Pandas and Numpy

Welcome back to CS 2100!

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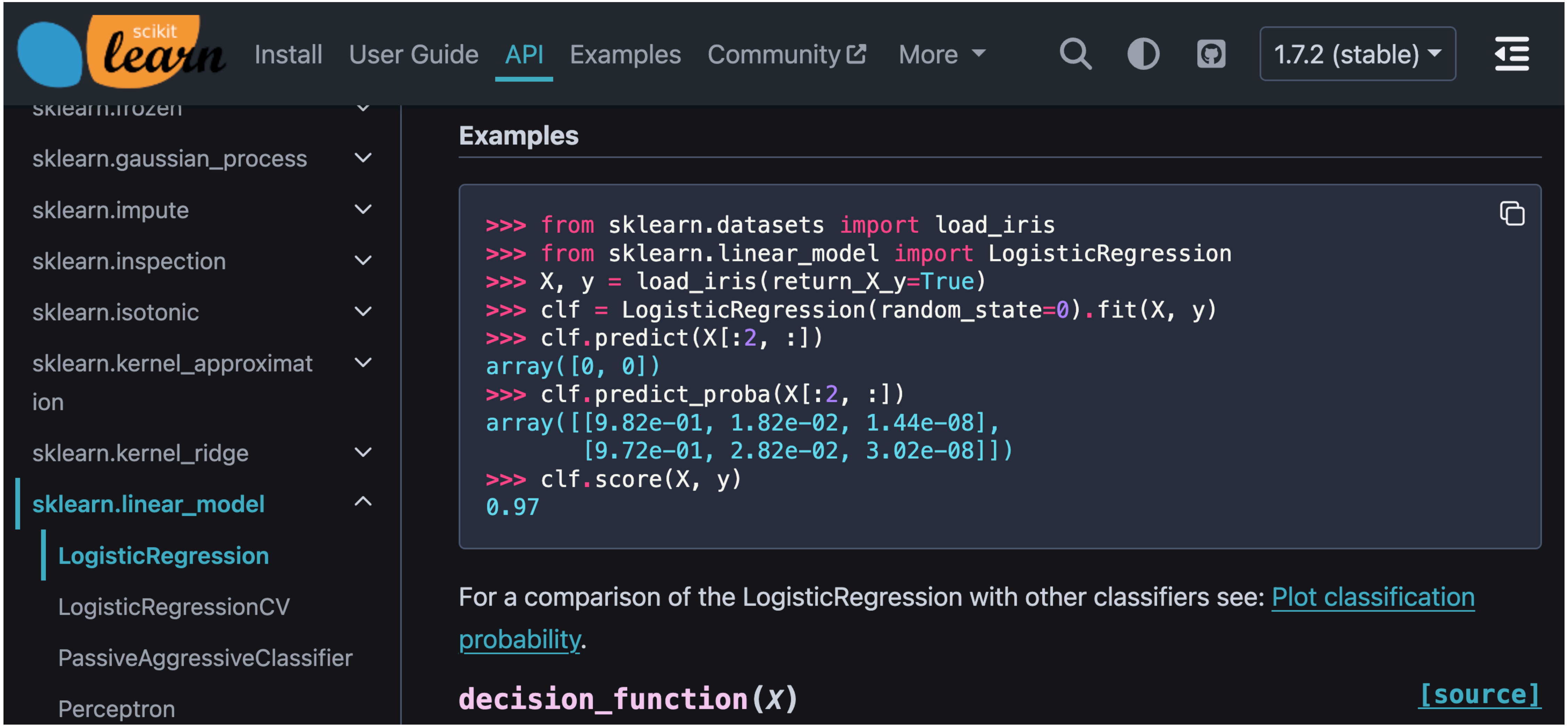
Data Science

Effectively storing, manipulating, and analyzing collections of data

POV you're a data scientist who needs an example for how to do "logistic regression" in Python



Examples

```
>>> from sklearn.datasets import load_iris
>>> from sklearn.linear_model import LogisticRegression
>>> X, y = load_iris(return_X_y=True)
>>> clf = LogisticRegression(random_state=0).fit(X, y)
>>> clf.predict(X[:2, :])
array([0, 0])
>>> clf.predict_proba(X[:2, :])
array([[9.82e-01, 1.82e-02, 1.44e-08],
       [9.72e-01, 2.82e-02, 3.02e-08]])
>>> clf.score(X, y)
0.97
```

For a comparison of the LogisticRegression with other classifiers see: Plot classification probability.

`decision_function(X)` [source]

Python's two built-in categories of sequential types:

Containers (list, tuple)

Store references to objects stored externally

- Takes more space to store -- each element is a separate object with its own header containing metadata
- Iteration is slower -- Python jumps between memory locations to access each element

Flat Sequences (str, bytes, array)

Raw value elements stored internally within the sequence

- Stored in consecutive memory locations
- Elements MUST be same type
- Fast iteration
- Efficient multi-dimensional data (matrices)

Good for math and data processing

Arrays: efficient for storing numbers

```python
from array import array

a = array("l", [1, 2, 3])

print(type(a))
print(a[0])
```

```
<class 'array.array'>
1
```

Arrays are built in to Python

NumPy Arrays:

Container format for passing data between compatible scientific computing libraries such as SciPy and Pandas

```python
import numpy as np

v1 = np.array([
    [1, 2, 3],
    [4, 5, 6]
])

print(v1)
print("v1 Python type:", type(v1))
print("NumPy array type:", v1.dtype)
print("v1 as python list:", v1.tolist())
```

You may need to `pip install numpy`

Numpy (Numerical Python)

- a library that provides data structures and algorithms for numeric applications
- developed in 2005 by Travis Oliphant by combining Numeric and Numarray projects

Live-coding: get the sum of `n` number of dice rolls

Hint: generate 20 (4x5) random integers between a lower (inclusive) and upper (exclusive) bound like this:

```python
from typing import Any
import numpy as np

nums: np.ndarray[Any, np.dtype[np.int64]] =
        np.random.randint(10, 20, size=(4,5))

print(nums)
```

```
[[10 13 17 10 19]
 [13 15 11 12 11]
 [13 10 16 17 19]
 [13 18 12 14 12]]
```

Poll: What is this function doing?

```python
def something(n: int) -> np.ndarray:
    matrix = np.random.randint(n, size=(n, n))
    return np.mean(matrix, axis=1)
```

1. It creates a vector of length 1 (just one number) which is the average of `n` random numbers between 0 and `n`
2. It creates a vector of length `n`, and each element in it is the average of `n` random numbers between 0 and `n`
3. It creates a vector of length 1 which is the average of `n` squared random numbers between 0 and `n`
4. It creates a vector of length `n`, and each element in it is a random number between 0 and `n`

Reshaping vectors

```python
import numpy as np

a = np.arange(6)
print(a)

print("\nReshape")
a.shape = (2, 3)
print(a)

print("\nTranspose")
print(a.transpose())
```

```
[0 1 2 3 4 5]

Reshape
[[0 1 2]
 [3 4 5]]

Transpose
[[0 3]
 [1 4]
 [2 5]]
```

Doing this using Python lists would be a nightmare!

POV you want to add two lists of numbers, but elementwise rather than concatenating them

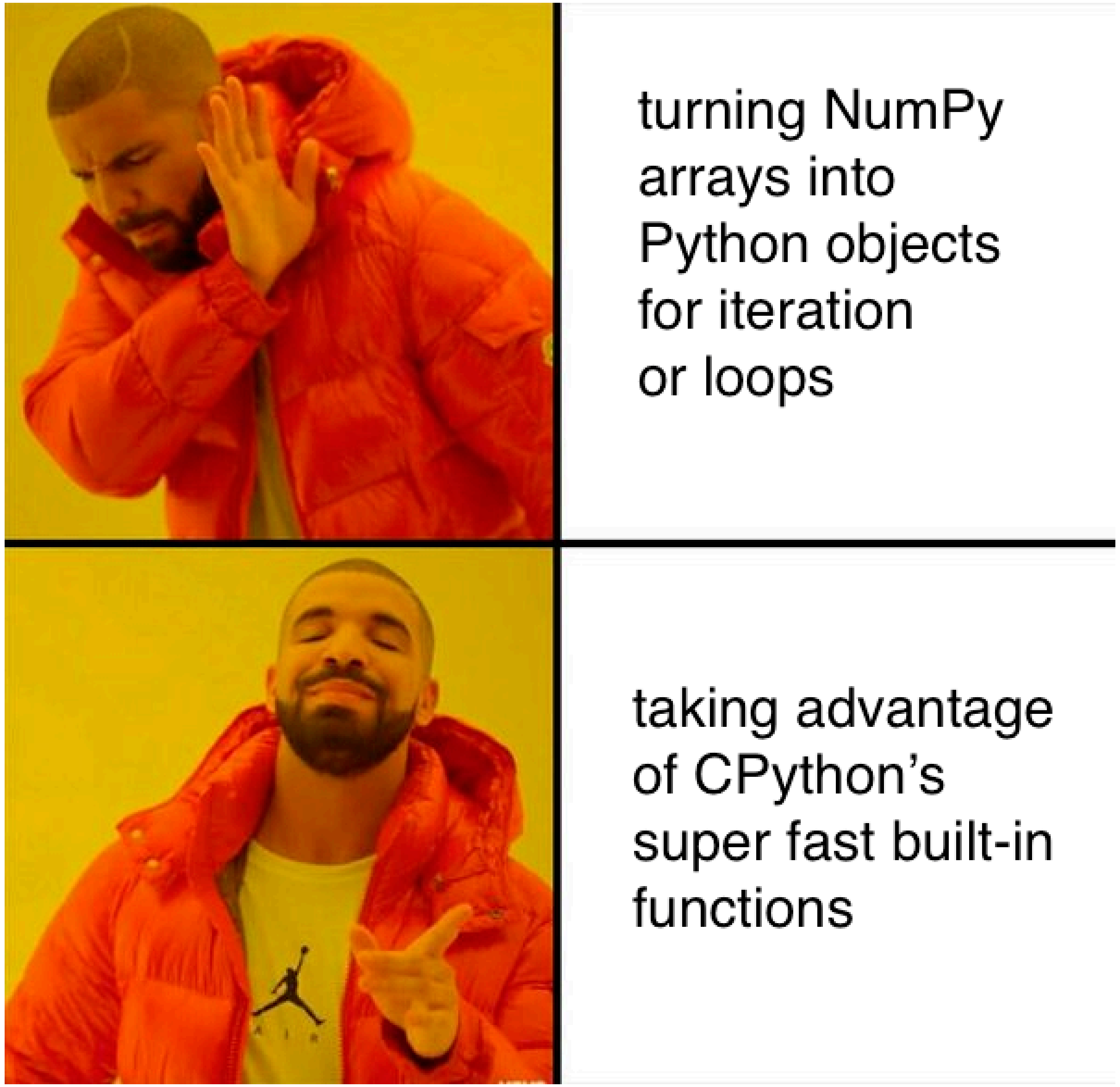
```
v1 = np.array([
    [1, 2, 3],
    [4, 5, 6]
])

v2 = np.array([
    [7, 8, 9],
    [0, 0, 0]
])

print(v1 + v2)
```

```
[[ 8 10 12]
 [ 4  5  6]]
```

List comprehension is nice… but not as efficient as NumPy arrays


turning NumPy arrays into Python objects for iteration or loops
taking advantage of CPython's super fast built-in functions

Adding arrays where only one of the side lengths match

```python
v1 = np.array([
    [1, 2, 3],
    [4, 5, 6]
])

v2 = np.array(
    [7, 8, 9],
)

print(v1 + v2)
```

```
[[ 8 10 12]
 [11 13 15]]
```

If two vectors being added have different dimensions, it will raise a `ValueError`.
The exception: if one of the vectors is 1D, with a length equal to the length of each row in the other vector, it will add that vector to each row (broadcasting).

Other operations which are different in NumPy arrays versus lists:

Operation	List	NumPy Array
Adding	Concatenating	Elementwise addition
Multiplying	Repeatedly concatenating	
Length	Number of elements	

Other operations which are different in NumPy arrays versus lists:

Operation	List	NumPy Array
Adding	Concatenating	Elementwise addition
Multiplying	Repeatedly concatenating	Elementwise multiplication
Length	Number of elements	

Other operations which are different in NumPy arrays versus lists:

Operation	List	NumPy Array
Adding	Concatenating	Elementwise addition
Multiplying	Repeatedly concatenating	Elementwise multiplication
Length	Number of elements	Norm (distance from origin)

Another thing data scientists do often:

Work with spreadsheets of data

But using `open('file.csv'. 'r')` to iterate through the file and read it line-by-line is a common but tedious thing -- there must be a library

Pandas: a library for manipulating tabular data (spreadsheets)

- developed by Wes McKinney in 2008
- name derived from the term Panel Data
- designed to perform data analaysis and visualisation
- uses NumPy arrays to store underlying data

You may need to:

1. `pip install pandas`
2. `pip install pandas-stubs`

Main Pandas data types:

- Series: one-dimensional labelled arrays of any data type
- DataFrames: two-dimensional labelled arrays of any data type
- Time series: index at data times
- Panel: three-dimensional container of data

Creating a basic dataframe in Pandas

```python
import pandas as pd

df = pd.DataFrame(
    {'Person': ['Elephant', 'Cat'],
    'Age': [13, 10]})
print(df)
```

```
     Person  Age
0       Cat   10
1  Elephant   13
```

Read in a dataframe that is stored in a CSV file

CSV = a spreadsheet stored as Comma-Separated Values

data.csv:

```
Person,Age
Cat,10
Elephant,13
```

Code to read it as a dataframe:

```
df = pd.read_csv('/path/to/data.csv')
```

Code to put a dataframe into a new CSV:

```
df.to_csv('new_file.csv')
```

Exercise:

```
data = {
    'title': ['The Matrix', 'Inception', 'Interstellar', 'Blade Runner'],
    'year': [1999, 2010, 2014, 1982],
    'rating': [8.7, 8.8, 8.6, 8.1]
}
df = pd.DataFrame(data)
```

Let's:

- get the average rating
- print a sentence like `"The Matrix was released in 1999"` for each movie
- add a new movie `"Dune"` with `year=2021` and `rating=8.0`

Common Pandas operations: selecting a column

```
print(list(df['Age']))  # [10, 13]

print(df['Age'])
```

```
0    10
1    13
Name: Age, dtype: int64
```

Common Pandas operations: iterating through rows

```python
for index, row in df.iterrows():
    print(f'Row number {index}:\n{row}\n')
```

```
Row number 0:
Person    Cat
Age        10
Name: 0, dtype: object

Row number 1:
Person    Elephant
Age             13
Name: 1, dtype: object
```

Common Pandas operations: iterating through rows

Each row is a dict

```
for index, row in df.iterrows():
    print(f"{row['Person']}'s age is {row['Age']}")
```

```
Cat's age is 10
Elephant's age is 13
```

Common Pandas operations: adding more rows

Create another dataframe and use `concat()` to concatenate them

```
new_rows = pd.DataFrame({
    'Person': ['Dog', 'Giraffe'],
    'Age': [3, 6]})

df = pd.concat([df, new_rows], ignore_index=True)
print(df)
```

```
     Person  Age
0       Cat   10
1  Elephant   13
2       Dog    3
3   Giraffe    6
```

Common Pandas operations: adding more columns

```python
df['BFF'] = ['Cat', 'Giraffe', 'Cat', 'Elephant']
print(df)
```

```
     Person  Age       BFF
0       Cat   10       Cat
1  Elephant   13   Giraffe
2       Dog    3       Cat
3   Giraffe    6  Elephant
```

(BFF = best friend forever)

We will do more Pandas operations (like sorting and filtering) in Lecture 15.

Poll: How can I find the age of the oldest person in `df`?

1. `df(max['Age'])`
2. `max(df['Age'])`
3. `max(row['Age'] for _, row in df.iterrows())`
4. `max('Age' for _, row in df.iterrows())`

Raising Errors

Like this `ZeroDivisionError`:

```python
def int_divide(num1: int, num2: int) -> int:
    """Returns the result of dividing num1 and num2, rounded to the nearest int"""
    if num2 == 0:
        raise ZeroDivisionError
    return round(num1 / num2)

print(int_divide(7, 3))  # 2
```

Raising Errors

If there is not a built-in error which fits our needs, we can create our own:

```python
class CatPettingError(Exception):
    """Custom exception raised when cat petting has gone wrong"""
    def __init__(self, message: str = "The cat did not like that."):
        super().__init__(message)

def pet_cat() -> None:
    if random() < 0.3:
        raise CatPettingError
    print('purrr')

for i in range(5):
    pet_cat()
```

Raising Errors

Only two differences between our custom exception and the built-in errors:

- Its name (CatPettingError)
- The message it prints when raised ("The cat did not like that.")
  - useful if we want to give the client a more useful hint as to what went wrong

Exercise

Let's write a function that writes a given dataframe to a given file, but only if that file does not already exist. If it exists, then it should raise a `FileExistsError`.

Solution:

```
import os

def safe_to_csv(df: pd.core.frame.DataFrame, filename: str) -> None:
    if os.path.exists(filename):
        raise FileExistsError
    df.to_csv(filename)
```

Another tool used in HW:

The OS module

Particularly useful:

- `os.path.exists("path/to/file")` checks if the file exists
- `os.path.join('base/path', 'filename')` safely combines the base path and the filename to create a `str` holdiong the path to the file
- `os.listdir('path/to/directory')` lists the files in the directory

Because the function `open('filename', 'w')` overwrites the file if it already exists, these functions in the `os` module can help us to prevent overwriting precious files.

Poll:

1. What is your main takeaway from today?
2. What would you like to revisit next time?