Advanced Data Management (CSCI 680/490)

Python

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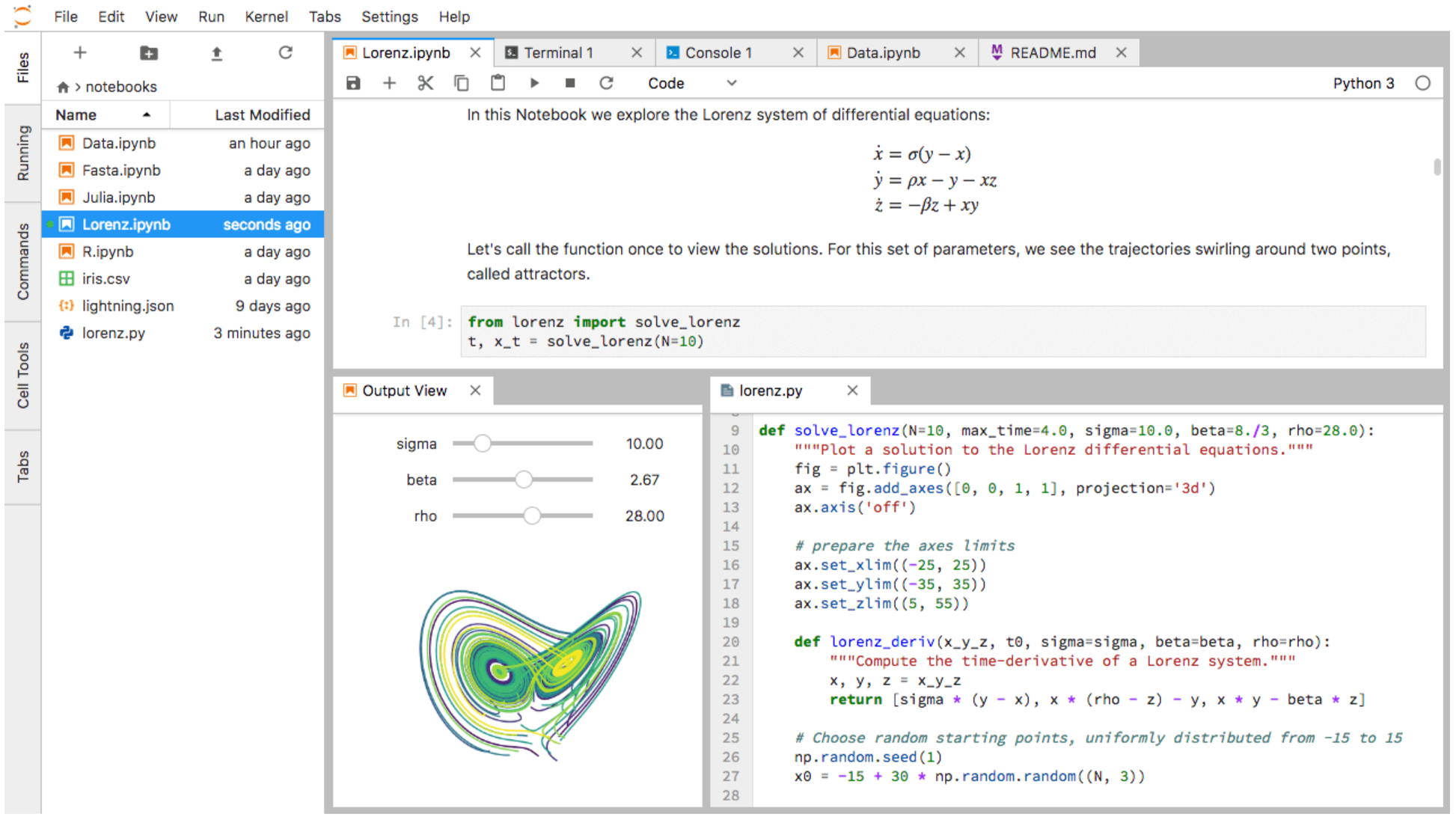
JupyterLab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Python 3
In this Notebook we explore the Lorenz system of differential equations:
$\dot{x} = \sigma(y - x)$
$\dot{y} = \rho x - y - xz$
$\dot{z} = -\beta z + xy$
Let's call the function once to view the solutions. For this set of parameters, we see the trajectories swirling around two points, called attractors.
In [4]:
from lorenz import solve_lorenz
t, x_t = solve_lorenz(N=10)
Output View
sigma 10.00
beta 2.67
rho 28.00
lorenz.py
def solve_lorenz(N=10, max_time=4.0, sigma=10.0, beta=8./3, rho=28.0):
"""Plot a solution to the Lorenz differential equations."""
fig = plt.figure()
ax = fig.add_axes([0, 0, 1, 1], projection='3d')
ax.axis('off')
# prepare the axes limits
ax.set_xlim((-25, 25))
ax.set_ylim((-35, 35))
ax.set_zlim((5, 55))
def lorenz_deriv(x_y_z, t0, sigma=sigma, beta=beta, rho=rho):
"""Compute the time-derivative of a Lorenz system."""
x, y, z = x_y_z
return [sigma * (y - x), x * (rho - z) - y, x * y - beta * z]
# Choose random starting points, uniformly distributed from -15 to 15
np.random.seed(1)
x0 = -15 + 30 * np.random.random((N, 3))

JupyterLab Notebooks

- Can write code or plain text (can be styled Markdown)
  - Choose the type of cell using the dropdown menu
- Cells break up your code, but all data is **global**
  - Defining a variable `a` in one cell means it is available in **any** other cell
  - This includes cells **above** the cell `a` was defined in!
- Remember **Shift+Enter** to execute
- Enter just adds a new line
- Use `?<function_name>` for help
- Use Tab for **auto-complete** or suggestions
- Tab also indents, and Shift+Tab unindents

Assignment 1

- To be released soon (planning on tomorrow)
- Using Python for data analysis
- Provided a1.ipynb file (right-click and download)
- Use basic python for now to demonstrate language knowledge
- Use Anaconda or hosted Python environment
- Turn .ipynb file in via Blackboard

Local Jupyter Environment

- www.anaconda.com/download/
- Anaconda has Jupyter Lab
- Use Python 3.9 version (**not** 2.7)
- Anaconda Navigator
  - GUI application for managing Python environment
  - Can install packages
  - Can start JupyterLab
- Can also use the shell to do this:
  - `$ jupyter lab`
  - `$ conda install <pkg_name>`

Hosted Jupyter Environments

- Nice to have ability to configure everything locally, but… you have to configure everything locally
- Solution: Cloud-hosted Jupyter (and Jupyter-like) environments
- Pros: No setup
- Cons: Limitations on resources: data and compute
- Options:
  - Google Colab (need a Google account)
  - Binder
  - JupyterLite

Using Hosted Jupyter Environments

- Data:
  - Either point to a public URL or upload the data
  - Large datasets may not be supported, data may be deleted if uploaded (and isn't in Google Drive, etc.)
- Notebooks:
  - Can download the notebook locally (e.g. to use with a conda environment)
  - Currently, Python 3.8
- Differences:
  - Colab has tweaked much of the interface (e.g. different nomenclature)

Questions about Python?

Why do we create and use functions?

Functions

- Calling functions is as expected:

```
mul(2,3) # computes 2*3 (mul from operator package)
```

  - Values passed to the function are parameters
  - May be variables!

```
a = 5
b = 7
mul(a,b)
```

- `print` is a function

```
print("This line doesn't end.", end=" ")
print("See it continues")
```

  - `end` is also a parameter, but this has a different syntax (keyword argument!)

Defining Functions

- `def` keyword
- Arguments have names but **no types**

```
def hello(name):
    print(f"Hello {name}")
```

- Can have defaults:

```
def hello(name="Jane Doe"):
    print(f"Hello {name}")
```

- With defaults, we can skip the parameter: `hello()` or `hello("John")`
- Also can pick and choose arguments:

```
def hello(name1="Joe", name2="Jane"):
    print(f"Hello {name1} and {name2}")
hello(name2="Mary")
```

Return statement

- Return statement gives back a value:

```
def mul(a,b):
    return a * b
```

- Variables changed in the function won't be updated:

```
def increment(a):
    a += 1
    return a
b = 12
c = increment(b)
print(b,c)
```

Python Containers

- Container: store more than one value
- Mutable versus immutable: Can we update the container?
  - Yes → mutable
  - No → immutable
  - Lists are mutable, tuples are immutable
- Lists and tuples may contain values of different types:
- List: `[1,"abc",12.34]`
- Tuple: `(1, "abc", 12.34)`
- You can also put functions in containers!
- `len` function: number of items: `len(l)`

Indexing and Slicing

- Just like with strings
- Indexing:
  - Where do we start counting?
  - Use brackets `[]` to retrieve one value
  - Can use negative values (count from the end)
- Slicing:
  - Use brackets plus a colon to retrieve multiple values: `[<start>:<end>]`
  - Returns a **new** list (`b = a[:]`)
  - Don't need to specify the beginning or end
  - Can add a second colon to specify the increment `[<start>:<end>:<step>]`

Tuples

- `months = ('January','February','March','April', 'May','June','July','August','September','October', 'November','December')`
- Useful when you know you're not going to change the contents or add or delete values
- Can index and slice
- Also, can create new tuples from existing ones:
  - `t = (1,2,3)`
    `u = (4,5,6)`
  - `v = t + u # v` points to a **new** object
  - `t += u # t` is a **new** object

Modifying Lists

- Add to a list l:
  - `l.append(v)`: add one value (`v`) to the end of the list
  - `l.extend(vlist)`: add multiple values (`vlist`) to the end of `l`
  - `l.insert(i, v)`: add one value (`v`) at index `i`
- Remove from a list `l`:
  - `del l[i]`: deletes the value at index `i`
  - `l.pop(i)`: removes the value at index `i` (and returns it)
  - `l.remove(v)`: removes the **first** occurrence of value `v` (careful!)
- Changing an entry:
  - `l[i] = v`: changes the value at index `i` to `v` (Watch out for `IndexError`!)

Modifying a list

- `v = [1,2,3]`
  `w = [4,5,6]`
- `x = v + w # x` is a **new** list `[1,2,3,4,5,6]`
- `v.extend(w) # v` is mutated to `[1,2,3,4,5,6]`
- `v += w # v` is mutated to `[1,2,3,4,5,6]`
- `v.append(w) # v` is mutated to `[1,2,3,[4,5,6]]`
- `x = v + 4 #` **error**
- `v += 4 #` **error**
- `v += [4] # v` is mutated to `[1,2,3,4]`

in: Checking for a value

- The `in` operator:
  - `'a' in l`
  - `'a' not in l`
- Not very fast for lists

For loops

- Used much more frequently than while loops
- Is actually a "for-each" type of loop
- In Java, this is:
  -
```
for (String item : someList) {
    System.out.println(item);
}
```
- In Python, this is:
  -
```
for item in someList:
    print(item)
```
- Grabs each element of `someList` in order and puts it into `item`
- Be careful modifying container in a for loop! (e.g. `someList.append(new_item)`)

What about counting?

- In C++:
- ```
  for(int i = 0; i < 100; i++) {
      cout << i << endl;
  }
  ```
- In Python:
- ```
  for i in range(0,100): # or range(100)
      print(i)
  ```
- `range(100)` vs. `list(range(100))`
- What about only even integers?

Exercise

- Given variables `x` and `y`, print the long division answer of `x` divided by `y` with the remainder.
- Examples:
  - `x = 11, y = 4` should print `"2R3"`
  - `x = 15, y = 2` should print `"7R1"`

Quiz

- Suppose I want to write Python code to print the numbers from 1 to 100. What errors do you see?

```
// print the numbers from 1 to 100
int counter = 1
while counter < 100 {
    print counter
    counter++
}
```

Quiz

- Suppose `a = ['a', 'b', 'c', 'd']` and `b = (1, 2, 3)`
- What happens with?
  - `a[0]`
  - `a[1:2]`
  - `b[:-2]`
  - `b.append(4)`
  - `a.extend(b)`
  - `a.pop(0)`
  - `b[0] = "100"`
  - `b + (4,)`

Quiz

- Suppose `a = ['a', 'b', 'c', 'd']` and `b = (1, 2, 3)`
- What happens with?
  - `a[0] # 'a'`
  - `a[1:2] # ['b']`
  - `b[:-2] # (1,)`
  - `b.append(4) # error`
  - `a.extend(b) # ['a', 'b', 'c', 'd', 1, 2, 3]`
  - `a.pop(0) # 'a' with side effect a becomes ['b', 'c', 'd']`
  - `b[0] = "100" # error`
  - `b + (4,) # (1,2,3,4)`

Dictionaries

- One of the most useful features of Python
- Also known as associative arrays
- Exist in other languages but a core feature in Python
- Associate a key with a value
- When I want to find a value, I give the dictionary a key, and it returns the value
- Example: InspectionID (key) → InspectionRecord (value)
- Keys must be immutable (technically, hashable):
  - Normal types like numbers, strings are fine
  - Tuples work, but lists do not (TypeError: unhashable type: 'list')
- There is only one value per key!

Dictionaries

- Defining a dictionary: curly braces
- `states = {'MA': 'Massachusetts, 'RI': 'Road Island', 'CT': 'Connecticut'}`
- Accessing a value: use brackets!
- `states['MA']` or `states.get('MA')`
- Adding a value:
- `states['NH'] = 'New Hampshire'`
- Checking for a key:
- `'ME' in states` → returns `True` or `False`
- Removing a value: `states.pop('CT') or del states['CT']`
- Changing a value: `states['RI'] = 'Rhode Island'`

Dictionaries

- Combine dictionaries: `d1.update(d2)`
  - `update` overwrites any key-value pairs in `d1` when the same key appears in `d2`
  - `d1 | d2`
- `len(d)` is the number of entries in `d`

Extracting Parts of a Dictionary

- `d.keys()`: the keys only
- `d.values()`: the values only
- `d.items()`: key-value pairs as a collection of tuples:
  `[(k1, v1), (k2, v2), …]`
- Unpacking a tuple or list

```
- t = (1,2)
  a, b = t
```

- Iterating through a dictionary:

```
for (k,v) in d.items():
    if k % 2 == 0:
        print(v)
```

- Important: keys, values, and items are in added order!

Example: Counting Letters

- Write code that takes a string `s` and creates a dictionary with that counts how often each letter appears in `s`
- `count_letters("Mississippi")` →
  `{'s': 4, 'i': 4, 'p': 2', …}`

Sets

- Just the keys from a dictionary
- Only one copy of each item
- Define like dictionaries without values
  - `s = {'a','b','c','e'}`
  - `'a' in s # True`
- Mutation
  - ```
    s.add('f')
    s.add('a') # only one copy
    s.remove('c')
    ```
- One gotcha:
  - `{}` is an empty **dictionary** not an empty set
    ```

Nesting Containers

- Can have lists inside of lists, tuples inside of tuples, dictionaries inside of dictionaries
- Can also have dictionaries inside of lists, tuples inside of dictionaries, …
-
```
d = {"Brady": [(2015, 4770, 36), (2014, 4109, 33)],
     "Luck": [(2015, 1881, 15), (2014, 4761, 40)],
     …
    }
```

- JavaScript Object Notation (JSON) looks very similar for literal values; Python allows variables in these types of structures

Nesting Code

- Can have loops inside of loops, if statements inside of if statements
- Careful with variable names:
- ```
  l = {0: 0, 1: 3, 4: 5, 9: 12}
  for i in range(100):
      square = i ** 2
      max_val = l[square]
      for i in range(max_val):
          print(i)
  ```
- Strange behavior, likely unintended, but Python won't complain!
  ```

None

- Like null in other languages, used as a placeholder when no value exists
- The value returned from a function that doesn't return a value

```
def f(name):
    print("Hello,", name)
v = f("Patricia") # v will have the value None
```

- Also used when you need to create a new list or dictionary:

```
def add_letters(s, d=None):
    if d is None:
        d = {}
    d.update(count_letters(s))
```

- Looks like `d={}` would make more sense, but that causes issues
- `None` serves as a **sentinel** value in `add_letters`

is and ==

- `==` does a normal equality comparison
- `is` checks to see if the object is the exact same object
- Common style to write statements like `if d is None: …`
- Weird behavior:

```
- a = 4 - 3
  a is 1 # True
- a = 10 ** 3
  a is 1000 # False
- a = 10 ** 3
  a == 1000 # True
```

- Generally, avoid `is` unless writing `is None`

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- a = 4 - 3
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```

Python caches common integer objects

- Generally, avoid `is` unless writing `is None`

Objects

- `d = dict() # construct an empty dictionary object`
- `l = list() # construct an empty list object`
- `s = set() # construct an empty set object`
- `s = set([1,2,3,4]) # construct a set with 4 numbers`
- Calling methods:
  - `l.append('abc')`
  - `d.update({'a': 'b'})`
  - `s.add(3)`
- The method is tied to the object preceding the dot (e.g. `append` modifies `l` to add `'abc'`)

Python Modules

- Python module: a file containing definitions and statements
- Import statement: like Java, get a module that isn't a Python builtin

```
import collections
d = collections.defaultdict(list)
d[3].append(1)
```

- `import <name> as <shorter-name>`

```
import collections as c
```

- `from <module> import <name>` : don't need to refer to the module

```
from collections import defaultdict
d = defaultdict(list)
d[3].append(1)
```

Other Collections

- `collections.defaultdict`: specify a default value for any item in the dictionary (instead of `KeyError`)
- `collections.OrderedDict`: keep entries ordered according to when the key was inserted
  - `dict` objects are ordered in Python 3.7 but `OrderedDict` has some other features (equality comparison, reversed)
- `collections.Counter`: counts hashable objects, has a `most_common` method

Example: Counting Letters

- Write code that takes a string `s` and creates a dictionary with that counts how often each letter appears in `s`
- `count_letters("Mississippi")` →
  `{'s': 4, 'i': 4, 'p': 2', …}`

Solution using Counter

- Use an existing library made to count occurrences

```
from collections import Counter
Counter("Mississippi")
```

- produces

```
Counter({'M': 1, 'i': 4, 's': 4, 'p': 2})
```

- Improve: convert to lowercase first