Statistical Methods in Natural Language Processing (NLP)

Class 5: Introduction to Python: Pandas and Matplotlip

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Introduction to Python

1. Series and DataFrames in Python
2. Basic Plots
3. Descriptive Statistics in Python
4. Distributions in SciPy

Introduction to Python

1. Python 2.7 or higher (including Python 3)
2. pandas
3. NumPy
4. matplotlib
5. IPython
6. NLTK

Pandas, Matplotlip, NLTK

- **Pandas**, is a package that provides functionality for analyzing data in the form of tables, such as those we have in Excel, Libreoffice Calc. The most important data structure is the DataFrame which is very similar to R dataframes. Pandas also provide functionality for reshaping, sorting, manipulating, etc., data.
- The second library we will be using is **NumPy**, which offers the basic functionality for conducting mathematics, including statistics, linear algebra, and Fourier transformations.
- **Matplotlib** provides functionality for creating plots and graphs.
- **NLTK** is a Natural Language Toolkit implemented in Python.
- So, to start an analysis add the following code on your code file. The code imports the libraries and provide a designated name for each library. So, we will be calling pandas for instance we will use the name pd followed by a period and the name of a function. This will become more clear soon.

Import Libraries

```
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import nltk
```

Data Manipulation with Pandas

1. Series
2. DataFrames
3. Date-Time objects

Series

A Series is a single vector of data with an index for each element. A similar structure in numpy is the array.

```
measurements = pd.Series([328259, 22781, 30857, 4164, 328387])
measurements
```

The printed output is the following:

```
Out[1]:
0     328259
1      22781
2      30857
3       4164
4     328387
dtype: int64
```

Values and Indexes

Series consist of **values** and **indexes**, we can call them separately in the following manner:

```
measurements.values
Out[2]:
array([328259,   22781,   30857,     4164,  328387])
```

```
measurements.index
```

Selecting Values in Series

```
measurements[3]
Out[4]:
4164
```

Selecting Values in Series

We can select values based on logical operations as well

```
measurements[measurements < 20000]
Out[5]:
Ecuador      4164
dtype: int64
```

or

```
measurements[measurements == 22781]
Out[6]:
Argentina      22781
dtype: int64
```

Providing optional labels to Series

These numbers are not very informative so we want to provide labels. So, if we know that these numbers represent the number of books published in 2010 we might want to provide the name of the country as an index.

```
measurements = pd.Series([328259, 22781, 30857, 4164, 328387],
    index=['USA', 'Argentina', 'Sweden', 'Ecuador', 'China'])

measurements
Out[7]:
USA          328259
Argentina     22781
Sweden        30857
Ecuador        4164
China        328387
dtype: int64
```

Selecting Values in Series using labels

We can use these labels to select the value.

```
measurements['USA']
328259
```

Series and labels

Also, we can provide labels both to the array of values and to the index:

```
measurements.name = 'Book Counts'
measurements.index.name = 'Countries'
measurements
Out[71]:
Countries
USA          328259
Argentina     22781
Sweden        30857
Ecuador        4164
China        328387
Name: Book Counts, dtype: int64
```

Selecting Values in Series using specific criteria

We might be interested to select only the countries whose name ends in letter 'a':

```
measurements[[name.endswith('a') or name.endswith('A') for name in measurements.index]]
USA          328259
Argentina     22781
China        328387
dtype: int64
```

The following provides information about the position of these numbers:

```
[name.endswith('a') or name.endswith('A') for name in measurements.index]

[True, True, False, False, True]
```

Maths and Series

NumPy's math functions and statistics can be applied to Series, e.g.,

```
np.mean(measurements)
142889.6
```

Series and Dictionaries

Series are very similar objects to standard dictionaries (dict) in Python:

```
Bookpublications = {'Italy':59743, 'Argentina':22781,
      'Poland': 31500, 'Vietnam': 24589, 'Indonesia': 24000}

pd.Series(Bookpublications)
Argentina     22781
Indonesia     24000
Italy         59743
Poland        31500
Vietnam       24589
dtype: int64
```

DataFrame

```
data = pd.DataFrame(
{'counts':[ 328259, 22781, 30857, 4164, 328387, 59743,  31500, 24589],
 'year':[2010, 2010, 2010, 2010, 2010, 2005, 2010, 2009],
'country':['USA',  'Argentina', 'Sweden', 'Ecuador',
            'China', 'Italy', 'Poland', 'Vietnam']})
data
```

DataFrame

The output now is a table as we expect it to be:

```
      country  counts  year
0         USA  328259  2010
1   Argentina   22781  2010
2      Sweden   30857  2010
3     Ecuador    4164  2010
4       China  328387  2010
5       Italy   59743  2005
6      Poland   31500  2010
7     Vietnam   24589  2009
```

Selecting Values from DataFrames

To select the values of the column, we can use its name:

```
data['counts']
```

```
0     328259
1      22781
2      30857
3       4164
4     328387
5      59743
6      31500
7      24589
Name: counts, dtype: int64
```

Selecting Values from DataFrames

```
data.counts
Out[95]:
0     328259
1      22781
2      30857
3       4164
4     328387
5      59743
6      31500
7      24589
Name: counts, dtype: int64
```

Changing the order of columns

```
data[['country', 'year', 'counts']]
```

Indexes

The index of columns is provided by the following:

```
data.columns
Out[91]:
Index(['country', 'counts', 'year'], dtype='object')
```

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Types and selections

```
type(data.counts)
pandas.core.series.Series
```

```
type(data[['counts']])
pandas.core.frame.DataFrame
```

Selecting Rows

To select a row in a DataFrame, we index its *ix* attribute in the following way:

```
data.ix[3]
Out[98]:
country      Ecuador
counts          4164
year            2010
Name: 3, dtype: object
```

Dictionaries and DataFrames

We might create DataFrames using dictionaries

```
Alternatively, we can create a DataFrame with a dict of dicts:
In [111]:

data = pd.DataFrame(
{0:{'AA': 1, 'gender': 'Male', 'height': 168},
1: {'AA': 2, 'gender': 'Male', 'height': 180},
2: {'AA': 3, 'gender': 'Female', 'height': 170},
3: {'AA': 4, 'gender': 'Female', 'height': 169},
4: {'AA': 5, 'gender': 'Female', 'height': 170},
5: {'AA': 6, 'gender': 'Male', 'height': 165}})

In [112]:

data
Out[112]:
            0     1       2       3       4     5
AA          1     2       3       4       5     6
gender   Male  Male  Female  Female  Female  Male
height    168   180     170     169     170   165
```

Transpose Function

To get the 'standard' DataFrame output we need to transpose the code:

```
data = data.T
data
Out[113]:
  AA  gender  height
0  1    Male     168
1  2    Male     180
2  3  Female     170
3  4  Female     169
4  5  Female     170
5  6    Male     165
```

Indexes and values

DataFrames have indexes and values which are called in the following way:

```
data.values
```

The output is following

```
array([[1, 2, 3, 4, 5, 6],
       ['Male', 'Male', 'Female', 'Female', 'Female', 'Male'],
       [168, 180, 170, 169, 170, 165]], dtype=object)
```

Indexes and values

and the index is called by `data.index` and the result is:

```
Index(['AA', 'gender', 'height'], dtype='object')
```

We cannot change the index, if we try, e.g., data.index[1] = 5 Python will provide the following message: "Index does not support mutable operations".

Selecting columns and changing values

To select a column:

```
heights = data.height
heights
Out[116]:
0      168
1      180
2      170
3      169
4      170
5      165
Name: height, dtype: object
```

Selecting columns and changing values

To change a value

```
heights[5] = 191
heights
Out[117]:
0      168
1      180
2      170
3      169
4      170
5      191
Name: height, dtype: object
```

```
data
Out[118]:
  AA  gender  height
0  1    Male     168
1  2    Male     180
2  3  Female     170
3  4  Female     169
4  5  Female     170
5  6    Male     191
```

The copy function

```
ht = data.height.copy()
ht[5] = 180
data
Out[141]:
   AA  gender  height
0   1    Male     168
1   2    Male     180
2   3  Female     177
3   4  Female     169
4   5  Female     170
5   6    Male     191
```

Create/ modify columns by assignment

```
data.height[2] = 177
data
Out[122]:
   AA  gender  height
0   1    Male     168
1   2    Male     180
2   3  Female     177
3   4  Female     169
4   5  Female     170
5   6    Male     180
```

Create/ modify columns by assignment

```
data['Status'] = 'Printed'
data
Out[143]:
   AA  gender  height   Status
0   1    Male     168  Printed
1   2    Male     180  Printed
2   3  Female     177  Printed
3   4  Female     169  Printed
4   5  Female     170  Printed
5   6    Male     191  Printed
```

Create/ modify columns by assignment

The following method does not create a column:

```
data.libraryNo = 999
data
Out[146]:
   AA  gender  height   Status
0   1    Male     168  Printed
1   2    Male     180  Printed
2   3  Female     177  Printed
3   4  Female     169  Printed
4   5  Female     170  Printed
5   6    Male     191  Printed
```

Create/ modify columns by assignment

```
data.libraryNo
999
```

Create DataFrame Columns using Series

We can define a Series object as column in a DataFrame

```
test = pd.Series([0]*2 + [3]*2)
test

data['test'] = test
data
```

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Strings in DataFrames

We created a Series of 4 numbers. Note however that the DataFrame contains six rows. This is not a problem when we use numbers because Python automatically add NaN to fill the empty rows. Nevertheless, when we employ other data structures such as strings Python will show an error message: ValueError: Length of values does not match length of index.

```
# Popular Authors
authors = ['Stephen King', 'J.K. Rowling', 'Mark Twain', 'George R. R. Martin']
data['authors'] = authors
```

Strings in DataFrames

To correct the error, we simply add a string Series that has the same length as the DataFrame

```
authors = ['Stephen King', 'J.K. Rowling', 'Mark Twain',
'George R. R. Martin', 'Charles Dickens', 'Arthur Conan Doyle']
data['favorite_authors'] = authors
```

This time the output is correct:

```
data
   AA  gender  height   Status  test      favorite_authors
0   1    Male     168  Printed   0.0          Stephen King
1   2    Male     180  Printed   0.0          J.K. Rowling
2   3  Female     177  Printed   3.0            Mark Twain
3   4  Female     169  Printed   3.0   George R. R. Martin
4   5  Female     170  Printed   NaN       Charles Dickens
5   6    Male     165  Printed   NaN    Arthur Conan Doyle
```

Deleting Columns in DataFrames

To delete the column test from the DataFrame data

```
del data['test']
data
  AA  gender  height   Status                authors
0  1    Male     168  Printed           Stephen King
1  2    Male     180  Printed           J.K. Rowling
2  3  Female     177  Printed             Mark Twain
3  4  Female     169  Printed   George R. R. Martin
4  5  Female     170  Printed        Charles Dickens
5  6    Male     165  Printed     Arthur Conan Doyle
```

DataFrame as a simple narray

To get the data as a simple `narray` we need to employ the attribute `values`.

```
array([[1, 'Male', 168, 'Printed', 'Stephen King'],
       [2, 'Male', 180, 'Printed', 'J.K. Rowling'],
       [3, 'Female', 177, 'Printed', 'Mark Twain'],
       [4, 'Female', 169, 'Printed', 'George R. R. Martin'],
       [5, 'Female', 170, 'Printed', 'Charles Dickens'],
       [6, 'Male', 165, 'Printed', 'Arthur Conan Doyle']],
dtype=object)
```

The dtype here is “object” because we have numeric and string data and differs when we have numeric or other type of data.

Merging DataFrames

df1 = pd.DataFrame('A': ['A0', 'A1', 'A2', 'A3'], 'B': ['B0', 'B1', 'B2', 'B3'], 'C': ['C0', 'C1', 'C2', 'C3'], 'D': ['D0', 'D1', 'D2', 'D3'], index=[0, 1, 2, 3])
Example from http://pandas.pydata.org/pandas-docs/stable/merging.html

df1

	A	B	C	D
0	A0	B0	C0	D0
1	A1	B1	C1	D1
2	A2	B2	C2	D2
3	A3	B3	C3	D3

df2

	A	B	C	D
4	A4	B4	C4	D4
5	A5	B5	C5	D5
6	A6	B6	C6	D6
7	A7	B7	C7	D7

df3

	A	B	C	D
8	A8	B8	C8	D8
9	A9	B9	C9	D9
10	A10	B10	C10	D10
11	A11	B11	C11	D11

Result

	A	B	C	D
0	A0	B0	C0	D0
1	A1	B1	C1	D1
2	A2	B2	C2	D2
3	A3	B3	C3	D3
4	A4	B4	C4	D4
5	A5	B5	C5	D5
6	A6	B6	C6	D6
7	A7	B7	C7	D7
8	A8	B8	C8	D8
9	A9	B9	C9	D9
10	A10	B10	C10	D10
11	A11	B11	C11	D11

Date and Time

Python can manipulate date and time objects using the `datetime` module. It allows the production of calculations using time and date objects and also provides classes for controlling the output (see also, https://docs.python.org/2/library/datetime.html)

```
from datetime import datetime
#%%
now = datetime.now()
now
```

and the result is

```
datetime.datetime(2017, 1, 6, 14, 41, 4, 481168)
```

Date and Time

To get the date only

```
#%%
now.date()
```

and the output in this case is datetime.date(2017, 1, 6). To find the day

```
#%%
now.day
```

and the output is 6.

Date and Time

Also, for the time

```
#%%
now.time()
```

and the output is datetime.time(14, 41, 4, 481168). We can also ask which is the week day:

```
#%%
now.weekday()
```

that will generate the output 4

```
#%%
from datetime import date, time
```

Date and Time

```
#%%
time(3, 24)

#%%
age = now - datetime(1980, 8, 16)
age/365

#%%
days=(datetime(2017, 3, 10) - datetime(2017, 8, 16))
days.days
```

Importing data

We suggest that you use comma-separated value or CSV files when interacting with Python and other statistical software. In computing, CSV files stores tabular data (numbers and text) in plain text. Columns are separated by commas; rows are terminated by newlines. This file format is not proprietary, the files can be edited in text editors and spreadsheet software, such as Excel and Calc.

Importing data

```
dur = pd.read_csv("data/duration.csv", sep=";")
dur
Out[153]:
    experiment  duration
0            A       199
1            A       184
2            A       242
3            A       236
4            A       216
5            A       176
6            A       223
7            A       186
8            A       210
9            A       220
..         ...       ...
95           C       221
96           C       239
97           C       235
98           C       248
99           C       204
100          C       226
101          C       206
102          C       194
103          C       205
104          C       182

[105 rows x 2 columns]
```

Importing data

We can also import another dataframe and add a column titled AA.

```
fricative = pd.read_table("data/fricatives.csv", sep=',')
fricative['AA'] = pd.Series(range(1,8827))
```

Head

```
# %%
fricative.head()
# %%
```

```
   id  duration  intensity          cog         sdev       skew        kurt  \
0   1  0.060398  32.671794   757.605236  1104.704765  13.835014  210.523631
1   2  0.045656  38.906220   732.582945  1065.089424  12.654465  186.856393
2   3  0.050907  47.209304   647.696728  1627.357767   7.647966   61.615315
3   4  0.051049  41.703970  1017.179353  2318.797907   5.570367   33.783925
4   5  0.028408  44.345609  1132.524942   848.894793   7.105495  108.453910

  Segment Vowel Variety      Stress   Voice Position   AA
0       d     a      CG  Unstressed  Voiced   Middle  1.0
1       d     a      CG  Unstressed  Voiced   Middle  2.0
2       d     a      CG  Unstressed  Voiced   Middle  3.0
3       d     a      CG  Unstressed  Voiced   Middle  4.0
4       d     a      CG  Unstressed  Voiced   Middle  5.0
```

Skipping Rows

We can skip rows if we do not want them in the analysis:

```
# %%
testfric=pd.read_csv("data/fricatives.csv", skiprows=[2,3,4,5,6])
len(testfric.index)
```

To import a small number of rows from, we can use `nrows`:

```
# %%
pd.read_csv("data/fricatives.csv", nrows=4)
```

Skipping Rows

```
# %%
pd.read_csv("data/fricatives.csv").head(20)


pd.isnull(pd.read_csv("data/fricatives.csv")).head(20)
```

Empty Cells

When we import data Python identifies empty cells, or NA values as NA data; to designated that specific values or symbols should be considered NA values, we can specify this as follows

```
pd.read_csv("data/fricatives.csv",
 na_values=['?', -9999999]).head(20)
```

Saving Data

There are different methods to save data. To save data in CSV format

```
# ## Writing Data to Files
fricative.to_csv("fricative-01.csv")
```

Creating Plots using Pandas

Using pandas we can also make some basic plotting.

```
fricative['duration'].plot()
```

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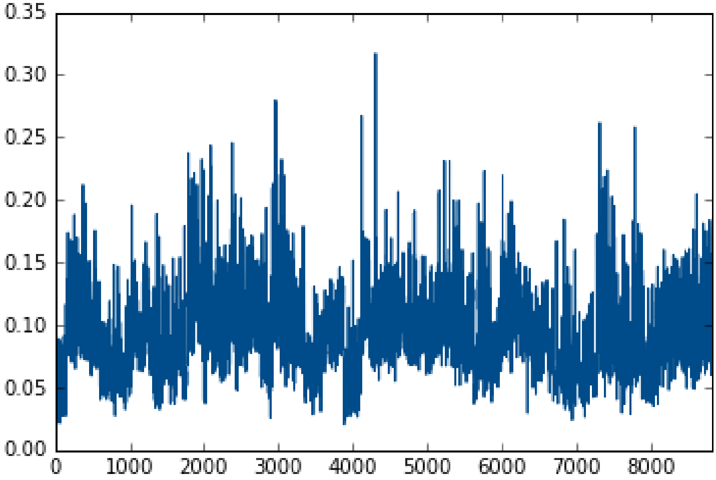
Creating Plots using Pandas

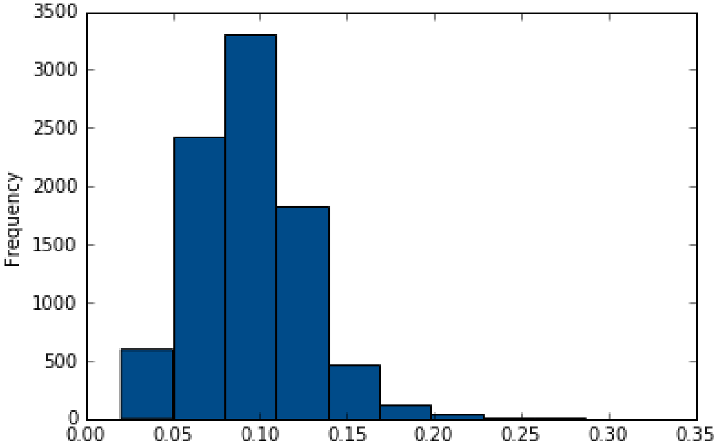
```
################################################################################

# %%
fricative = pd.read_csv("data/fricatives.csv", sep=',')
fricative['duration'].plot()
# %%
fricative['duration'].plot(kind='hist')

# %%
fricative['duration'].plot(kind='box',showfliers=False)
```


0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0
1000
2000
3000
4000
5000
6000
7000
8000

Creating Plots using Pandas



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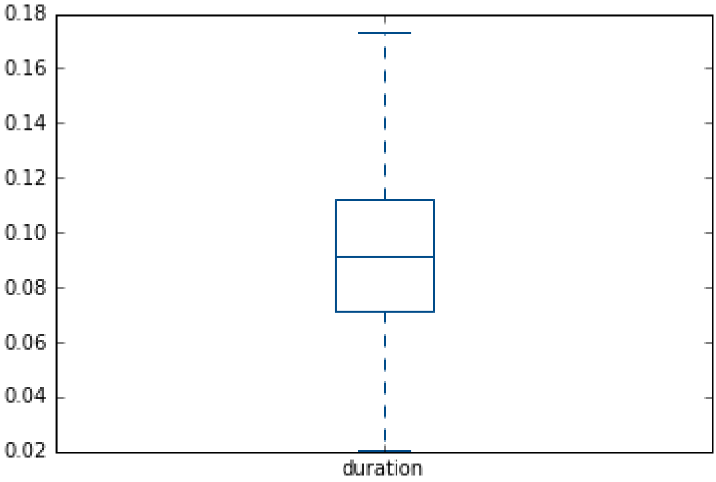
Creating Plots using Pandas



Creating Plots using Matplotlib

```
import matplotlib.pyplot as plt
plt.plot([1,2,3,4])
plt.ylabel('some numbers')
plt.show()
```

Basic Descriptive Statistics using Pandas

```
In [208]:

fricative.sum()
Out[208]:
duration                                                   827.811
intensity                                                   346024
cog                                                    5.05981e+07
sdev                                                   2.40776e+07
skew                                                       21699.9
kurt                                                        328392
Segment       dddddddddddddddddddddddddddddddddddddddddd...
Vowel         aaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaa...
Variety       CGCGCGCGCGCGCGCGCGCGCGCGCGCGCGCGCGCGCGCGCG...
Stress        UnstressedUnstressedUnstressedUnstressedUnstre...
Voice         VoicedVoicedVoicedVoicedVoicedVoicedVoicedVoic...
Position      MiddleMiddleMiddleMiddleMiddleMiddleMiddleMidd...
AA                                                     3.89536e+07
dtype: object
```

Calculating the Mean

```
In [209]:

fricative.mean()
Out[209]:
duration          0.093782
intensity        39.254023
cog            5732.200660
sdev           2727.724598
skew              2.458354
kurt             37.203150
AA             4413.500000
dtype: float64
```

Calculating the Standard Deviation

```
In [211]:

fricative.std()
Out[211]:
duration          0.031759
intensity         8.272744
cog            3425.508087
sdev           1339.636724
skew              4.785687
kurt            138.622132
AA             2547.991071
dtype: float64
```

Descriptive Statistics and Counts

```
In [212]:

fricative.count()
Out[212]:
duration     8827
intensity    8815
cog          8827
sdev         8827
skew         8827
kurt         8827
Segment      8827
Vowel        8827
Variety      8827
Stress       8827
Voice        8827
Position     8827
AA           8826
dtype: int64
```

Finding Missing Values and NaNs

```
fricative.intensity.hasnans
Out[215]:
True
In  [221]:

fricative.intensity.isnull().sum()
Out[221]:
12
```

Descriptive Statistics: Describe Function

Describe:

```
In [222]:

fricative.describe()
Out[222]:
          duration    intensity           cog         sdev        skew  \
count  8827.000000  8815.000000   8827.000000  8827.000000  8827.000000
mean      0.093782    39.254023   5732.200660  2727.724598     2.458354
std       0.031759     8.272744   3425.508087  1339.636724     4.785687
min       0.020333     5.278827    419.757883   228.697624    -5.250996
25%       0.071596          NaN   2385.869561  1771.421219    -0.113557
50%       0.091452          NaN   6175.724355  2368.203536     0.925865
75%       0.112412          NaN   8344.008050  3595.757817     2.953676
max       0.316844    69.455969  18606.542539  9253.436646    59.853567

              kurt           AA
count  8827.000000  8826.000000
mean     37.203150  4413.500000
std     138.622132  2547.991071
min      -1.892874     1.000000
25%       0.512395          NaN
50%       3.432032          NaN
75%      12.453753          NaN
max    3999.613892  8826.000000
describe can detect non-numeric data and sometimes yield useful information about it.
```

Descriptive Statistics: Describe Function

```
fricative.sdev.describe()
Out[224]:
count     8827.000000
mean      2727.724598
std       1339.636724
min        228.697624
25%       1771.421219
50%       2368.203536
75%       3595.757817
max       9253.436646
Name: sdev, dtype: float64
```

Pantas and Scipy

- Scipy provides mathematical functions
- For more information see http://docs.scipy.org/doc/scipy/reference/stats.html

Probability distributions in Python

- make a random variable representing a dice (unif distribution)

```
from scipy.stats import randint
dice = randint(1, 7)
```

- roll the dice 1000 times

```
outcomes = dice.rvs(1000)
```

- What is the probability of getting 5?

```
dice.pmf(5)
```

- You can also count the mean(), variance, and standard deviation: dice.mean(), dice.var(), dice.std().

Plotting the Distribution in Python

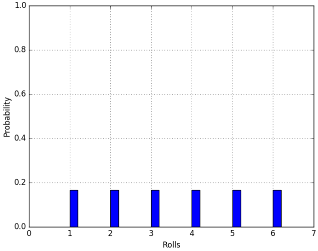


Figure: Probabilities of dice rolls.

```python
import scipy.stats
from matplotlib import pyplot as plt
dice = scipy.stats.randint(1, 7)
rolls = [1,2,3,4,5,6]
pmf_values = dice.pmf(rolls)
plt.bar(rolls, pmf_values, width=0.2)
# some cosmetics
plt.axis([0, 7, 0, 1])
plt.xlabel('Rolls')
plt.ylabel('Probability')
plt.grid()
plt.show()
# plt.savefig('dice_rolls.png')
```

Next Class

- Hypothesis Testing
- Statistical Models