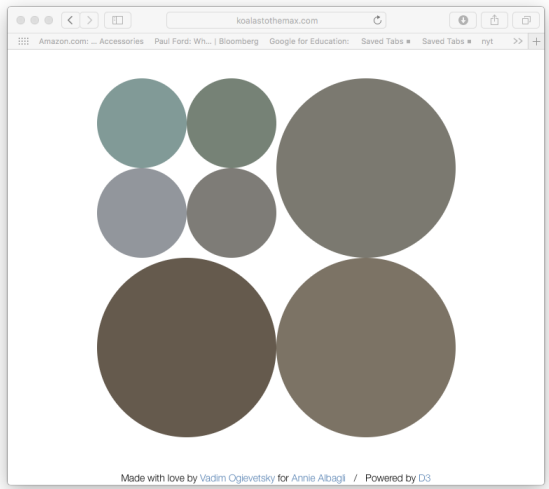




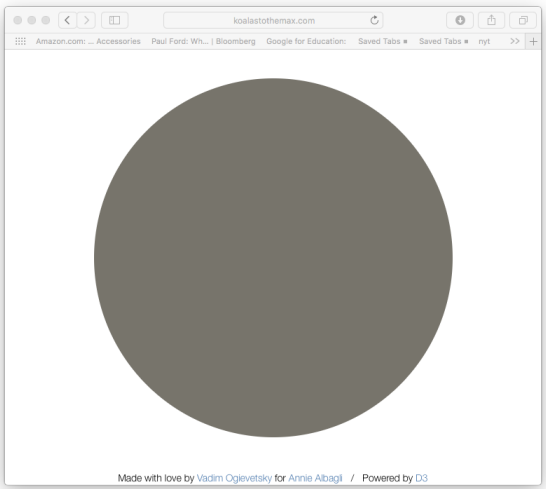
From Last Time: koalas

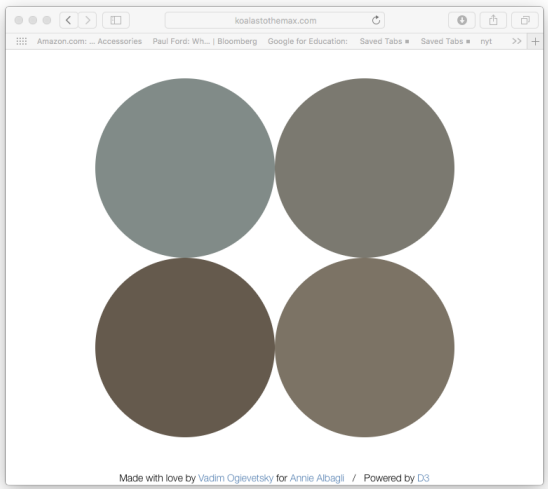


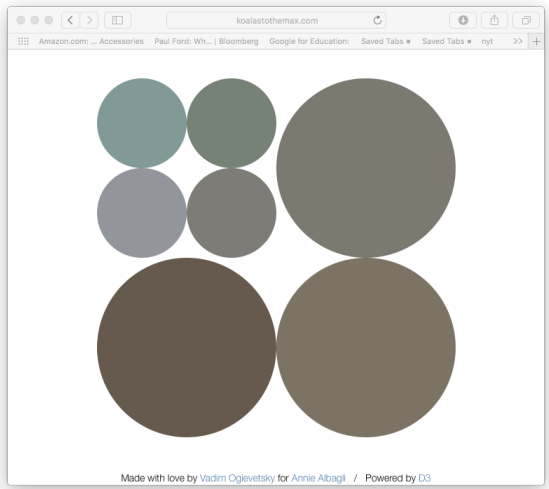




From Last Time: koalas

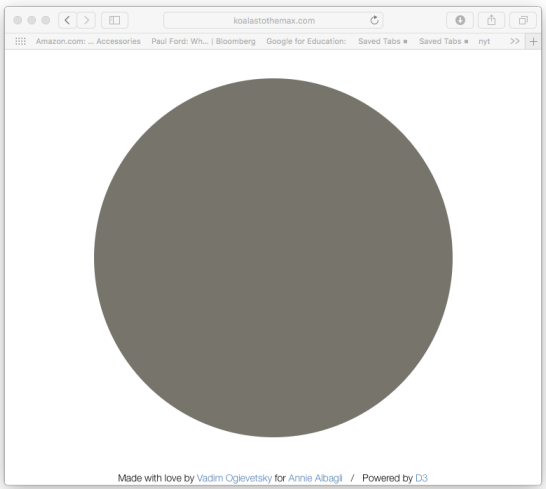


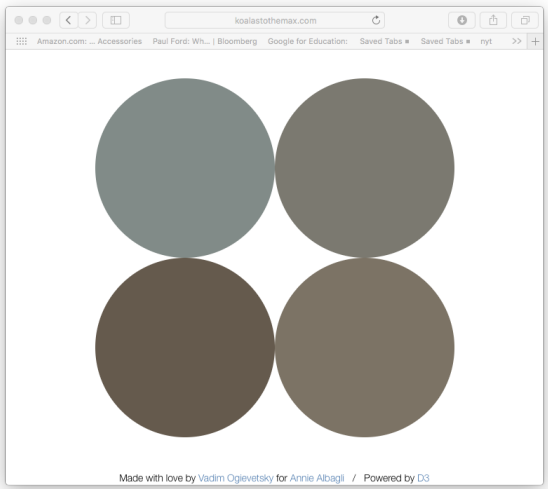


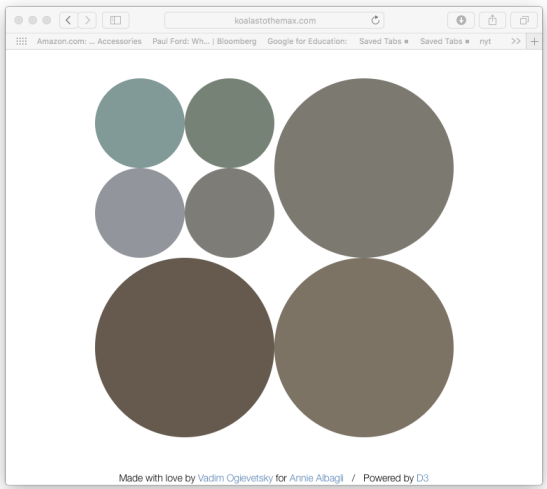


`http://koalastothemax.com`

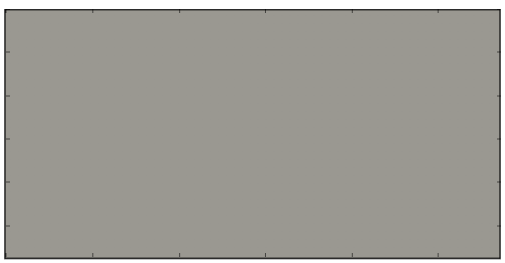
From Last Time: koalas



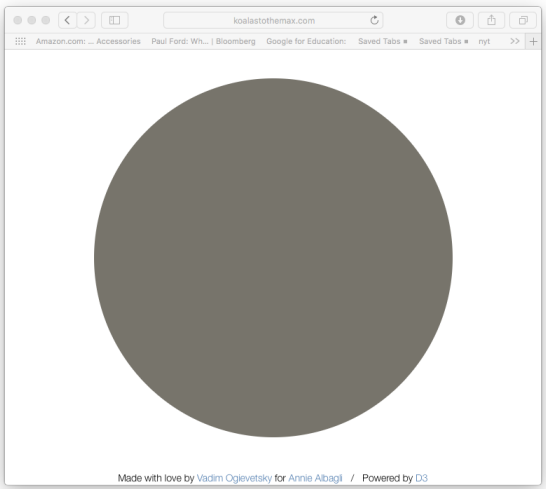


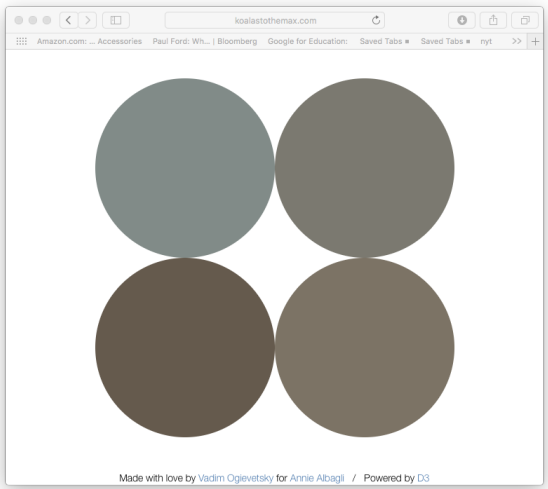


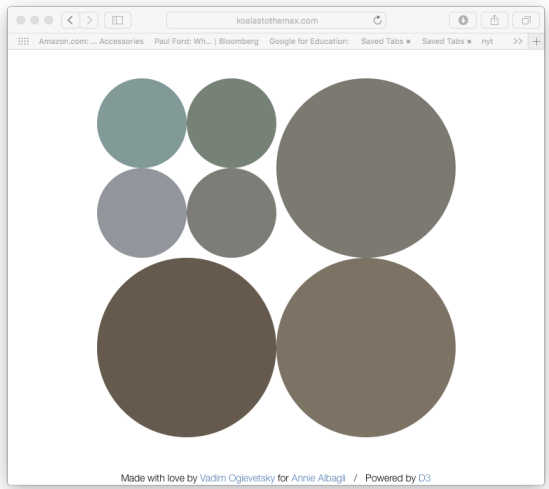
`http://koalastothemax.com`



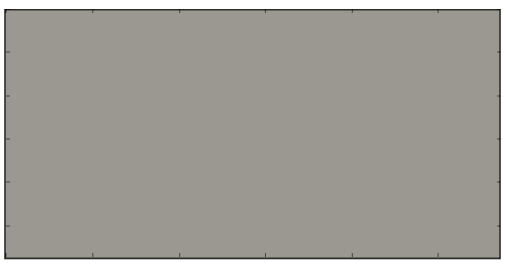
From Last Time: koalas

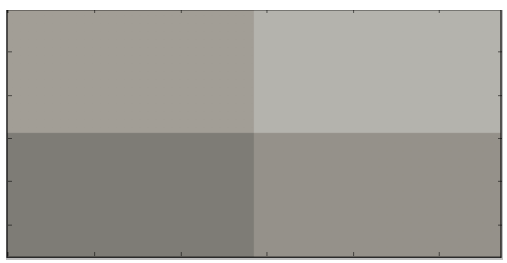




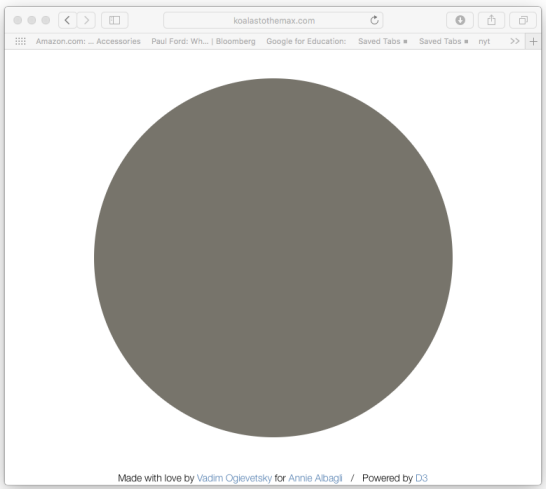


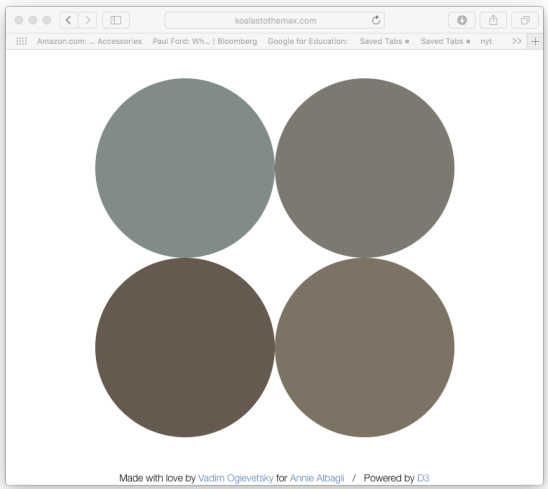
`http://koalastothemax.com`

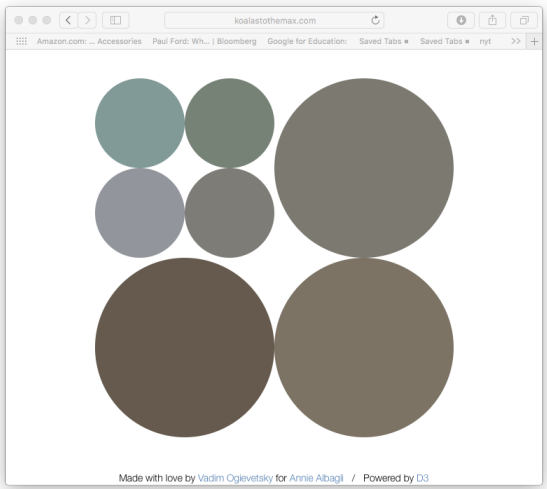




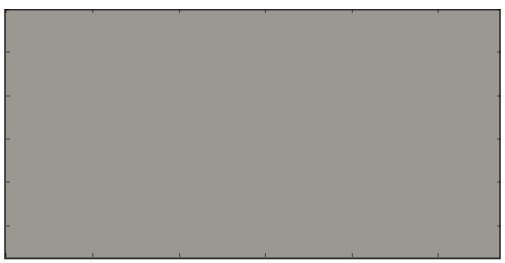
From Last Time: koalas

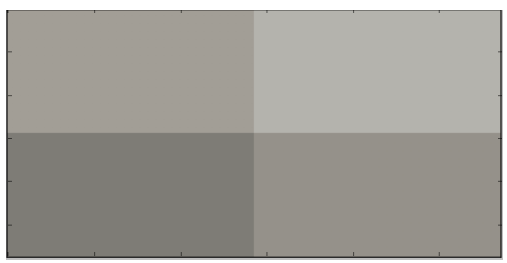


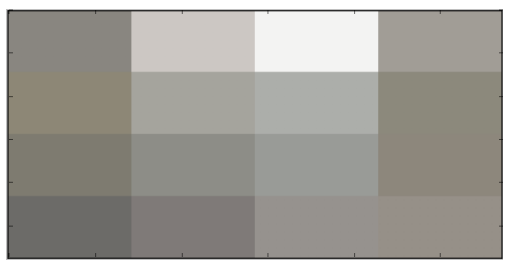




`http://koalastothemax.com`



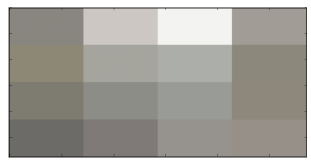




From Last Time: koalas

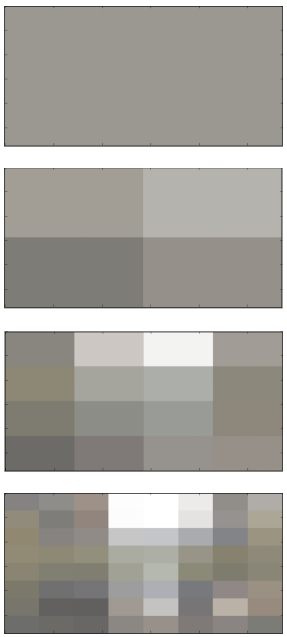
Process:





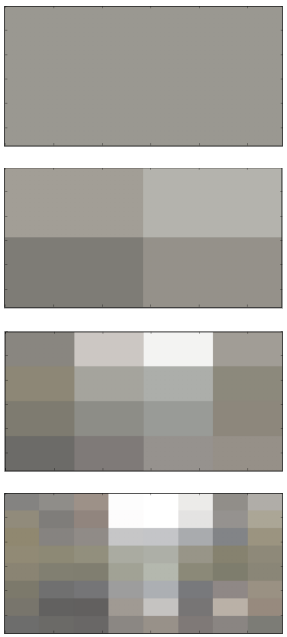

Get template from `github` → Fill in missing functions → Test locally idle3/python3 → Submit to Gradescope

From Last Time: koalas



```
69  def main():
70      inFile = input('Enter image file name: ')
71      img = plt.imread(inFile)
72
73      #Divides the image in 1/2, 1/4, 1/8, ... 1/2^8, and displays each:
74      for i in range(8):
75          img2 = img.copy()   #Make a copy to average
76          quarter(img2,i)     #Split in half i times, and average regions
77
78          plt.imshow(img2)    #Load our new image into pyplot
79          plt.show()          #Show the image (waits until closed to continue)
80
81      #Shows the original image:
82      plt.imshow(img)         #Load image into pyplot
83      plt.show()              #Show the image (waits until closed to continue)
84
85
```

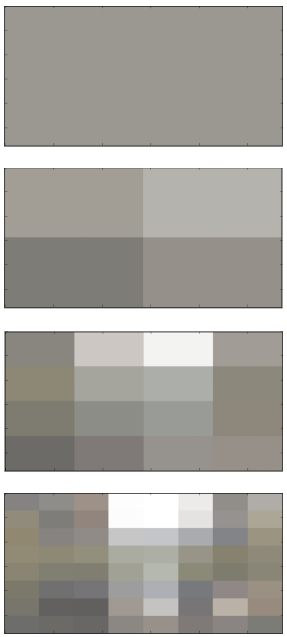
From Last Time: koalas



```
69  def main():
70      inFile = input('Enter image file name: ')
71      img = plt.imread(inFile)
72
73      #Divides the image in 1/2, 1/4, 1/8, ... 1/2^8, and displays each:
74      for i in range(8):
75          img2 = img.copy()   #Make a copy to average
76          quarter(img2,i)     #Split in half i times, and average regions
77
78          plt.imshow(img2)    #Load our new image into pyplot
79          plt.show()          #Show the image (waits until closed to continue)
80
81      #Shows the original image:
82      plt.imshow(img)         #Load image into pyplot
83      plt.show()              #Show the image (waits until closed to continue)
84
85
```

- The `main()` is written for you.

From Last Time: koalas



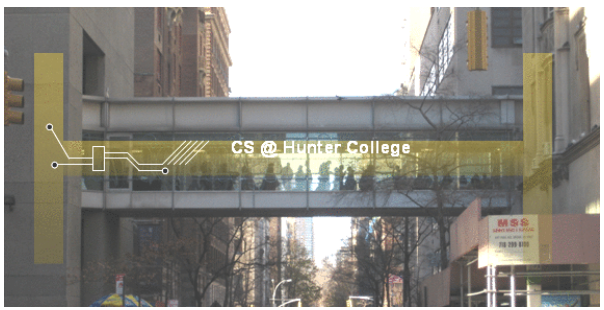
```
69  def main():
70      inFile = input('Enter image file name: ')
71      img = plt.imread(inFile)
72
73      #Divides the image in 1/2, 1/4, 1/8, ... 1/2^8, and displays each:
74      for i in range(8):
75          img2 = img.copy()   #Make a copy to average
76          quarter(img2,i)     #Split in half i times, and average regions
77
78          plt.imshow(img2)    #Load our new image into pyplot
79          plt.show()          #Show the image (waits until closed to continue)
80
81      #Shows the original image:
82      plt.imshow(img)         #Load image into pyplot
83      plt.show()              #Show the image (waits until closed to continue)
84
85
```

- The `main()` is written for you.
- Only fill in two functions: `average()` and `setRegion()`.

Top-Down Design

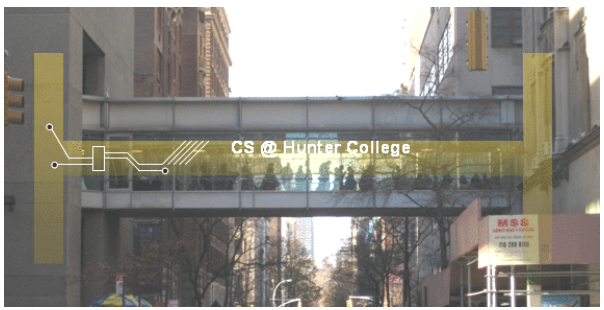
- The last example demonstrates **top-down design**: breaking into subproblems, and implementing each part separately.

Top-Down Design



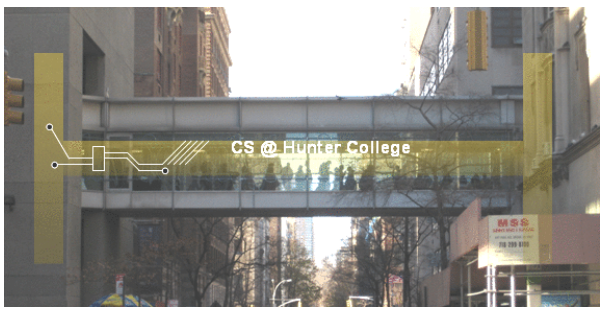
- The last example demonstrates **top-down design**: breaking into subproblems, and implementing each part separately.
  - Break the problem into tasks for a "To Do" list.

Top-Down Design



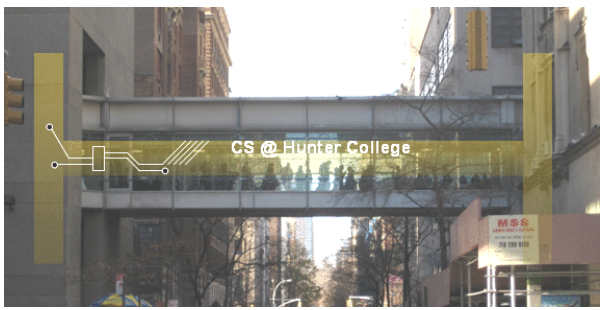
- The last example demonstrates **top-down design**: breaking into subproblems, and implementing each part separately.
  - Break the problem into tasks for a "To Do" list.
  - Translate list into function names & inputs/returns.

Top-Down Design



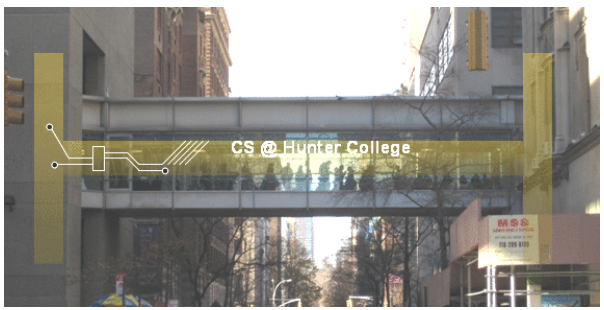
- The last example demonstrates **top-down design**: breaking into subproblems, and implementing each part separately.
  - Break the problem into tasks for a "To Do" list.
  - Translate list into function names & inputs/returns.
  - Implement the functions, one-by-one.

Top-Down Design



- The last example demonstrates **top-down design**: breaking into subproblems, and implementing each part separately.
  - Break the problem into tasks for a "To Do" list.
  - Translate list into function names & inputs/returns.
  - Implement the functions, one-by-one.
- Excellent approach since you can then test each part separately before adding it to a large program.

Top-Down Design



- The last example demonstrates **top-down design**: breaking into subproblems, and implementing each part separately.
  - Break the problem into tasks for a "To Do" list.
  - Translate list into function names & inputs/returns.
  - Implement the functions, one-by-one.
- Excellent approach since you can then test each part separately before adding it to a large program.
- Very common when working with a team: each has their own functions to implement and maintain.

In Pairs or Triples:

- Write the missing functions for the program:

```
def main():
    tess = setUp()     #Returns a purple turtle with pen up.
    for i in range(5):
        x,y = getInput()       #Asks user for two numbers.
        markLocation(tess,x,y) #Move tess to (x,y) and stamp.
```

In Pairs or Triples:

- Write the missing functions for the program:

```
def main():
    tess = setUp()      #Returns a purple turtle with pen up.
    for i in range(5):
        x,y = getInput()        #Asks user for two numbers.
        markLocation(tess,x,y) #Move tess to (x,y) and stamp.
```

Group Work: Fill in Missing Pieces

```
def main():
    tess = setUp()    #Returns a purple turtle with pen up.
    for i in range(5):
        x,y = getInput()       #Asks user for two numbers.
        markLocation(tess,x,y) #Move tess to (x,y) and stamp.
```

Group Work: Fill in Missing Pieces

1. Write import statements.

```
import turtle
```

```
def main():
    tess = setUp()    #Returns a purple turtle with pen up.
    for i in range(5):
        x,y = getInput()       #Asks user for two numbers.
        markLocation(tess,x,y) #Move tess to (x,y) and stamp.
```

Third Part: Fill in Missing Pieces

1. Write import statements.
2. Write down new function names and inputs.

```
import turtle
def setUp():
    #FILL IN
def getInput():
    #FILL IN
def markLocation(t,x,y):
    #FILL IN
```

```
def main():
    tess = setUp()    #Returns a purple turtle with pen up.
    for i in range(5):
        x,y = getInput()       #Asks user for two numbers.
        markLocation(tess,x,y) #Move tess to (x,y) and stamp.
```

Third Part: Fill in Missing Pieces

1. Write import statements.
2. Write down new function names and inputs.
3. Fill in return values.

```
import turtle
def setUp():
    #FILL IN
    return(newTurtle)
def getInput():
    #FILL IN
    return(x,y)
def markLocation(t,x,y):
    #FILL IN



def main():
    tess = setUp()    #Returns a purple turtle with pen up.
    for i in range(5):
        x,y = getInput()       #Asks user for two numbers.
        markLocation(tess,x,y) #Move tess to (x,y) and stamp.
```

Third Part: Fill in Missing Pieces

1. Write import statements.
2. Write down new function names and inputs.
3. Fill in return values.
4. Fill in body of functions.

```
import turtle
def setUp():
    newTurtle = turtle.Turtle()
    newTurtle.penup()
    return(newTurtle)
def getInput():
    x = int(input('Enter x: '))
    y = int(input('Enter y: '))
    return(x,y)
def markLocation(t,x,y):
    t.goto(x,y)
    t.stamp()
def main():
    tess = setUp()    #Returns a purple turtle with pen up.
    for i in range(5):
        x,y = getInput()       #Asks user for two numbers.
```

In Pairs or Triples:

- Write a function that takes a number as an input and prints its corresponding name.

In Pairs or Triples:

- Write a function that takes a number as an input and prints its corresponding name.
- For example,

In Pairs or Triples:

- Write a function that takes a number as an input and prints its corresponding name.
- For example,
  - `num2string(0)` returns: `zero`

In Pairs or Triples:

- Write a function that takes a number as an input and prints its corresponding name.
- For example,
  - `num2string(0)` returns: `zero`
  - `num2string(1)` returns: `one`

In Pairs or Triples:

- Write a function that takes a number as an input and prints its corresponding name.
- For example,
  - `num2string(0)` returns: `zero`
  - `num2string(1)` returns: `one`
  - `num2string(2)` returns: `two`

In Pairs or Triples:

- Write a function that takes a number as an input and prints its corresponding name.
- For example,
  - `num2string(0)` returns: `zero`
  - `num2string(1)` returns: `one`
  - `num2string(2)` returns: `two`
- You may assume that only single digits, 0,1,...,9, are given as input.

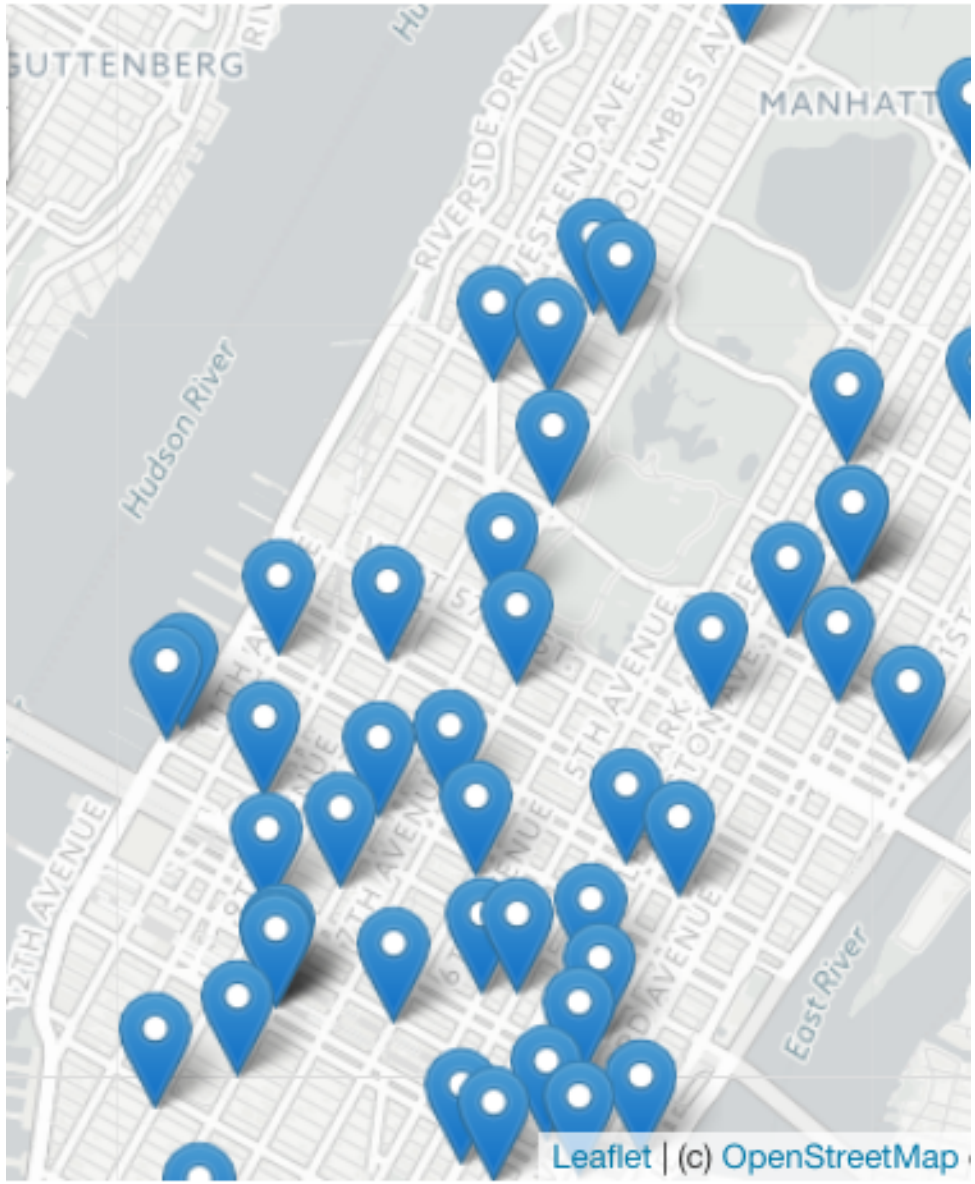
Python Tutor

(On github)

Today's Topics

- Recap: Functions & Top Down Design
- **Mapping GIS Data**
- Random Numbers
- Indefinite Loops
- CS Survey

Folium



Folium

- A module for making HTML maps.

Folium

- A module for making HTML maps.
- It's a Python interface to the popular `leaflet.js`.

Folium

- A module for making HTML maps.
- It's a Python interface to the popular `leaflet.js`.
- Outputs `.html` files which you can open in a browser.

Folium

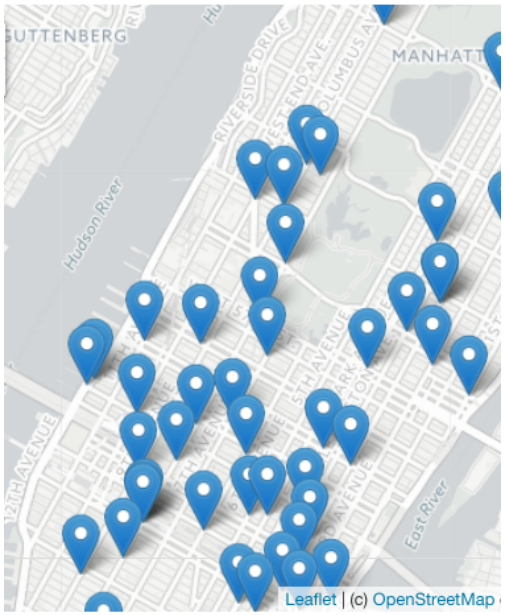
- A module for making HTML maps.
- It's a Python interface to the popular `leaflet.js`.
- Outputs `.html` files which you can open in a browser.
- An extra step:

Folium

- A module for making HTML maps.
- It's a Python interface to the popular `leaflet.js`.
- Outputs `.html` files which you can open in a browser.
- An extra step:

Write code. → *Run program.* → *Open .html in browser.*

Demo



(Map created by Folium.)

Folium

- To use:

```
import folium
```

Folium

- To use:

  ```
  import folium
  ```

- Create a map:

  ```
  myMap = folium.Map()
  ```

Folium

- To use:

  ```
  import folium
  ```

- Create a map:

  ```
  myMap = folium.Map()
  ```

- Make markers:

  ```
  newMark = folium.Marker([lat,lon],popup=name)
  ```

Folium

- To use:

  ```
  import folium
  ```

- Create a map:

  ```
  myMap = folium.Map()
  ```

- Make markers:

  ```
  newMark = folium.Marker([lat,lon],popup=name)
  ```

- Add to the map:

  ```
  newMark.add_to(myMap)
  ```

Folium

- To use:

  ```
  import folium
  ```

- Create a map:

  ```
  myMap = folium.Map()
  ```

- Make markers:

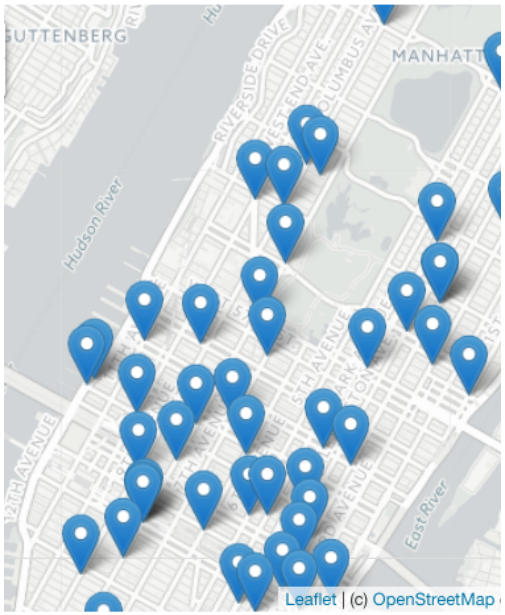
  ```
  newMark = folium.Marker([lat,lon],popup=name)
  ```

- Add to the map:

  ```
  newMark.add_to(myMap)
  ```

- Many options to customize background map ("tiles") and markers.

Demo



(Python program using Folium.)

In Pairs of Triples

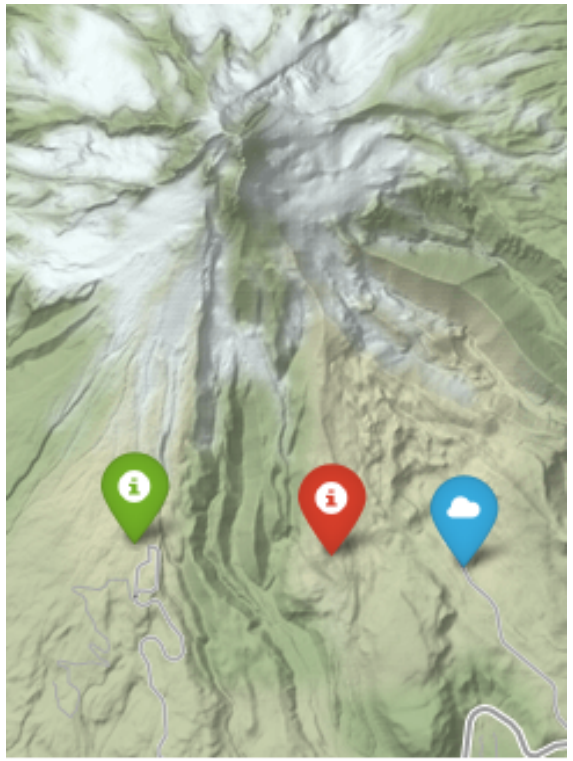
- Predict which each line of code does:

```
m = folium.Map(
    location=[45.372, -121.6972],
    zoom_start=12,
    tiles='Stamen Terrain'
)

folium.Marker(
    location=[45.3288, -121.6625],
    popup='Mt. Hood Meadows',
    icon=folium.Icon(icon='cloud')
).add_to(m)

folium.Marker(
    location=[45.3311, -121.7113],
    popup='Timberline Lodge',
    icon=folium.Icon(color='green')
).add_to(m)

folium.Marker(
    location=[45.3300, -121.6823],
    popup='Some Other Location',
    icon=folium.Icon(color='red', icon='info-sign')
).add_to(m)
```



(example from Folium documentation)

Today's Topics

- Recap: Functions & Top Down Design
- Mapping GIS Data
- **Random Numbers**
- Indefinite Loops
- CS Survey

Python's random package

- Python has a built-in package for generating pseudo-random numbers.

```
import turtle
import random

trey = turtle.Turtle()
trey.speed(10)

for i in range(100):
  trey.forward(10)
  a = random.randrange(0,360,90)
  trey.right(a)
```

Python's random package

- Python has a built-in package for generating pseudo-random numbers.
- To use:

```
import random
```

```
import turtle
import random

trey = turtle.Turtle()
trey.speed(10)

for i in range(100):
  trey.forward(10)
  a = random.randrange(0,360,90)
  trey.right(a)
```

Python's random package

- Python has a built-in package for generating pseudo-random numbers.
- To use:

  `import random`

- Useful command to generate whole numbers:

  `random.randrange(start,stop,step)`

  which gives a number chosen randomly from the specified range.

```
import turtle
import random

trey = turtle.Turtle()
trey.speed(10)

for i in range(100):
  trey.forward(10)
  a = random.randrange(0,360,90)
  trey.right(a)
```

Python's random package

```
import turtle
import random

trey = turtle.Turtle()
trey.speed(10)

for i in range(100):
  trey.forward(10)
  a = random.randrange(0,360,90)
  trey.right(a)
```

- Python has a built-in package for generating pseudo-random numbers.
- To use:

  `import random`

- Useful command to generate whole numbers:

  `random.randrange(start,stop,step)`

  which gives a number chosen randomly from the specified range.
- Useful command to generate real numbers:

Python's random package

```
import turtle
import random

trey = turtle.Turtle()
trey.speed(10)

for i in range(100):
  trey.forward(10)
  a = random.randrange(0,360,90)
  trey.right(a)
```

- Python has a built-in package for generating pseudo-random numbers.
- To use:

  `import random`

- Useful command to generate whole numbers:

  `random.randrange(start,stop,step)`

  which gives a number chosen randomly from the specified range.
- Useful command to generate real numbers:

  `random.random()`

  which gives a number chosen (uniformly) at random from [0.0,1.0).

Python's random package

```
import turtle
import random

trey = turtle.Turtle()
trey.speed(10)

for i in range(100):
  trey.forward(10)
  a = random.randrange(0,360,90)
  trey.right(a)
```

- Python has a built-in package for generating pseudo-random numbers.
- To use:

  `import random`

- Useful command to generate whole numbers:

  `random.randrange(start,stop,step)`

  which gives a number chosen randomly from the specified range.
- Useful command to generate real numbers:

  `random.random()`

  which gives a number chosen (uniformly) at random from [0.0,1.0).
- Very useful for simulations, games, and testing.

Trinket

```
import turtle
import random

trey = turtle.Turtle()
trey.speed(10)

for i in range(100):
  trey.forward(10)
  a = random.randrange(0,360,90)
  trey.right(a)
```

(Demo turtle random walk)

Today's Topics

- Recap: Functions & Top Down Design
- Mapping GIS Data
- Random Numbers
- **Indefinite Loops**
- CS Survey

In Pairs or Triples:

Predict what the code will do:

```
dist = int(input('Enter distance: '))
while dist < 0:
    print('Distances cannot be negative.')
    dist = int(input('Enter distance: '))

print('The distance entered is', dist)
```

Python Tutor

```
dist = int(input('Enter distance: '))
while dist < 0:
    print('Distances cannot be negative.')
    dist = int(input('Enter distance: '))

print('The distance entered is', dist)
```

(Demo with pythonTutor)

Indefinite Loops

```
dist = int(input('Enter distance: '))
while dist < 0:
    print('Distances cannot be negative.')
    dist = int(input('Enter distance: '))

print('The distance entered is', dist)
```

```
#Spring 2012 Final Exam, #8

nums = [1,4,0,6,5,2,9,8,12]
print(nums)
i=0
while i < len(nums)-1:
    if nums[i] < nums[i+1]:
        nums[i], nums[i+1] = nums[i+1], nums[i]
    i=i+1

print(nums)
```

- Indefinite loops repeat as long as the condition is true.

Indefinite Loops

```
dist = int(input('Enter distance: '))
while dist < 0:
    print('Distances cannot be negative.')
    dist = int(input('Enter distance: '))

print('The distance entered is', dist)
```

```
#Spring 2012 Final Exam, #8

nums = [1,4,0,6,5,2,9,8,12]
print(nums)
i=0
while i < len(nums)-1:
    if nums[i] < nums[i+1]:
        nums[i], nums[i+1] = nums[i+1], nums[i]
    i=i+1

print(nums)
```

- Indefinite loops repeat as long as the condition is true.
- Could execute the body of the loop zero times, 10 times, infinite number of times.

Indefinite Loops

```
dist = int(input('Enter distance: '))
while dist < 0:
    print('Distances cannot be negative.')
    dist = int(input('Enter distance: '))

print('The distance entered is', dist)
```

```
#Spring 2012 Final Exam, #8

nums = [1,4,0,6,5,2,9,8,12]
print(nums)
i=0
while i < len(nums)-1:
    if nums[i] < nums[i+1]:
        nums[i], nums[i+1] = nums[i+1], nums[i]
    i=i+1

print(nums)
```

- Indefinite loops repeat as long as the condition is true.
- Could execute the body of the loop zero times, 10 times, infinite number of times.
- The condition determines how many times.

Indefinite Loops

```
dist = int(input('Enter distance: '))
while dist < 0:
    print('Distances cannot be negative.')
    dist = int(input('Enter distance: '))

print('The distance entered is', dist)
```

```
#Spring 2012 Final Exam, #8

nums = [1,4,0,6,5,2,9,8,12]
print(nums)
i=0
while i < len(nums)-1:
    if nums[i] < nums[i+1]:
        nums[i], nums[i+1] = nums[i+1], nums[i]
    i=i+1

print(nums)
```

- Indefinite loops repeat as long as the condition is true.
- Could execute the body of the loop zero times, 10 times, infinite number of times.
- The condition determines how many times.
- Very useful for checking input, simulations, and games.

Indefinite Loops

```
dist = int(input('Enter distance: '))
while dist < 0:
    print('Distances cannot be negative.')
    dist = int(input('Enter distance: '))

print('The distance entered is', dist)
```

```
#Spring 2012 Final Exam, #8

nums = [1,4,0,6,5,2,9,8,12]
print(nums)
i=0
while i < len(nums)-1:
    if nums[i] < nums[i+1]:
        nums[i], nums[i+1] = nums[i+1], nums[i]
    i=i+1

print(nums)
```

- Indefinite loops repeat as long as the condition is true.
- Could execute the body of the loop zero times, 10 times, infinite number of times.
- The condition determines how many times.
- Very useful for checking input, simulations, and games.
- More details next lecture...

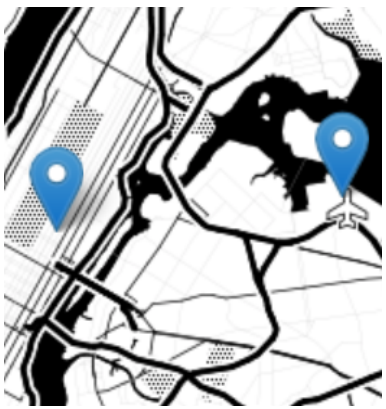
Today's Topics

- Recap: Functions & Top Down Design
- Mapping GIS Data
- Random Numbers
- Indefinite Loops
- **CS Survey**

CS Survey Talk

Prof. Anita Raja
Artificial Intelligence

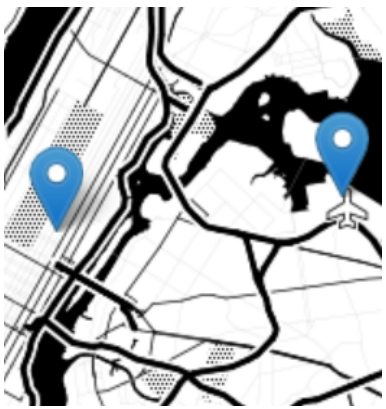
Design Challenge: Routing Traffic



Driving times to LGA with x cars already en route:

- $T_{RFK}(x) = 14 + \frac{x}{10{,}000}$ for the RFK bridge.
- $T_{KQB}(x) = 18 + \frac{x}{5{,}000}$ for the Queensboro bridge.
- $T_{Tun}(x) = 16 + \frac{x}{1{,}000}$, for the Midtown Tunnel.

Design Challenge: Routing Traffic



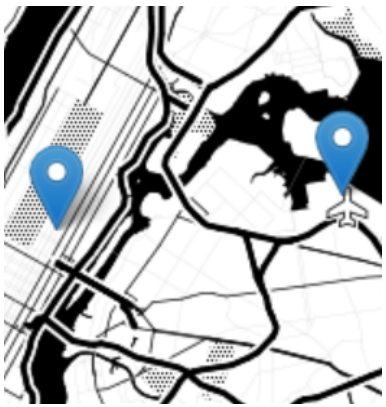
Driving times to LGA with x cars already en route:

- $T_{RFK}(x) = 14 + \frac{x}{10{,}000}$ for the RFK bridge.
- $T_{KQB}(x) = 18 + \frac{x}{5{,}000}$ for the Queensboro bridge.
- $T_{Tun}(x) = 16 + \frac{x}{1{,}000}$, for the Midtown Tunnel.

1. Assuming no traffic (i.e. $x = 0$), which is fastest?
2. How many cars would slow that route to make another route faster?
3. Should you always route all cars to the current fastest route? Why or why not?
4. How would you divide $50,000$ cars between the routes? Assume all start empty.

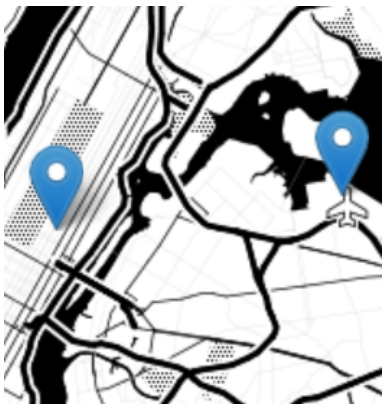
Recap

- On lecture slip, write down a topic you wish we had spent more time (and why).

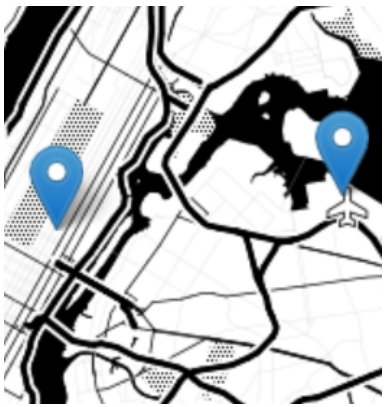


Recap

- On lecture slip, write down a topic you wish we had spent more time (and why).
- Top-down design: breaking into subproblems, and implementing each part separately.

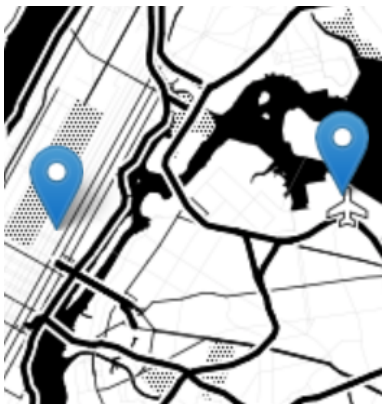


Recap



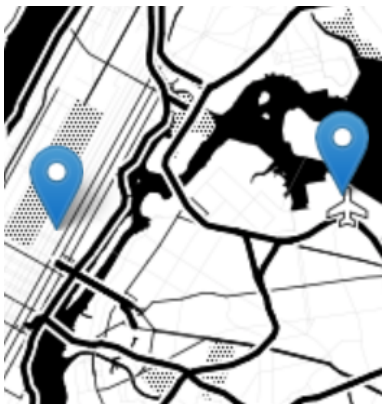
- On lecture slip, write down a topic you wish we had spent more time (and why).
- Top-down design: breaking into subproblems, and implementing each part separately.
- Excellent approach: can then test each part separately before adding it to a large program.

Recap



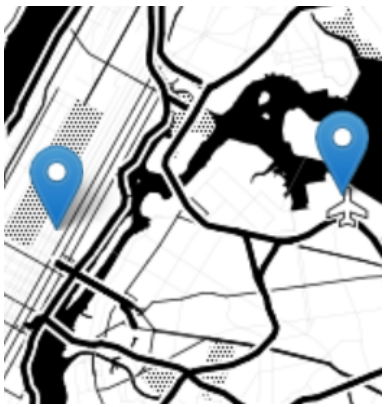
- On lecture slip, write down a topic you wish we had spent more time (and why).
- Top-down design: breaking into subproblems, and implementing each part separately.
- Excellent approach: can then test each part separately before adding it to a large program.
- When possible, design so that your code is flexible to be reused ("code reuse").

Recap



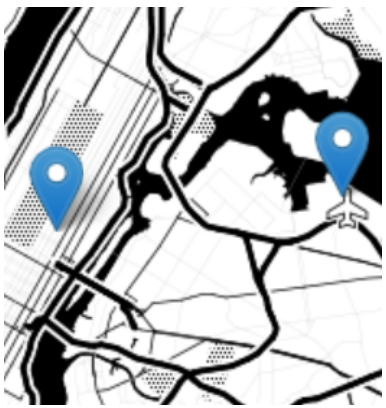
- On lecture slip, write down a topic you wish we had spent more time (and why).
- Top-down design: breaking into subproblems, and implementing each part separately.
- Excellent approach: can then test each part separately before adding it to a large program.
- When possible, design so that your code is flexible to be reused ("code reuse").
- Introduced a Python library, `Folium` for creating interactive HTML maps.

Recap



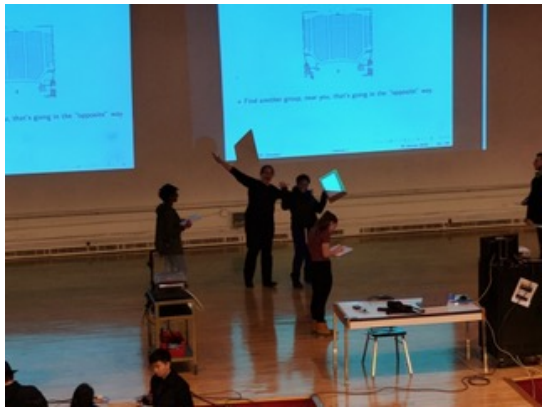
- On lecture slip, write down a topic you wish we had spent more time (and why).
- Top-down design: breaking into subproblems, and implementing each part separately.
- Excellent approach: can then test each part separately before adding it to a large program.
- When possible, design so that your code is flexible to be reused ("code reuse").
- Introduced a Python library, `Folium` for creating interactive HTML maps.
- Introduced `while` loops for repeating commands for an indefinite number of times.

Recap



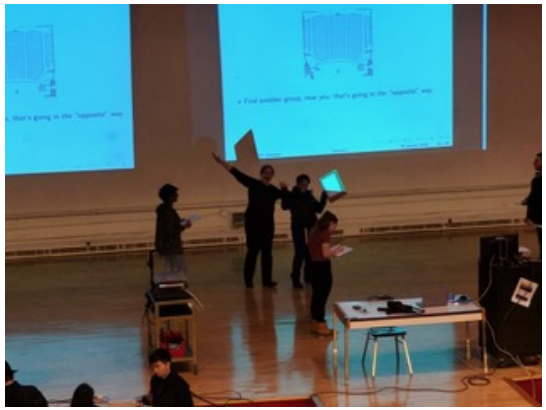
- On lecture slip, write down a topic you wish we had spent more time (and why).
- Top-down design: breaking into subproblems, and implementing each part separately.
- Excellent approach: can then test each part separately before adding it to a large program.
- When possible, design so that your code is flexible to be reused ("code reuse").
- Introduced a Python library, `Folium` for creating interactive HTML maps.
- Introduced `while` loops for repeating commands for an indefinite number of times.
- Pass your lecture slips to the aisles for the UTAs to collect.

Practice Quiz & Final Questions



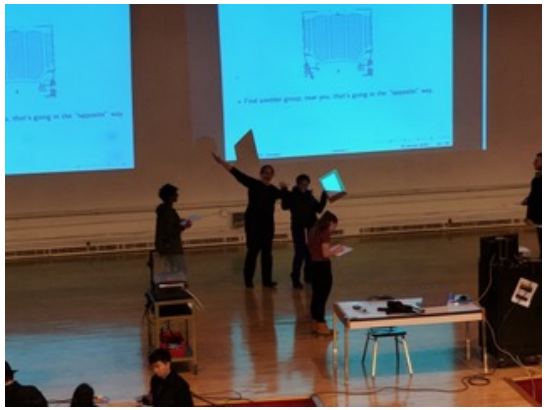
- Lightning rounds:

Practice Quiz & Final Questions



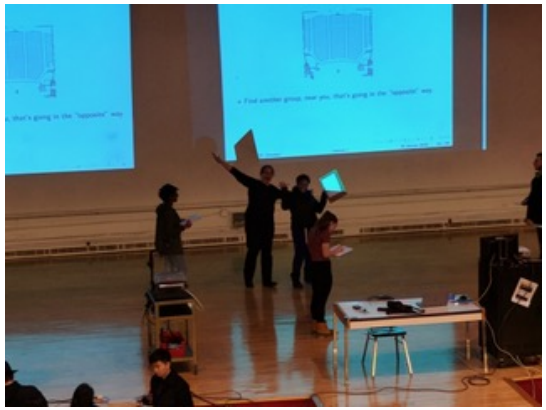
- Lightning rounds:
  - write as much you can for 60 seconds;

Practice Quiz & Final Questions



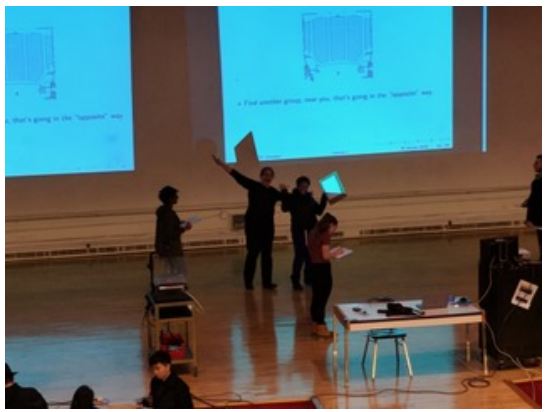
- Lightning rounds:
  - write as much you can for 60 seconds;
  - followed by answer; and

Practice Quiz & Final Questions



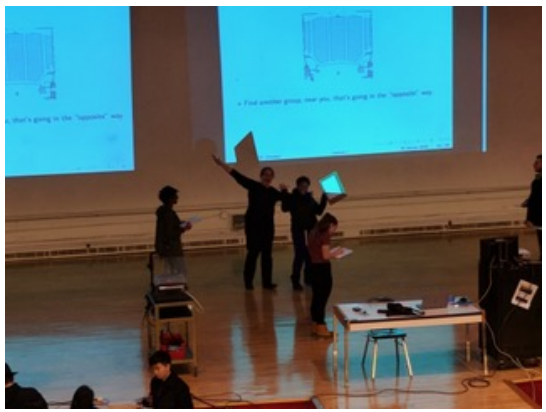
- Lightning rounds:
  - write as much you can for 60 seconds;
  - followed by answer; and
  - repeat.

Practice Quiz & Final Questions



- Lightning rounds:
  - write as much you can for 60 seconds;
  - followed by answer; and
  - repeat.
- Past exams are on the webpage (under Final Exam Information).

Practice Quiz & Final Questions



- Lightning rounds:
  - write as much you can for 60 seconds;
  - followed by answer; and
  - repeat.
- Past exams are on the webpage (under Final Exam Information).
- Theme: Functions & Top-Down Design (Summer 18, #7 & #5).