04-26-2023

CS051A

INTRO TO COMPUTER SCIENCE WITH TOPICS IN AI

24: Higher order functions

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Lectures

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Labs

Lecture 24: Higher order functions

- Higher order functions

Higher order functions

- Have you ever typed a function into the shell, but forgot the parentheses?

```
def my_function(x):
   return x+1
>>> my_function(2)
3
>>> my_function
<function my_function at 0x108e962f0>
>>> abs
<built-in function abs>
```

- Notice that it does NOT give an error.
    - Instead, it echoes the value, just like any other expression, in this case, the value is a function!

    ```
    >>> type(my_function)
    <class 'function'>
    ```

Higher order functions

- Functions in python are values, just like everything else!

  ```
  >>> y = my_function
  >>> y
  <function my_function at 0x108e962f0>
  >>> y(2)
  3
  >>> my_abs = abs
  >>> my_abs(-10)
  10
  ```

- we can pass them as parameters
- we can return them from functions
- we can even create them on the fly!

higher_order_functions.py

- What do the first four function in higher_order_functions.py do?
  - Take two arguments and do standard mathematical calculations
- What does add2 do in higher_order_functions.py?
  - Takes one parameter, a tuple of two items
  - Unpacks the tuple, adds and returns its items.
- What does double do in higher_order_functions.py?
  - Takes one parameter.
  - Multiplies by 2 and returns it.
- What does is_even do in higher_order_functions.py?
  - Takes one parameter, a number.
  - Returns whether this number is even.

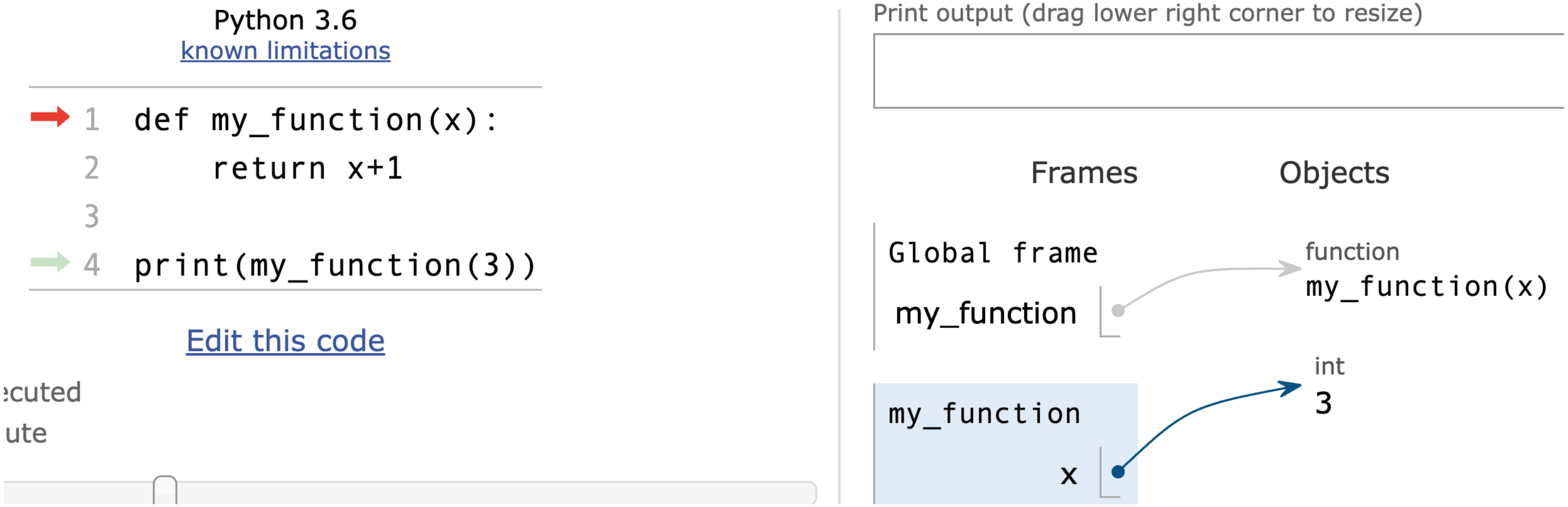
higher_order_functions.py

- What does apply_function do in higher_order_functions.py?
  - Takes three parameters
    - the first is a function!
    - applies the function passed as the first argument to the second and third argument and returns the result.
- We can call our apply_function function:

```
 >>> apply_function(add, 2, 3)
5
>>> apply_function(subtract, 2, 3)
 -1
```

- To pass a function as a parameter you just give the name of the function as the argument.
- def. What the keyword def actually does is:
  - create a new function
  - assign that function to a variable with the name of the function.

higher_order_functions.py



```
def my_function(x):
    return x+1

print(my_function(3))
```

https://pythontutor.com/visualize.html#mode=display

`higher_order_functions.py`

- What does the `apply_function_to_list` function do in `higher_order_functions.py`?
  - takes a function and a list as parameters
  - you can tell that the parameter `f` is a function because we apply it in the line with the append in it
  - iterates through each value in the list
  - applies the function `f`
  - appends the result of the function `f` to a list that is returned at the end.
- High-level: applies the function to each element in the list and returns a new list containing the result from each of those applications
- For example:

```
>>> apply_function_to_list(double, [1, 2, 3, 4])
[2, 4, 6, 8]
>>> apply_function_to_list(add2, [(1, 2), (3, 4)])
[3, 7]
```

higher_order_functions.py

- What does the apply_function_to_tuple function do in higher_order_functions.py?
  - takes a function and a list of two 2-tuples as parameters
  - The function should take two parameters
  - iterates through each 2-tuple in the list and unpacks it
  - applies the function f on the two items
  - appends the result of the function f to a list that is returned at the end.
- For example:

```
>>> apply_function_to_tuple(add, [(1, 2), (3, 4)])
[3, 7]
```

map

- `apply_function_to_list` is actually built in to python and is called `map`:

```
>>> help(map)
Help on class map in module builtins:
class map(object)
| map(func, *iterables) --> map object
|
| Make an iterator that computes the function using arguments from
| each of the iterables. Stops when the shortest iterable is exhausted.
```

- Takes as input a function and something that is iterable
  - only difference from `apply_function_to_list` is that it returns a map object (not a list), which is also iterable.

```
>>> map(double, [1, 2, 3, 4])
<map object at 0x7f7ff809b128>
>>> for val in map(double, [1, 2, 3, 4]):
        print(val)

2

4

6

8
```

map

- By itself, this may not seem useful, but we can do more complicated things. What would this print?

```
>>> for val in map(double, map(double, [1, 2, 3, 4])):
        print(val)
```

- The first map doubles it and then we iterate on this result and double it again!

`filter`

- What does the `filter_list` function do in `higher_order_functions.py` code?
    - Also takes a function `some_function` and a list `some_list` as parameters
- Are there any expectations on what `some_list` should do/return?
    - it's used in an `if` statement
    - it should return a `bool`, i.e. True or `False`
- Similarly to `map`, Python has a built-in function for this behavior called `filter`.
- The `filter` function returns a list of all elements of `some_list` that would return True when passed to `some_function`. Note how it differs from `map`.
- For example,

```
>>> list(map(is_even, [1, 2, 3, 4]))
[False, True, False, True]
>>> list(filter(is_even, [1, 2, 3, 4]))
[2, 4]
```

Lambda

- It can be a bit annoying having to write all of these simple functions to simply pass them as an argument to another function.
- Python allows us to create anonymous functions, i.e., functions that don't have an explicit name, but are simply code.
- The syntax is:
  `lambda <input>: <expression>`
- `<input>` is the parameter to the anonymous function.
  - If you need to pass multiple inputs, just pass them as a tuple.
- `<expression>` is the body of the function that is executed and returned. It can only be a single expression (i.e., something that represents a value).
- An example:

  ```
  >>> lambda x: x+1
  <function <lambda> at 0x7f7ff80981e0>
  ```

- Notice that it gives the same `function` type back, but it doesn't have a name!

  ```
  >>> (lambda x: x+1)(2)
  3
  ```

Lambda

- We can also associate it with a variable and call it, e.g.,

```
f = lambda x: x+1
>>> f(2)
3
```

- Makes life easier!

```
>>> filter_list(lambda num: num % 2 == 0, [1, 2, 3, 4])
[2, 4]
```

Lambda

- Let’s look at this unusual function that returns a… function

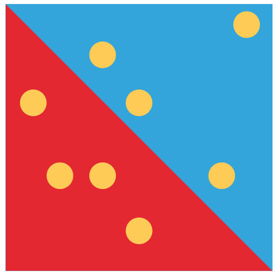
```
def kinda_crazy(num):
    def multiplier(x):
        return num * x
    return multiplier

>>>type(kinda_crazy(3))
<class 'function'>
>>>kinda_crazy(3)(2)
6
```

- We could use an anonymous function to be even more concise!

```
def crazy(num):
    return lambda x: num * x
>>> crazy(3)(2)
6
```

Monte Carlo sampling

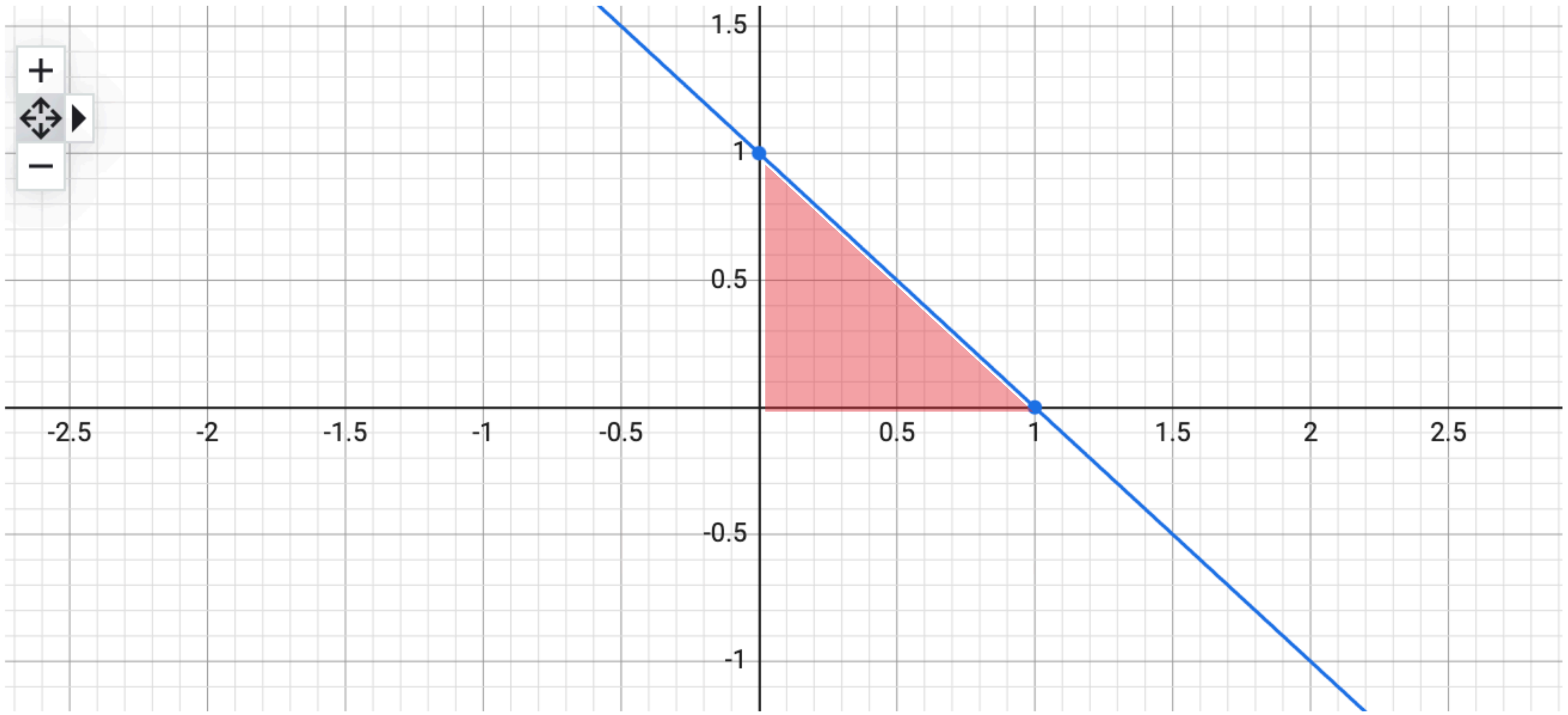
- Monte Carlo methods are a way of determining the answer to numerical problems via random sampling.
- General idea:
  - generate random samples
  - look at the outcome of those random samples
  - use the answer to the outcomes to estimate the answer for the original problem.
- An example: calculating the area of a shape
  - We want to calculate the area of a shape. Specifically, if I draw an arbitrary shape within a 1 by 1 box, can you tell me the area?
    - kind of hard!
  - What if I put a bunch of points uniformly in the box. Could I tell how many are inside the shape?
    - e.g., if I put 1000 points in the box with a triangle shape, how many would you expect in the triangle?
      - about 500
    - what would be the area of the triangle?
      - 500/1000 = 0.5
  - key idea: use the proportion of points that fall inside the shape to estimate the area.



`montecarlo.py`

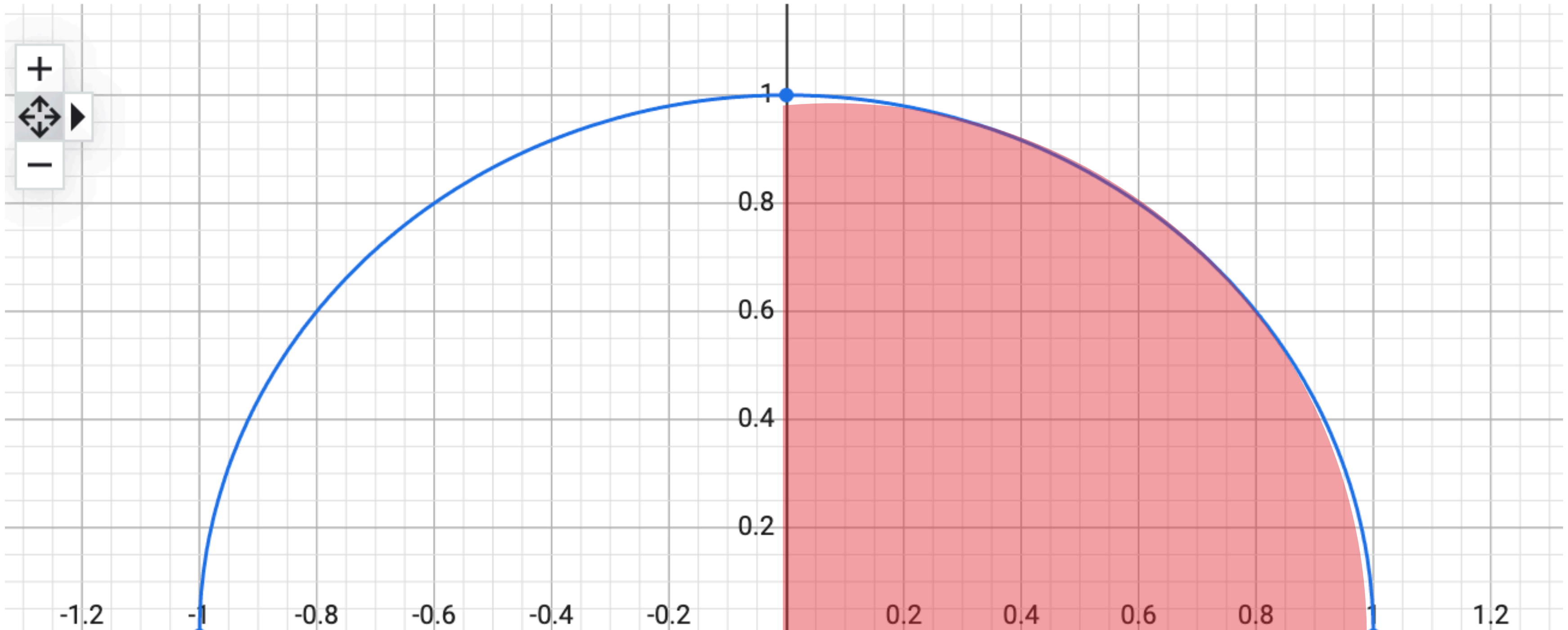
- Assuming $0 \leq x \leq 1$ and $0 \leq y \leq 1$ what does the `in_triangle` function do?
- Returns true if x and y are within the red triangle

Graph for 1-x



montecarlo.py

- Assuming $0 \leq x \leq 1$ and $0 \leq y \leq 1$ what does the does the `in_circle` function do?
- Returns true if x and y are inside the quarter circle.



montecarlo.py

- Write a function `monte_carlo` that takes two parameters: number of trials (samples) and a shape function
  - generate "trials" random points (x, y points between 0 and 1)
  - count how many are "inside" the shape
  - return the proportion, i.e., count/trials.
- Hint:
  - `import random`
  - `random.random() # returns random value between 0 and 1`

montecarlo.py

- Look at the `monte_carlo` function in `montecarlo.py` code
- We can use this to estimate the area of different shapes:

```
>>> monte_carlo(1000, in_triangle)
0.484
>>> monte_carlo(10000, in_triangle)
0.5005
>>> monte_carlo(100000, in_triangle)
0.49756
>>> monte_carlo(100000, in_circle)
0.7854
>>> monte_carlo(100000, in_circle)*4
3.14896
>>> monte_carlo(1000000, in_circle)*4
3.141972
>>> monte_carlo(10000000, in_circle)*4
3.141894
```

Resources

- higher-order_functions.py
- montecarlo.py

Homework

- Assignment 12 (cont'd)