Advanced Data Management (CSCI 490/680)

Python

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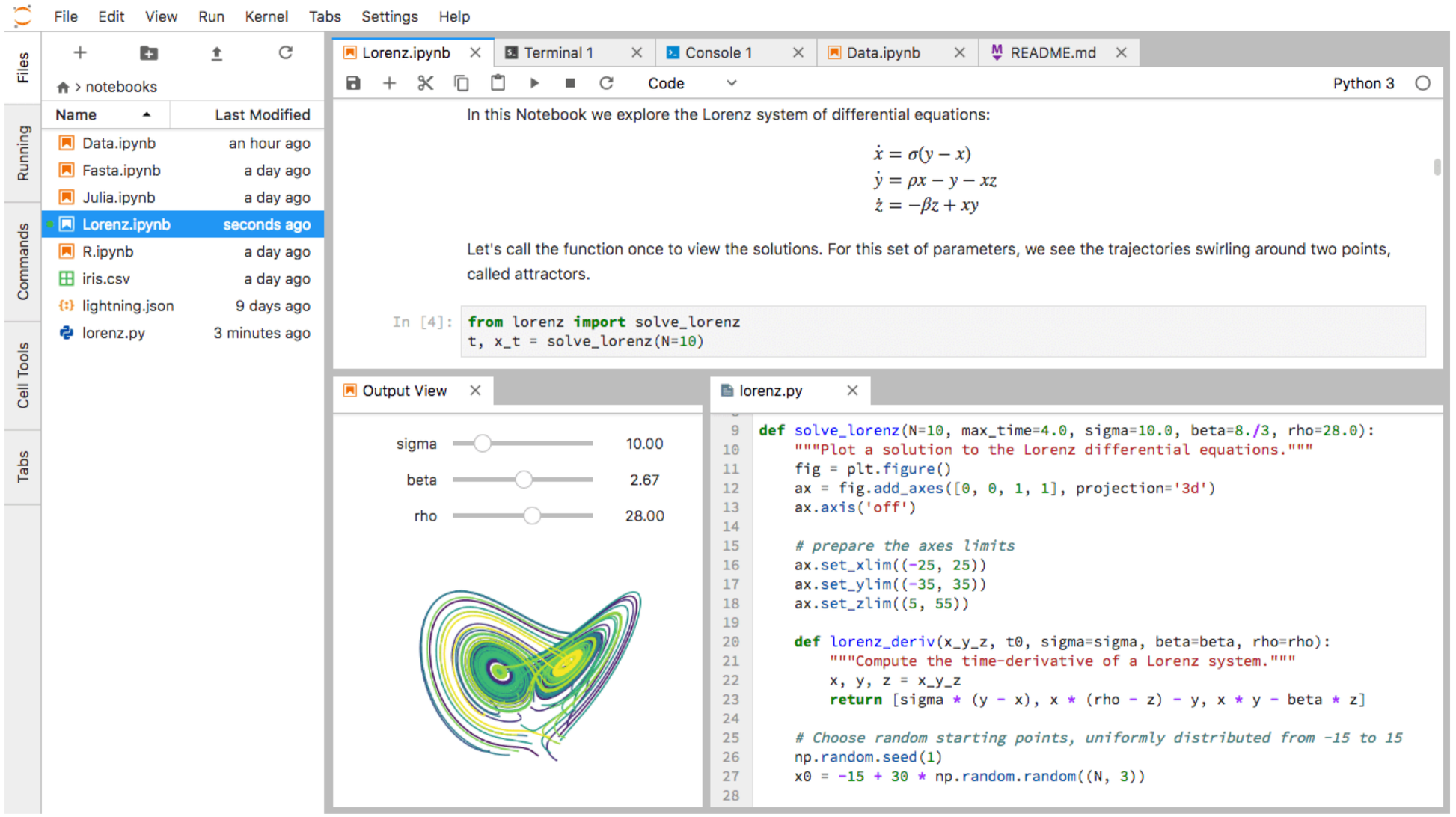
JupyterLab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In this Notebook we explore the Lorenz system of differential equations:
$\dot{x} = \sigma(y - x)$
$\dot{y} = \rho x - y - xz$
$\dot{z} = -\beta z + xy$
Let's call the function once to view the solutions. For this set of parameters, we see 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 that variable is accessible 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

Python

- Started in December 1989 by Guido van Rossum
- “Python has surpassed Java as the top language used to introduce U.S. students to programming…” (ComputerWorld, 2014)
- Python and R are the two top languages for data science
- High-level, interpreted language
- Supports multiple paradigms (OOP, procedural, imperative)
- Help programmers write **readable** code
- Use less code to do more
- Lots of libraries for python
  - Designed to be extensible

Python Compared to C++ and Java

- Dynamic Typing
  - A variable does not have a fixed type
  - Example: `a = 1; a = "abc"`
- Indentation
  - Braces define blocks in Java, good style is to indent but not required
  - Indentation is **critical** in Python

```
z = 20
if x > 0:
    if y > 0:
        z = 100
else:
    z = 10
```

Python Variables and Types

- No type declaration necessary
- Variables are names, not memory locations

```
a = 0
a = "abc"
a = 3.14159
```

- Don't worry about types, but think about types
- Strings are a type
- Integers are as big as you want them
- Floats can hold large numbers, too (double-precision)

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"`

Loops

- ```
  while <condition>:
      <indented block>
  # end of while block (indentation done)
  ```
- Remember the colon!
- ```
  a = 5
  while a > 0:
      print(a)
      a -= 2
  ```
- `a > 0` is the condition
- Python has standard boolean operators (`<, >, <=, >=, ==, !=`)
  - What does a boolean operation return?
  - Linking boolean comparisons (`and, or`)

break and continue

- `break` stops the execution of the loop
- `continue` skips the rest of the loop and goes to the next iteration

-
```
a = 7
while a > 0:
    a -= 2
    if a < 4:
        break
    print(a)
```

-
```
a = 7
while a > 0:
    a -= 2
    if a < 4 and a > 2:
        continue
    print(a)
```

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++
}
```

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

Quiz

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

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!)

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)`)

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!

Sets

- Sets are like dictionaries but without any values:
- `s = {'MA', 'RI', 'CT', 'NH'}; t = {'MA', 'NY', 'NH'}`
- `{}` is an empty dictionary, `set()` is an empty set
- Adding values: `s.add('ME')`
- Removing values: `s.discard('CT')`
- Exists: `"CT" in s`
- Union: `s | t => {'MA', 'RI', 'CT', 'NH', 'NY'}`
- Intersection: `s & t => {'MA', 'NH'}`
- Exclusive-or (xor): `s ^ t => {'RI', 'CT', 'NY'}`
- Difference: `s - t => {'RI', 'CT'}`

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

About this course

- Course web page is authoritative:
  - http://faculty.cs.niu.edu/~dakoop/cs680-2020sp
  - Schedule, Readings, Assignments will be posted online
  - Check the web site before emailing me
- Course is meant to be more "cutting edge"
  - Still focus on building skills related to data management
  - Tune into current research and tools
- Requires student participation: readings and discussions
- Exam Dates: Feb. 18, March 26, May 5 (final)

Assignment 1

- Using Python for data analysis
- Analyze hurricane data (through 2018)
- Provided a1.ipynb file (right-click and download)
- Use basic python (+ collections module) for now to demonstrate language knowledge
- Use Anaconda or hosted Python environment
- Due next Wednesday
- Turn .ipynb file in via Blackboard

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:
  - Azure Notebooks (can use your NIU account)
  - Google Colab (need a Google account)
  - Binder
  - Others…

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 3.6
- Differences:
  - Colab has tweaked much of the interface (e.g. different nomenclature)
  - Azure is, for the most part, running Jupyter
  - Azure is more of a preview than Colab

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 = 10 ** 3
  a == 1000 # True
```

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

Iterators

- Remember `range, values, keys, items`?
- They return **iterators**: objects that traverse containers, only need to know how to get the next element
- Given iterator `it, next(it)` gives the next element
- `StopIteration` exception if there isn't another element
- Generally, we don't worry about this as the for loop handles everything automatically…but you cannot index or slice an iterator
- `d.values()[0]` will not work!
- If you need to index or slice, construct a list from an iterator
- `list(d.values())[0]` or `list(range(100))[-1]`

List Comprehensions

- Shorthand for transformative or filtering for loops
- ```
  squares = []
  for i in range(10):
      squares.append(i**2)
  ```
- ```
  squares = [i**2 for i in range(10)]
  ```
- Filtering:
- ```
  squares = []
  for i in range(10):
      if i % 3 != 1:
          squares.append(i ** 2)
  ```
- ```
  squares = [i**2 for i in range(10) if i % 3 != 1]
  ```
- if clause **follows** the for clause

Dictionary Comprehensions

- Similar idea, but allow dictionary construction
- Could use lists:
  - `names = dict([(k, v) for k,v in … if …])`
- Native comprehension:
  - ```
    names = {"Al": ["Smith", "Brown"], "Beth":["Jones"]}
    first_counts ={k: len(v) for k,v in names.items()}
    ```
- Could do this with a for loop as well
    ```