F(unctional_programming)

Today in Python4LM:

- What is functional programming and why do I care?

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***Peak weirdness* will be achieved at the end of lecture!**

What *Really* are Functions?

First-Class Functions

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isinstance(echo, object) # => True
```

Functions are Objects!

What is Functional Programming?

Functional Programming – Overview

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  - **Declarative** – describe the problem to be solved, language implementation figures out the details. Examples: SQL, Prolog.
  - **Functional** – programs decompose into sets of functions, each of which takes inputs and produces outputs without internal state. Examples: Haskell, OCaml.

Python is a Multi-Paradigm Language

Supports many paradigms – programming is a choose-your-own adventure!

Functional Programming – Example

```python
# Procedural - "program flow"
def get_odds(arr):
    ret_list = []
    for elem in arr:
        if elem % 2 == 1:
            ret_list.append(elem)
    return ret_list
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    ret_list = []
    for elem in arr:
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# Functional - "programs are sets of functions"
def get_odds(arr):
    return list(filter(lambda elem: elem % 2 == 0, arr))
```

Why Functional Programming?

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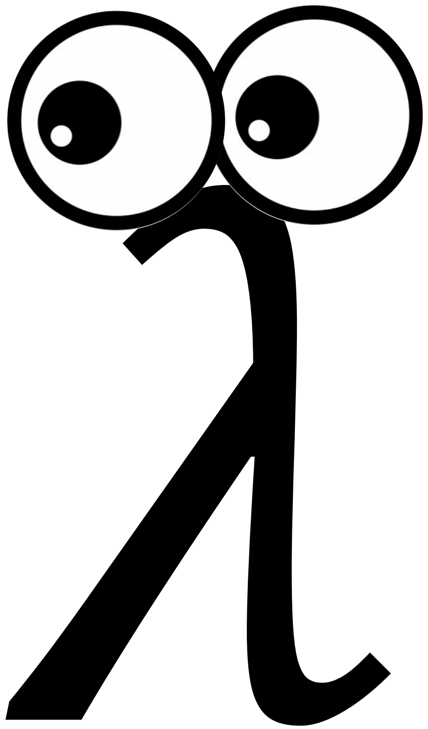
  - Fewer variables designed exclusively to, say, track an index.
- **Shorter, cleaner code** – recall the earlier example!
- **Modular** - functions are often reusable, so it’s faster to code the next thing. Also enables module-by-module testing and debugging.

Lambdas

Smaller, cuter functions!



Lambdas: Inline, Anonymous Functions

- Anonymous, on-the-fly functions, which can be passed as parameters into other functions.

```
>>> lambda params: expression
```

```
>>> # Check whether the first item in a pair (tuple) is greater than the
>>> # second
>>>
>>> lambda tup: tup[0] > tup[1]
```

Lambdas: Inline, Anonymous Functions

- Lambdas can customize the functionality of Python functions!

```
>>> # Find the maximum in a list of pairs by value of the second element.
>>>
>>> pairs = [(3, 2), (-1, 5), (4, 4)]
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- The whole point of a lambda is to be used inside a function call, then discarded. If we are binding it to a name to be called in the future, it may as well just be defined as a function!

The `map` Function

X Marks the Spot!

A Common Pattern

- Applying a function elementwise to an array, storing the result.

```
def length_of_all_elements(arr):
    ret_arr = []
    for elem in arr:
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>>> length_of_all_elements(["Parth", "Unicorn", "Michael"])
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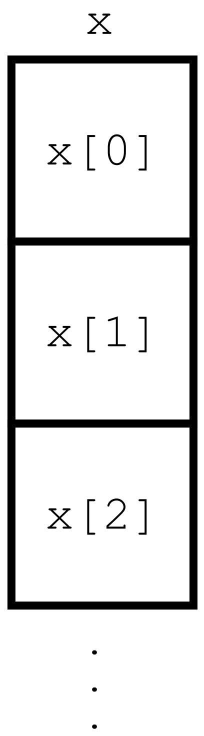

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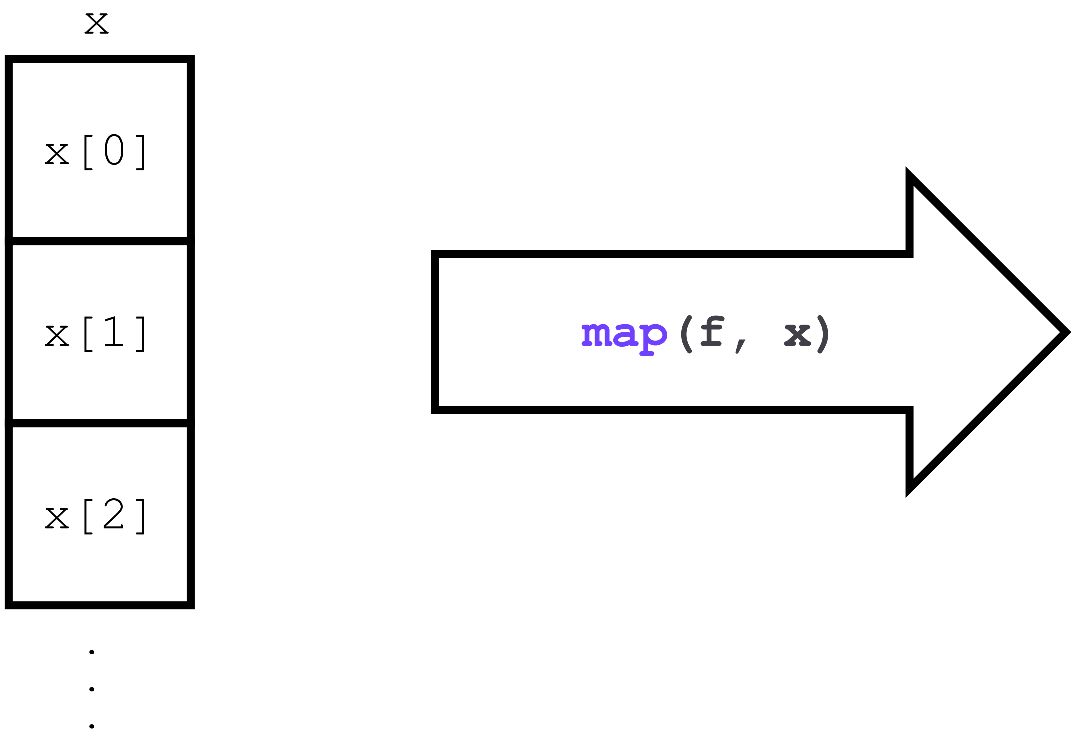

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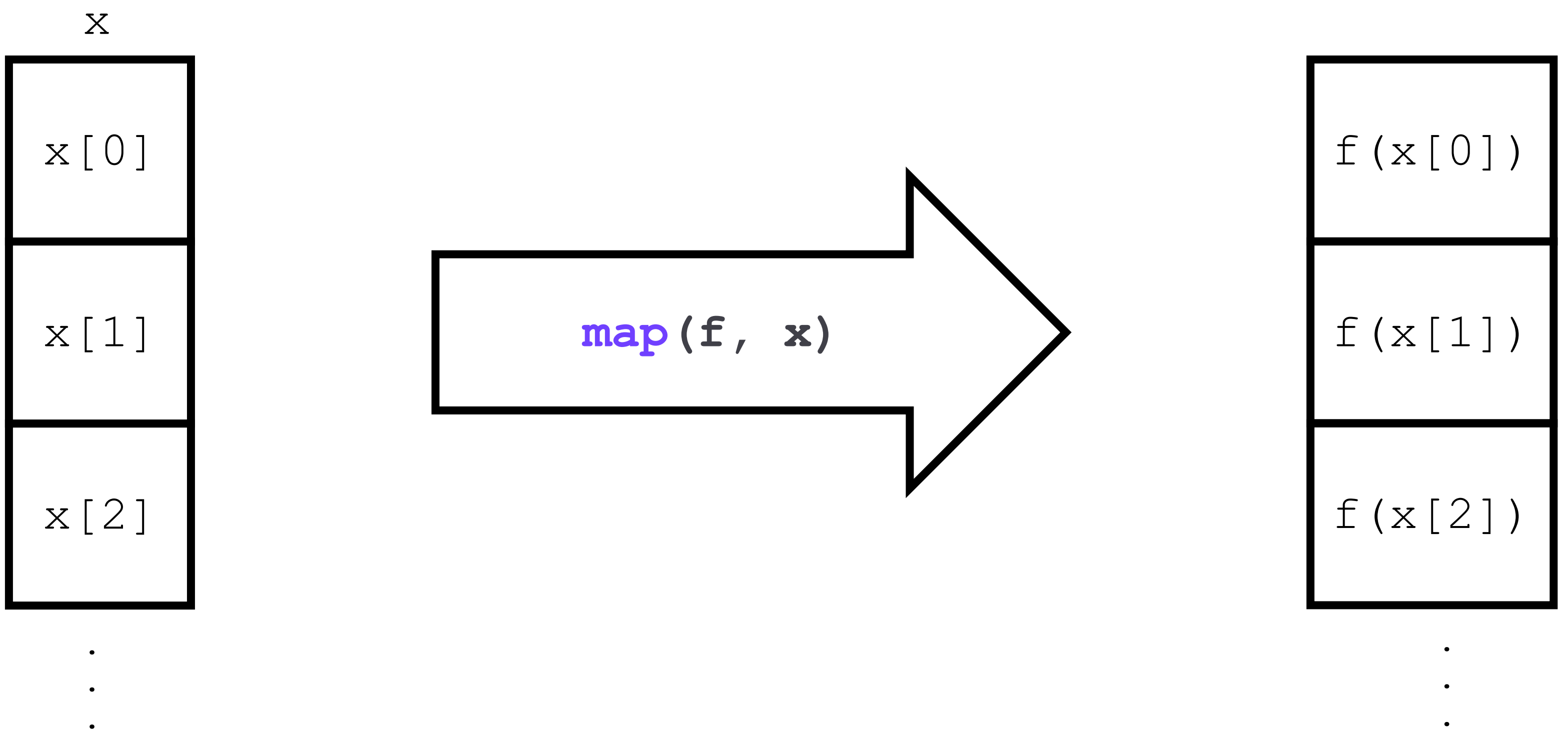

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```

The `filter` Function

#NoFilter #JokesDefinitelyAFilter

Another Common Pattern

- Extracting elements of an iterable which fulfill certain criteria.

```
def starts_with_m(arr):
    ret_arr = []
    for elem in arr:
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- As we saw earlier, we can use a list comprehension to construct a list, filtered by a conditional.

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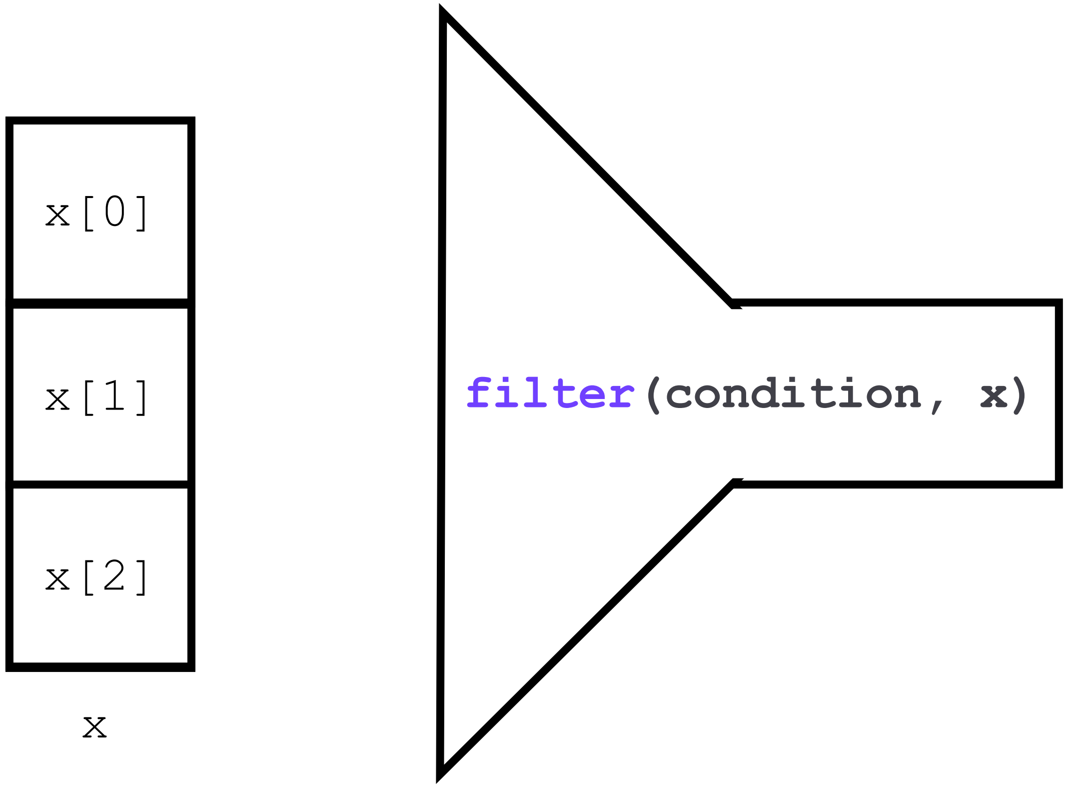

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Runtime and Space Considerations

- Memory
  - List comprehensions buffer all computed results.
  - Map/Filter compute elements only when called (more memory efficient!)
- Speed
  - List comprehensions don't have function call overhead. (The call to `map` or `filter` comes with extra overhead if you pass a lambda into it).
  - Filter/Map are occasionally faster, but the function call overhead usually means they are not.

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  - `with open("answers.txt") as f:`
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- Using `exit()` to end the program.
  - If imported as a module, this also exits the caller!

Iterators

An Old Example...

- Let’s revisit filtering out strings in a list that start with “M”.

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Why the conversion to `list`?

What’s Your Type?

- What do map and filter actually return?

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>>> arr = ["Parth", "Michael"]
>>> map_to_investigate = map(lambda x: x + "likes unicorns", arr)
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Iterators

- `map` and `filter` objects are iterators: represent a finite or infinite stream of data.
- Use the `next(iterator)` function to iterate through the elements of an iterator.
  - Raises `StopIteration` error upon termination.
- Use `iter(data_structure)` to build an iterator over a data structure.
  - E.g. `iter([1, 2, 3])` builds an iterator over a list

Example - Iterators

```
>>> names = ["Parth", "Michael", "Unicorn"]
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Example - Iterators

```
>>> names = ["Parth", "Michael", "Unicorn"]
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Traceback (most recent call last):
    File "<stdin>", line 1, in <module>
StopIteration
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For Loops Use Iterators

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# This code...
for data in data_source:
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For Loops Use Iterators

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# This code...
for data in data_source:
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# ...is equivalent to...
data_iter = iter(data_source)
while True:
    try:
        data = next(data_iter)
    except StopIteration:
        break
    else:
        do_something_to(data)
```

Reading Iterators

- Finite iterators can be read into data structures.

```
def starts_with_M(arr):
    return list(filter(lambda st: st[0].lower() == "m", arr))
```

Taking the output from an iterator, creating a `list` from it!

Generators

“Lazy List Comprehensions”

“Resumable Functions”

- Ordinary functions
  - Return a single, computed value

- Generators
  - Return an iterator that will generate a stream of values

“Resumable Functions”

- Ordinary functions
  - Return a single, computed value
  - Each call generates a new local namespace and new local variables.
  - Namespace is discarded upon exit.

- Generators
  - Return an iterator that will generate a stream of values
  - Local variables aren’t discarded upon suspension – pick up where you left off!

The Fibonacci Sequence

```python
# Let's write a generator to generate the Fibonacci sequence!
def fib():
    a, b = 0, 1
    while True:
        a, b = b, a+b
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1              # next(g) : 2, 3, 5, 8, 13, 21, 34...
>>>
```

The Fibonacci Sequence

```
# Let's write a generator to generate the Fibonacci sequence!
def fib():
    a, b = 0, 1
    while True:
        a, b = b, a+b
        yield a


>>> g = fib() # Namespace created, fib() pushed to stack.
>>> type(g)
<class 'generator'>
>>> next(g)
1
>>> next(g)
1              # next(g) : 2, 3, 5, 8, 13, 21, 34...
>>> max(g)       # What happens?
```

Lazy Generation

- We can use our generator to represent infinite streams of data in a finite way.
  - Since we can't work with the whole Fibonacci sequence – it's infinite – generators let us perform computation on elements of the sequence as we need to.

```
# Generating the Fibonacci sequence only on demand
def fibs_under(n):
    for num in fib(): # The generator we just made! Loops over 1, 1, 2...
        if num > n:
            break
        print(num)
```

Why Use Generators?

- Compute data on demand
    - Avoids expensive function calls
    - Reduces memory buffering

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  - Avoids expensive function calls
  - Reduces memory buffering

- Allows us to define infinite streams of data
  - We couldn't do this before!

Decorators

A Tale of Two Paradigms

Functions as Arguments

- We've already seen functions as arguments before!

```python
# We saw this in map and filter!
map(fn, iterable)
filter(fn, iterable)


# We can also write our own functions which take in functions as arguments
def do_twice(fn, *args):
    fn(*args)
    fn(*args)
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Parth is a wonderful person
Parth is a wonderful person
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Functions as Return Values

- We can also return functions from functions!

```
def make_divisibility_test(n):
    def is_divisible_by(m):
        return m % n == 0
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```


Is it too much to ask for both?

Decorators: Best of Both Worlds

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What in the world is this?
Pause for questions!

Using our Decorator

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def foo(a, b, c=1):
    return (a + b) * c



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Arguments: (2, 3) {}             # Printed from the debugging decorator
5                                # Returned from the function
>>> foo(2, 1, c=3)
Arguments: (2, 3) {'c': 1}       # Printed from the debugging decorator
9                                # Returned from the function
>>>
```

Making Things More Pythonic

```
def foo(a, b, c=1):
    return (a + b) * c

>>> foo = debug(foo)
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This isn't cool...

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This isn't cool...

This method of applying a decorator forces us to overwrite the namespace binding for "foo" in the global scope. Yuck!

Making Things More Pythonic

```
@debug
def foo(a, b, c=1):
    return (a + b) * c

>>> foo = debug(foo)
```

This new `@decorator` syntax applies a decorator at the time of function declaration.

Making Things More Pythonic

```
@debug
def foo(a, b, c=1):
    return (a + b) * c

>>> foo = debug(foo)   # This line becomes unnecessary!
```

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- Handle administrative logic (routing, permissions, etc.)

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- **Iterators/Generators** are useful for working with infinite – or finite, expensive – streams of data.
- **Decorators** are the neatest thing in the entire world.