lab03_Ganapathy_Anitha

May 29, 2022

1 W3 Lab: Perception

In this lab, we will learn basic usage of `pandas` library and then perform a small experiment to test the perception of length and area.

[1]:
```
import pandas as pd
import math
import matplotlib.pyplot as plt
%matplotlib inline
```

1.1 Vega datasets

Before going into the perception experiment, let's first talk about some handy datasets that you can play with.

It's nice to have clean datasets handy to practice data visualization. There is a nice small package called `vega-datasets`, from the altair project.

You can install the package by running

```
$ pip install vega-datasets
```

or

```
$ pip3 install vega-datasets
```

Once you install the package, you can import and see the list of datasets:

[2]:
```
from vega_datasets import data

data.list_datasets()
```

[2]:
```
['7zip',
 'airports',
 'annual-precip',
 'anscombe',
 'barley',
 'birdstrikes',
 'budget',
 'budgets',
```

```
'burtin',
'cars',
'climate',
'co2-concentration',
'countries',
'crimea',
'disasters',
'driving',
'earthquakes',
'ffox',
'flare',
'flare-dependencies',
'flights-10k',
'flights-200k',
'flights-20k',
'flights-2k',
'flights-3m',
'flights-5k',
'flights-airport',
'gapminder',
'gapminder-health-income',
'gimp',
'github',
'graticule',
'income',
'iowa-electricity',
'iris',
'jobs',
'la-riots',
'londonBoroughs',
'londonCentroids',
'londonTubeLines',
'lookup_groups',
'lookup_people',
'miserables',
'monarchs',
'movies',
'normal-2d',
'obesity',
'ohlc',
'points',
'population',
'population_engineers_hurricanes',
'seattle-temps',
'seattle-weather',
'sf-temps',
'sp500',
```

```
 'stocks',
 'udistrict',
 'unemployment',
 'unemployment-across-industries',
 'uniform-2d',
 'us-10m',
 'us-employment',
 'us-state-capitals',
 'volcano',
 'weather',
 'weball26',
 'wheat',
 'windvectors',
 'world-110m',
 'zipcodes']
```

or you can work with only smaller, local datasets.

[3]:
```
from vega_datasets import local_data
local_data.list_datasets()
```

[3]:
```
['airports',
 'anscombe',
 'barley',
 'burtin',
 'cars',
 'crimea',
 'driving',
 'iowa-electricity',
 'iris',
 'la-riots',
 'ohlc',
 'seattle-temps',
 'seattle-weather',
 'sf-temps',
 'stocks',
 'us-employment',
 'wheat']
```

Ah, we have the `anscombe` data here! Let's see the description of the dataset.

[4]:
```
local_data.anscombe.description
```

[4]:
```
"Anscombe's Quartet is a famous dataset constructed by Francis Anscombe [1]_.
Common summary statistics are identical for each subset of the data, despite the
subsets having vastly different characteristics."
```

1.2 Anscombe's quartet dataset

How does the actual data look like? Very conveniently, calling the dataset returns a Pandas dataframe for you.

[5]:
```
df = local_data.anscombe()
df.head()
```

[5]:

	Series	X	Y
0	I	10	8.04
1	I	8	6.95
2	I	13	7.58
3	I	9	8.81
4	I	11	8.33

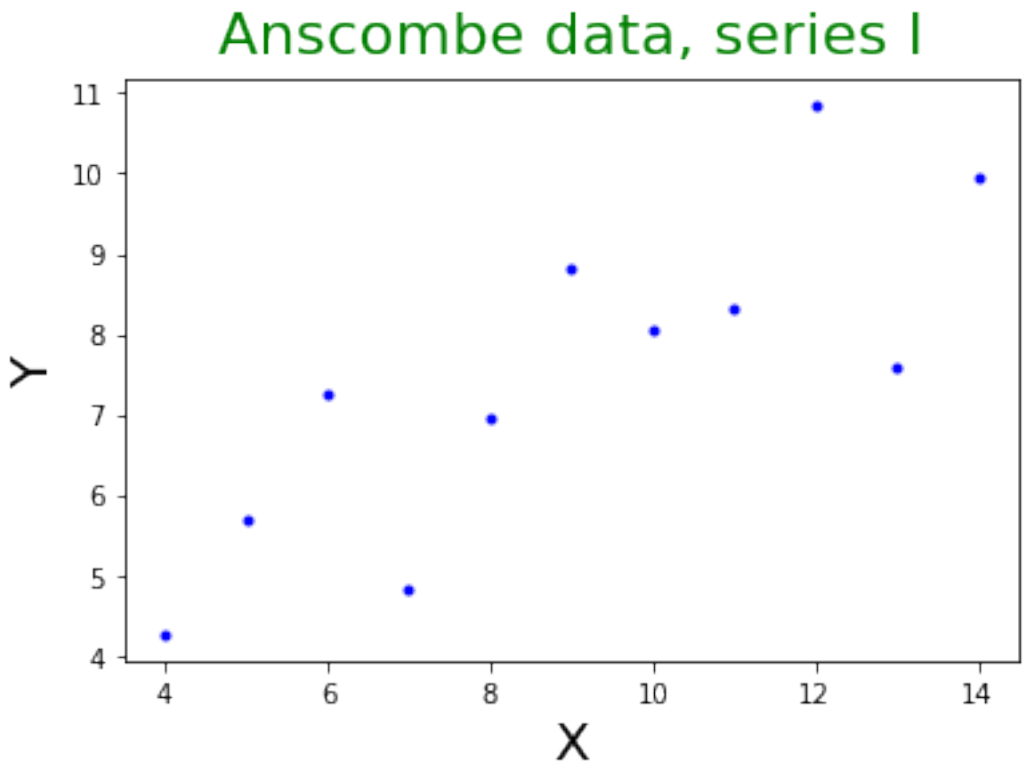
Q1: can you draw a scatterplot of the dataset "I"? You can filter the dataframe based on the `Series` column and use `plot` function that you used for the Snow's map.

[6]:
```
df['Series'].unique()
df[df['Series'] == 'I']
```

[6]:

	Series	X	Y
0	I	10	8.04
1	I	8	6.95
2	I	13	7.58
3	I	9	8.81
4	I	11	8.33
5	I	14	9.96
6	I	6	7.24
7	I	4	4.26
8	I	12	10.84
9	I	7	4.81
10	I	5	5.68

[7]:
```
# TODO: put your code here

df_I = df[df['Series'] == 'I']

fig, ax = plt.subplots()
ax = plt.scatter(df_I.X, df_I.Y, marker ='.', c='blue')
plt.title("Anscombe data, series I", fontsize = 22, c = 'green', pad=10)
plt.xlabel("X", fontsize = 20)
plt.ylabel("Y", fontsize = 20)
plt.show()
```



1.3 Some histograms with pandas

Let's look at a slightly more complicated dataset.

[8]:
```
car_df = local_data.cars()
car_df.head()
```

[8]:

	Name	Miles_per_Gallon	Cylinders	Displacement	Horsepower	Weight_in_lbs	Acceleration	Year	Origin
0	chevrolet chevelle malibu	18.0	8	307.0	130.0	3504	12.0	1970-01-01	USA
1	buick skylark 320	15.0	8	350.0	165.0	3693	11.5	1970-01-01	USA
2	plymouth satellite	18.0	8	318.0	150.0	3436	11.0	1970-01-01	USA
3	amc rebel sst	16.0	8	304.0	150.0	3433	12.0	1970-01-01	USA
4	ford torino	17.0	8	302.0	140.0	3449	10.5	1970-01-01	USA

[13]:
```
print("Before drop : ", car_df.columns)
car_df.drop(['Year'], axis = 1, inplace= True)
print("After drop : ", car_df.columns)
```

```
Before drop :  Index(['Name', 'Miles_per_Gallon', 'Cylinders', 'Displacement',
'Horsepower',
       'Weight_in_lbs', 'Acceleration', 'Year', 'Origin'],
      dtype='object')
After drop :  Index(['Name', 'Miles_per_Gallon', 'Cylinders', 'Displacement',
'Horsepower',
       'Weight_in_lbs', 'Acceleration', 'Origin'],
      dtype='object')
```

Pandas provides useful summary functions. It identifies numerical data columns and provides you with a table of summary statistics.

[14]:
```
car_df.describe()
```

[14]:

	Miles_per_Gallon	Cylinders	Displacement	Horsepower	Weight_in_lbs	\
count	398.000000	406.000000	406.000000	400.000000	406.000000	
mean	23.514573	5.475369	194.779557	105.082500	2979.413793	
std	7.815984	1.712160	104.922458	38.768779	847.004328	
min	9.000000	3.000000	68.000000	46.000000	1613.000000	
25%	17.500000	4.000000	105.000000	75.750000	2226.500000	
50%	23.000000	4.000000	151.000000	95.000000	2822.500000	
75%	29.000000	8.000000	302.000000	130.000000	3618.250000	
max	46.600000	8.000000	455.000000	230.000000	5140.000000	

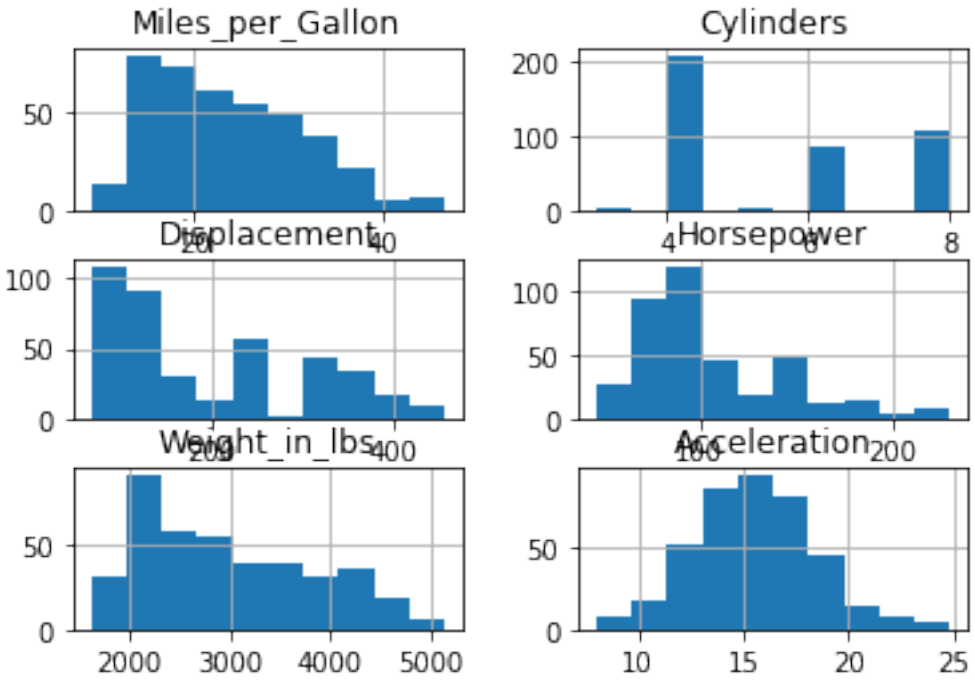
	Acceleration
count	406.000000
mean	15.519704
std	2.803359
min	8.000000
25%	13.700000
50%	15.500000
75%	17.175000
max	24.800000

If you ask to draw a histogram, you get all of them. :)

[15]:
```
car_df.hist()
```

[15]:
```
array([[<matplotlib.axes._subplots.AxesSubplot object at 0x7f25fe656dd0>,
        <matplotlib.axes._subplots.AxesSubplot object at 0x7f25fecddcd0>],
       [<matplotlib.axes._subplots.AxesSubplot object at 0x7f25fe4b9650>,
        <matplotlib.axes._subplots.AxesSubplot object at 0x7f25fe470190>],
       [<matplotlib.axes._subplots.AxesSubplot object at 0x7f25fe430290>,
        <matplotlib.axes._subplots.AxesSubplot object at 0x7f25fe3e8890>]],
```

```
dtype=object)
```

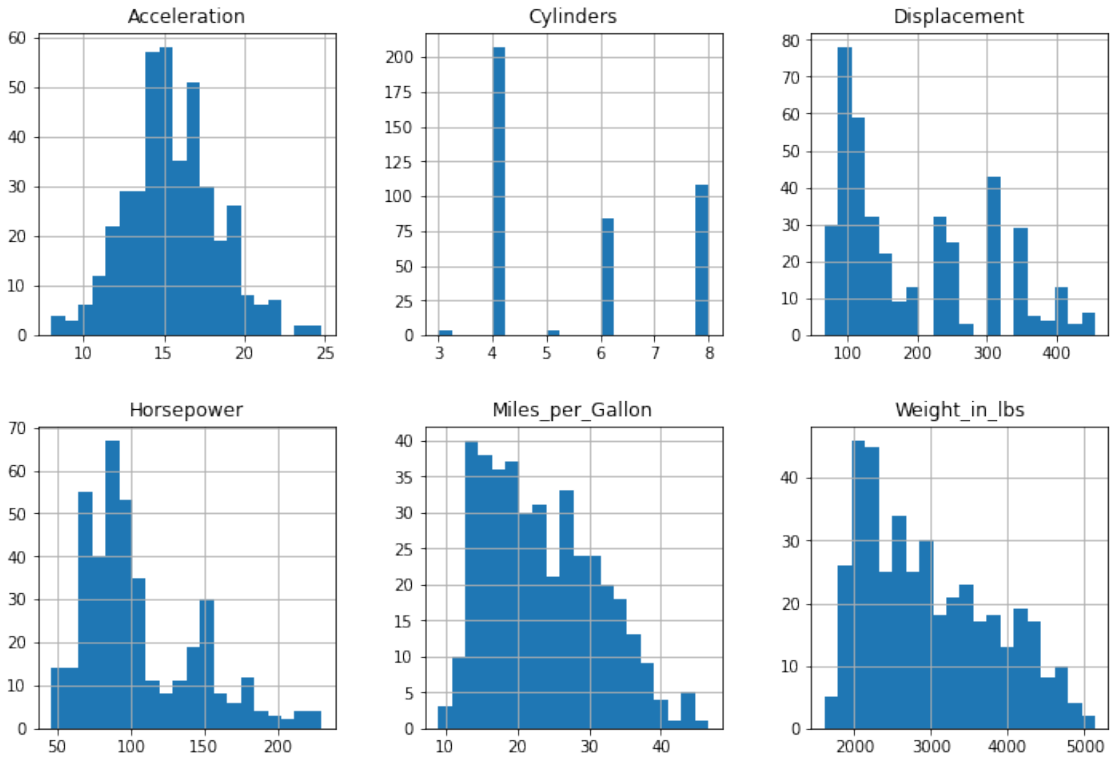


Well this is too small. You can check out the documentation and change the size of the figure.

Q2: by consulting the documentation, can you make the figure larger so that we can see all the labels clearly? And then make the layout 2 x 3 not 3 x 2, then change the number of bins to 20?

[23]:
```
# TODO: put your code here

# fig, ax = plt.subplots(2, 3)
car_df = car_df.sort_index(axis=1)
car_df.hist(figsize=(12,8),layout=(2,3), bins = 20)
```

[23]:
```
array([[<matplotlib.axes._subplots.AxesSubplot object at 0x7f25fc2a1e50>,
        <matplotlib.axes._subplots.AxesSubplot object at 0x7f25fc29a790>,
        <matplotlib.axes._subplots.AxesSubplot object at 0x7f25fc2435d0>],
       [<matplotlib.axes._subplots.AxesSubplot object at 0x7f25fc1faad0>,
        <matplotlib.axes._subplots.AxesSubplot object at 0x7f25fc1b1510>,
        <matplotlib.axes._subplots.AxesSubplot object at 0x7f25fc170510>]],
      dtype=object)
```



1.4 Your own psychophysics experiment!

Let's do an experiment! The procedure is as follows:

1. Generate a random number between [1, 10];
2. Use a horizontal bar to represent the number, i.e., the length of the bar is equal to the number;
3. Guess the length of the bar by comparing it to two other bars with length 1 and 10 respectively;
4. Store your guess (perceived length) and actual length to two separate lists;
5. Repeat the above steps many times;
6. How does the perception of length differ from that of area?.

First, let's define the length of a short and a long bar. We also create two empty lists to store perceived and actual length.

[24]:
```
import random
import time
import numpy as np

l_short_bar = 1
l_long_bar = 10

perceived_length_list = []
actual_length_list = []
```

1.4.1 Perception of length

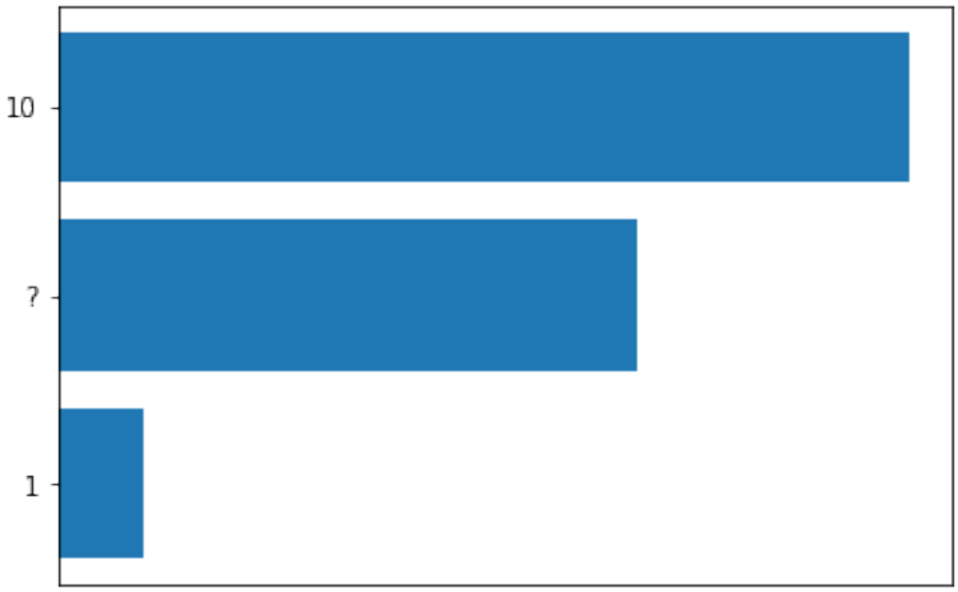
Let's run the experiment.

The `random` module in Python provides various random number generators, and the `random.uniform(a,b)` function returns a floating point number in [a,b].

We can plot horizontal bars using the `pyplot.barh()` function. Using this function, we can produce a bar graph that looks like this:

[25]:
```
mystery_length = random.uniform(1, 10)  # generate a number between 1 and 10.␣
↪this is the *actual* length.

plt.barh(np.arange(3), [l_short_bar, mystery_length, l_long_bar],␣
↪align='center')
plt.yticks(np.arange(3), ('1', '?', '10'))
plt.xticks([]) # no hint!
```

[25]:
```
([], <a list of 0 Text major ticklabel objects>)
```



Btw, `np.arange` is used to create a simple integer list `[0, 1, 2]`.

[28]:
```
np.arange(3)
```

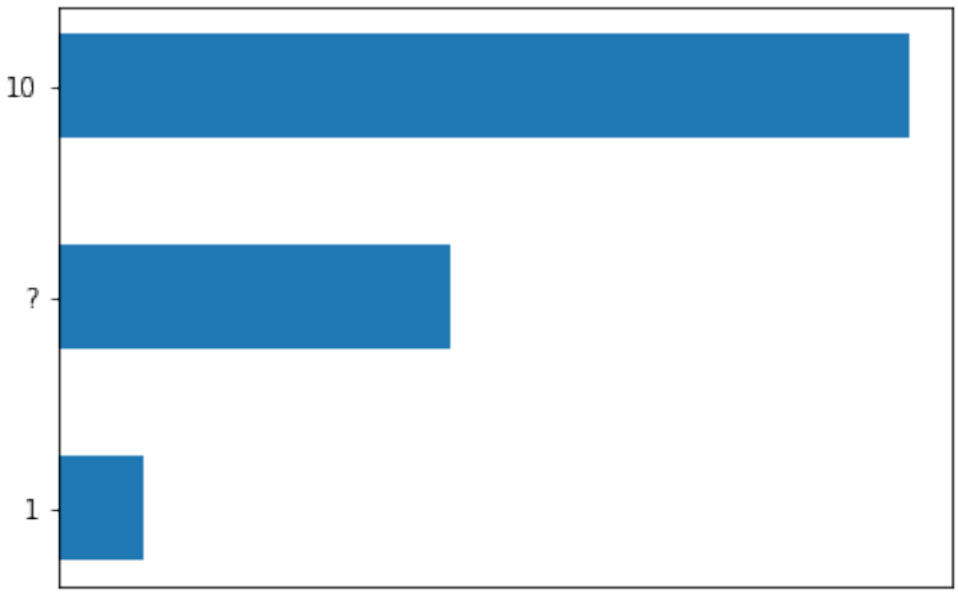
[28]:
```
array([0, 1, 2])
```

Now let's define a function to perform the experiment once. When you run this function, it picks a random number between 1.0 and 10.0 and show the bar chart. Then it asks you to input your

estimate of the length of the middle bar. It then saves that number to the `perceived_length_list` and the actual answer to the `actual_length_list`.

[27]:
```
def run_exp_once():
    mystery_length = random.uniform(1, 10)  # generate a number between 1 and 10.

    plt.barh(np.arange(3), [l_short_bar, mystery_length, l_long_bar], height=0.5, align='center')
    plt.yticks(np.arange(3), ('1', '?', '10'))
    plt.xticks([]) # no hint!
    plt.show()

    try:
        perceived_length_list.append( float(input()) )
    except:
        print("This should only fail in workflow. If you are running this in browser, this won't fail.")
        pass
    actual_length_list.append(mystery_length)
```

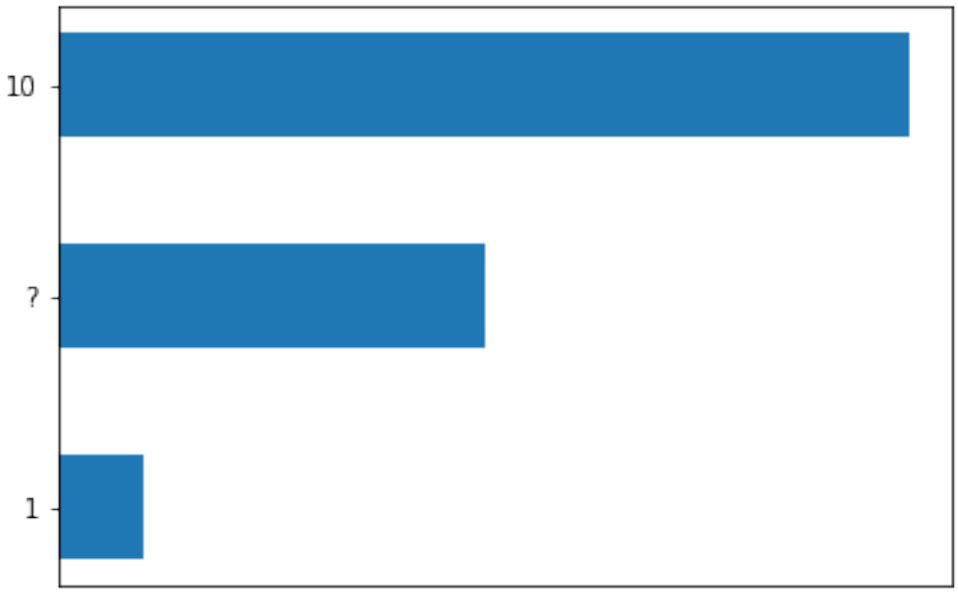
[29]:
```
run_exp_once()
```



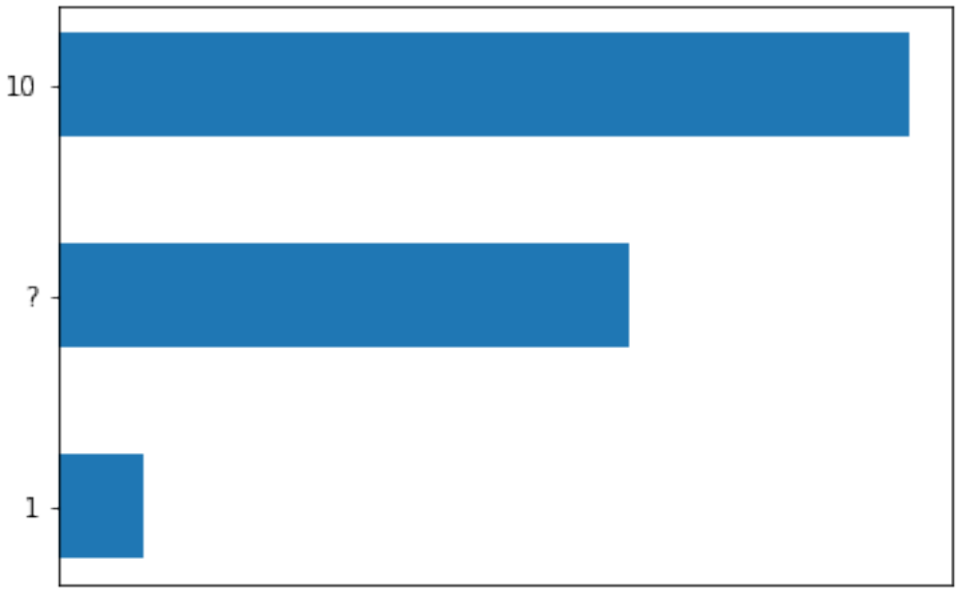
4.5

Now, run the experiment many times to gather your data. Check the two lists to make sure that you have the proper dataset. The length of the two lists should be the same.

[30]:
```
# TODO: Run your experiment many times here
for i in range(15):
  run_exp_once()
```

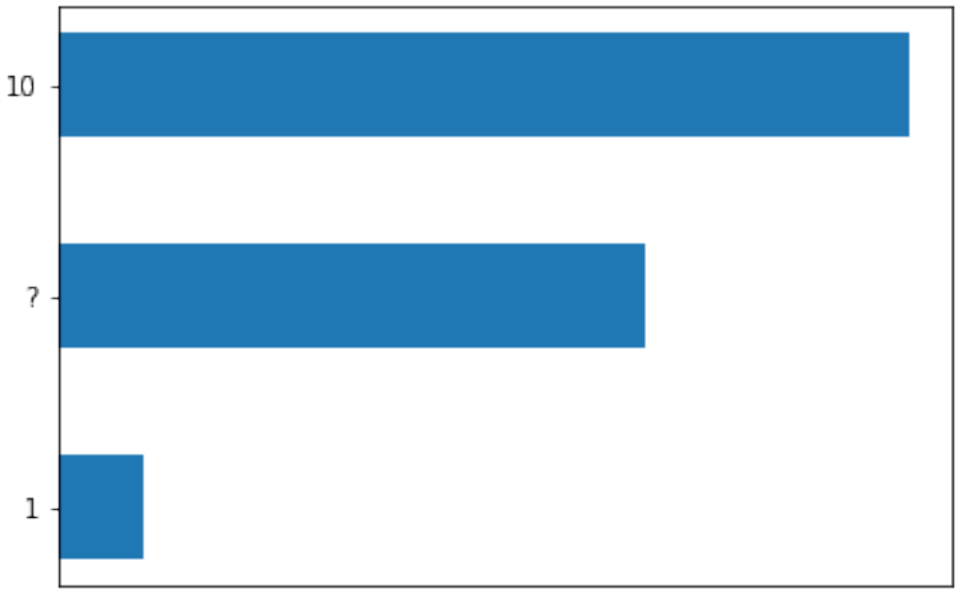


5

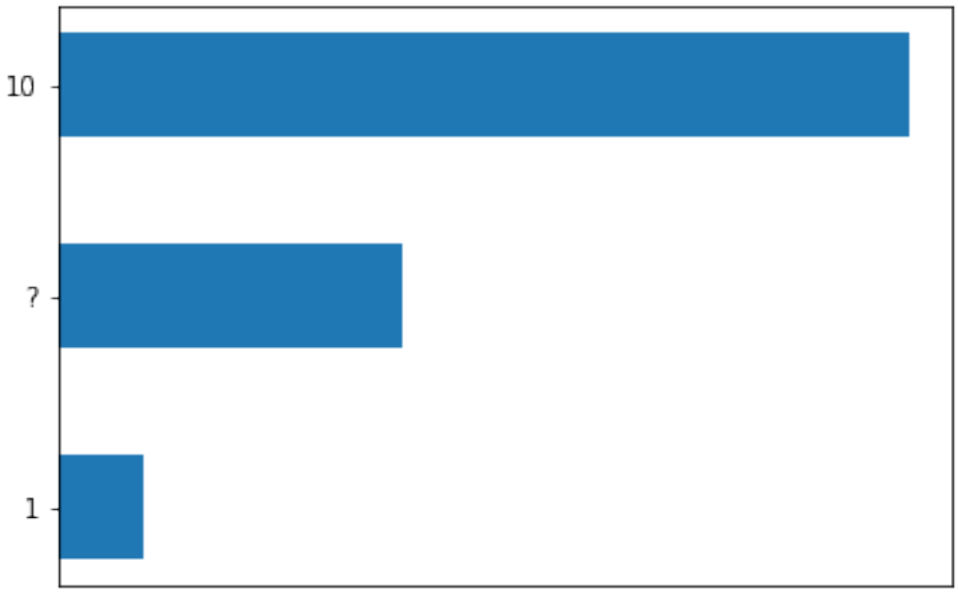


7

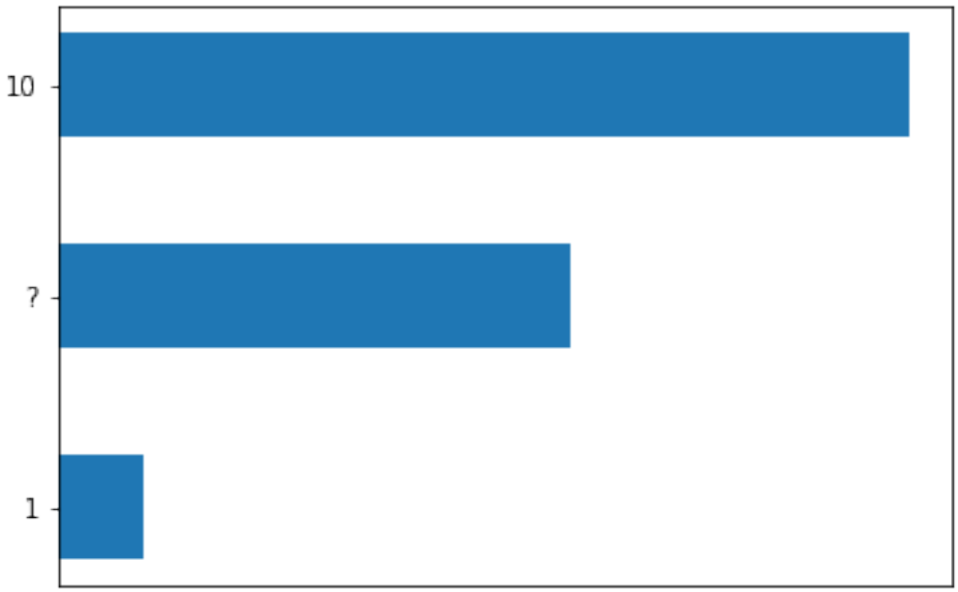
9



8



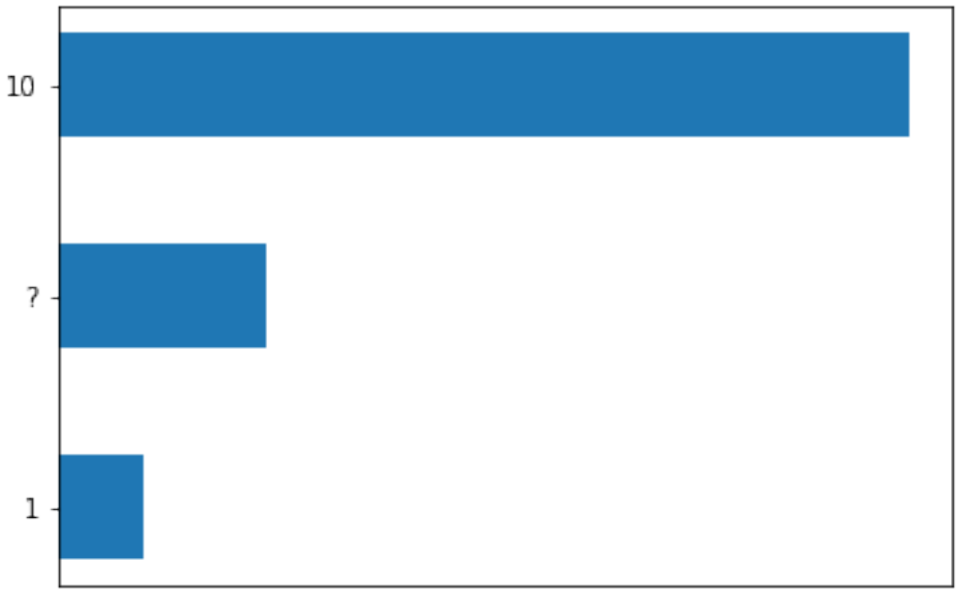

```
4
```




```
6.5
```

9

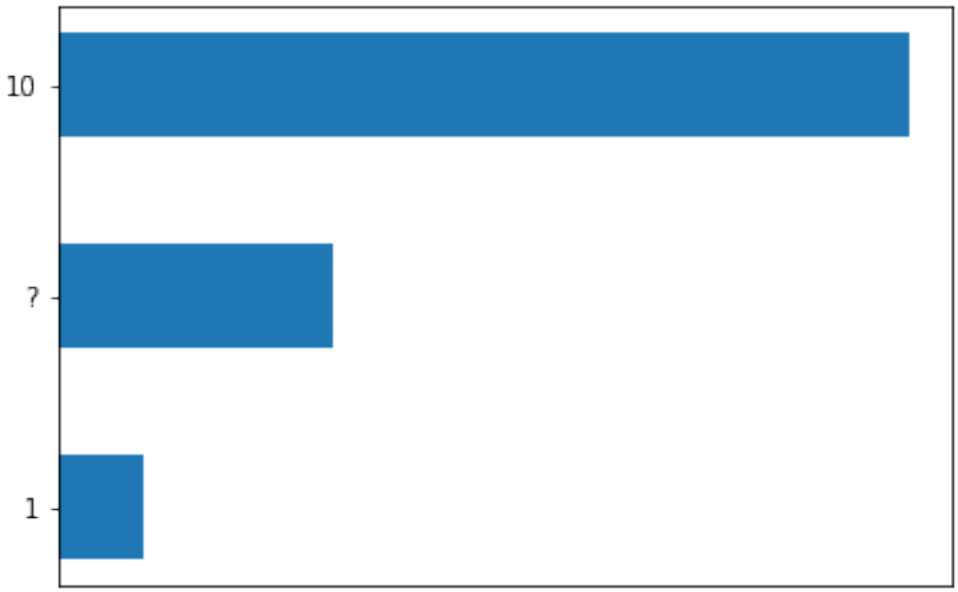
9.2



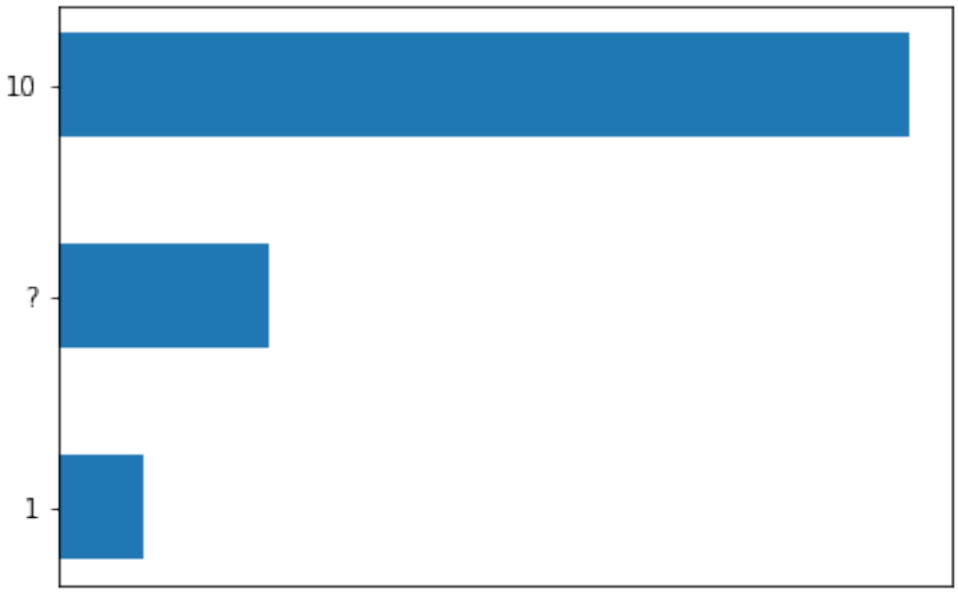
2.3

9

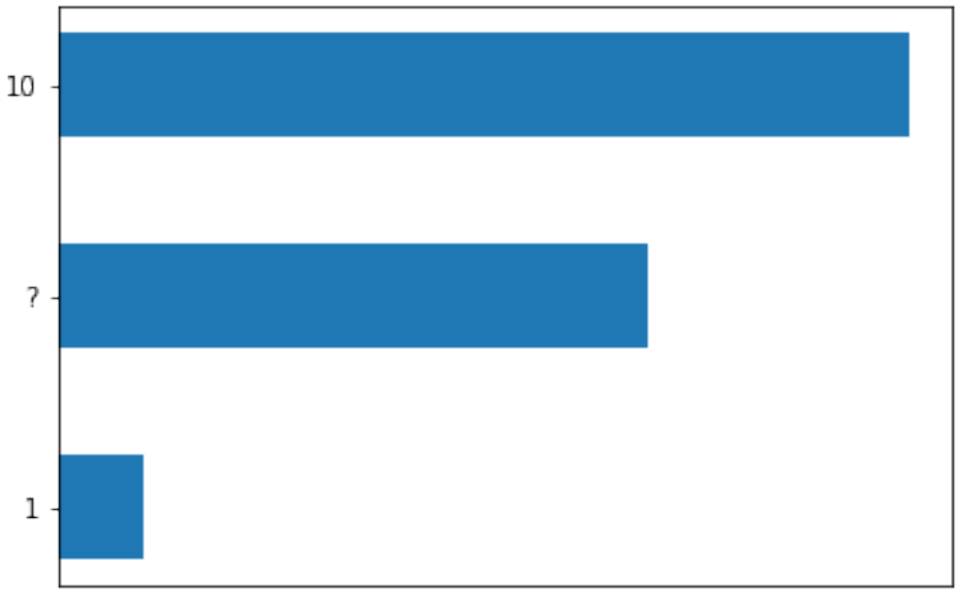

```
9
```




```
3.5
```



2



7.5

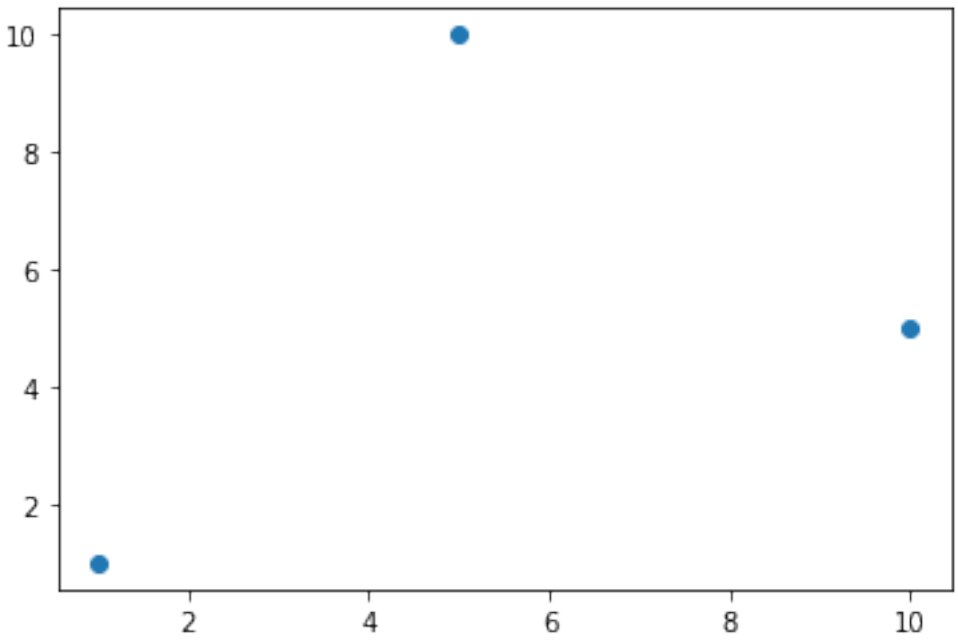
10

1.4.2 Plotting the result

Now we can draw the scatter plot of perceived and actual length. The `matplotlib`'s `scatter()` function will do this. This is the backend of the pandas' scatterplot. Here is an example of how to use `scatter`:

[31]:
```
plt.scatter(x=[1,5,10], y=[1,10, 5])
```

[31]:
```
<matplotlib.collections.PathCollection at 0x7f25fdb6e790>
```



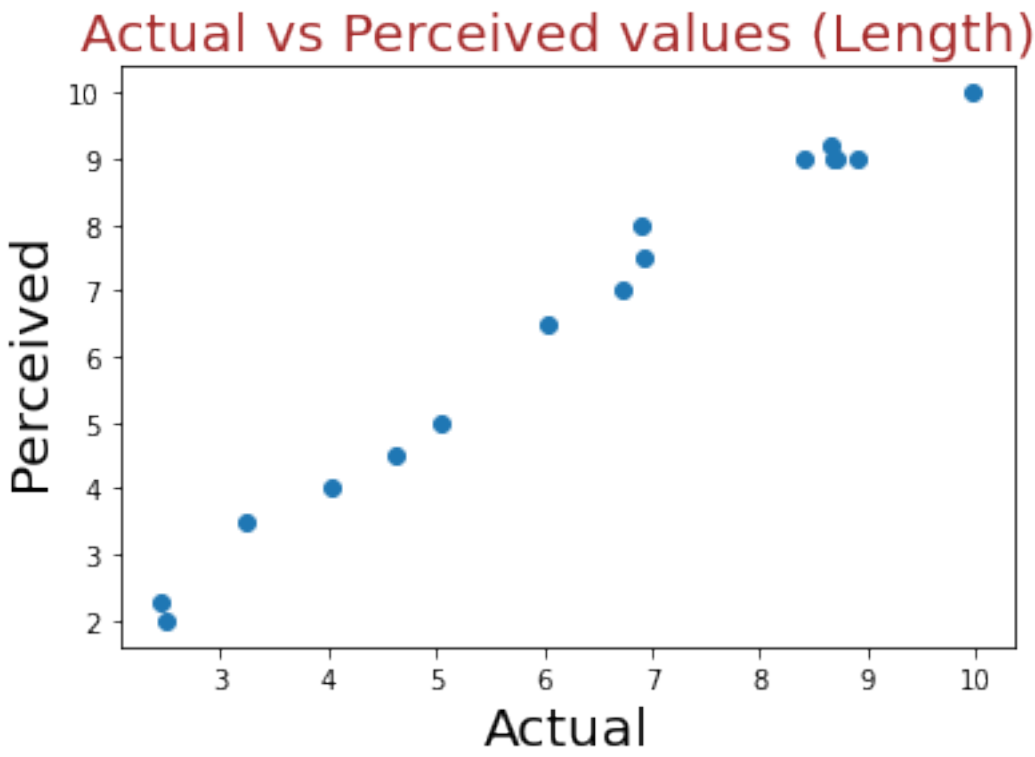
Q3: Now plot your result using the `scatter()` function. You should also use `plt.title()`, `plt.xlabel()`, and `plt.ylabel()` to label your axes and the plot itself.

[32]:
```
print("Actual values : ",  actual_length_list)
print("Perceived values : ", perceived_length_list)
```

```
Actual values :  [4.616392176396236, 5.035224169562559, 6.7288087106152625,
8.678720853483135, 6.8955033029772, 4.035798346623107, 6.0297193789407295,
8.91518414950425, 8.65951145773171, 2.4481776726049373, 8.41531401690498,
8.699226113138593, 3.2282269003133948, 2.491868706924514, 6.926632107070838,
9.981962129511246]
Perceived values :  [4.5, 5.0, 7.0, 9.0, 8.0, 4.0, 6.5, 9.0, 9.2, 2.3, 9.0, 9.0,
3.5, 2.0, 7.5, 10.0]
```

[33]:
```
# TODO: put your code here

plt.scatter(x=actual_length_list, y=perceived_length_list)
plt.title("Actual vs Perceived values (Length) ", fontsize = 20, c = "Brown")
plt.xlabel("Actual",  fontsize = 20)
plt.ylabel("Perceived",  fontsize = 20)
```

[33]:
```
Text(0, 0.5, 'Perceived')
```



Stevens power law wr.t the length is pretty much close but it needed keen observation and it didnt come naturally to me.

After plotting, let's fit the relation between actual and perceived lengths using a polynomial function. We can easily do it using `curve_fit(f, x, y)` in Scipy, which is to fit x and y using the function `f`. In our case, $f = a * x^b + c$. For instance, we can check whether this works by creating a fake dataset that follows the exact form:

[34]:
```
from scipy.optimize import curve_fit

def func(x, a, b, c):
    return a * np.power(x, b) + c

x = np.arange(20)  # [0,1,2,3, ..., 19]
y = np.power(x, 2) # [0,1,4,9, ... ]

popt, pcov = curve_fit(func, x, y)
print('{:.2f} x^{:.2f} + {:.2f}'.format(*popt))
```

```
1.00 x^2.00 + -0.00
```

[35]:
```
popt
pcov
```

[35]:
```
array([[ 1.07315181e-18, -3.85373325e-19, -4.25130522e-18],
       [-3.85373325e-19,  1.39065357e-19,  1.51864445e-18],
       [-4.25130522e-18,  1.51864445e-18,  2.85834913e-16]])
```

Q4: Now fit your data! Do you see roughly linear relationship between the actual and the perceived lengths? It's ok if you don't!

[37]:
```
# TODO: your code here
popt, pcov = curve_fit(func, actual_length_list, perceived_length_list)
print('{:.2f} x^{:.2f} + {:.2f}'.format(*popt))
```

```
3.08 x^0.65 + -3.39
```

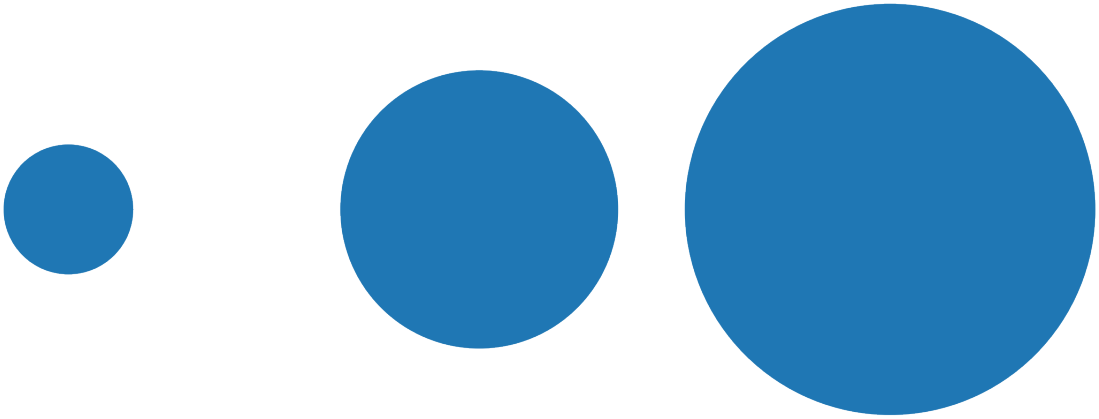
1.4.3 Perception of area

Similar to the above experiment, we now represent a random number as a circle, and the area of the circle is equal to the number.

First, calculate the radius of a circle from its area and then plot using the **`Circle()`** function. `plt.Circle((0,0), r)` will plot a circle centered at (0,0) with radius `r`.

[38]:
```
n1 = 0.005
n2 = 0.05

radius1 = np.sqrt(n1/np.pi) # area = pi * r * r
radius2 = np.sqrt(n2/np.pi)
random_radius = np.sqrt(n1*random.uniform(1,10)/np.pi)

plt.axis('equal')
plt.axis('off')
circ1 = plt.Circle( (0,0),         radius1, clip_on=False )
circ2 = plt.Circle( (4*radius2,0), radius2, clip_on=False )
rand_circ = plt.Circle((2*radius2,0), random_radius, clip_on=False )

plt.gca().add_artist(circ1)
plt.gca().add_artist(circ2)
plt.gca().add_artist(rand_circ)
```

[38]:
```
<matplotlib.patches.Circle at 0x7f25edd3d910>
```



Let's have two lists for this experiment.

[48]:
```
perceived_area_list = []
actual_area_list = []
```

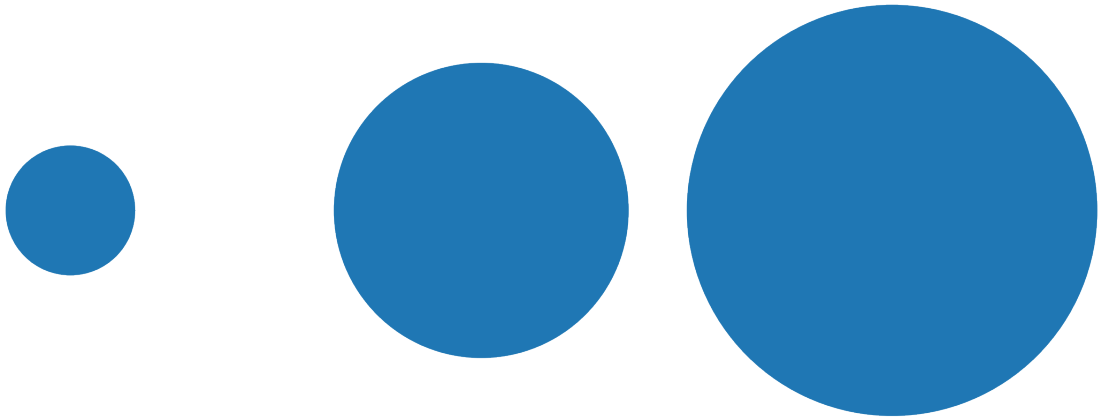
And define a function for the experiment.

[49]:
```
def run_area_exp_once(n1=0.005, n2=0.05):
    radius1 = np.sqrt(n1/np.pi) # area = pi * r * r
    radius2 = np.sqrt(n2/np.pi)

    mystery_number = random.uniform(1,10)
    random_radius = np.sqrt(n1*mystery_number/math.pi)

    plt.axis('equal')
    plt.axis('off')
    circ1 = plt.Circle( (0,0),         radius1, clip_on=False )
    circ2 = plt.Circle( (4*radius2,0), radius2, clip_on=False )
    rand_circ = plt.Circle((2*radius2,0), random_radius, clip_on=False )
    plt.gca().add_artist(circ1)
    plt.gca().add_artist(circ2)
    plt.gca().add_artist(rand_circ)
    plt.show()

    perceived_area_list.append( float(input()) )
    actual_area_list.append(mystery_number)
```

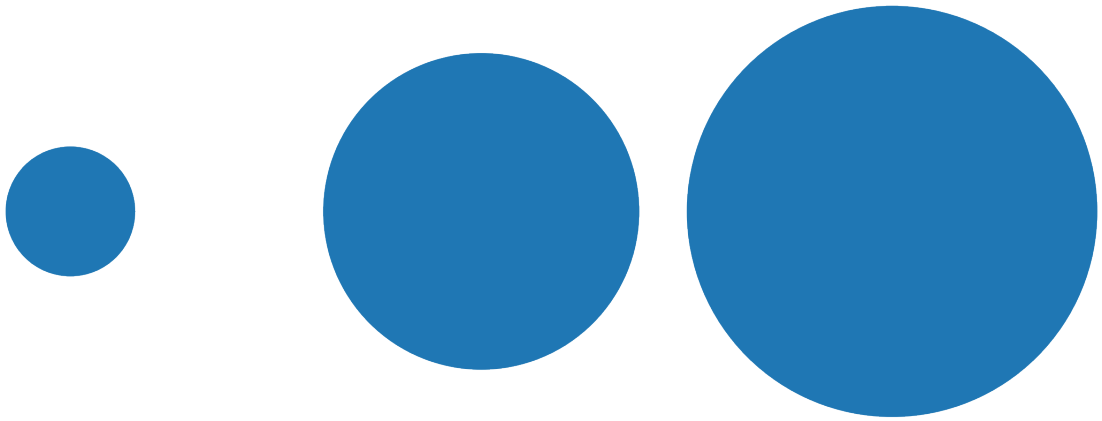
Q5: Now you can run the experiment many times, plot the result, and fit a power-law curve!

[50]:
```
# TODO: put your code here. You can use multiple cells.

for i in range(0,10):
```

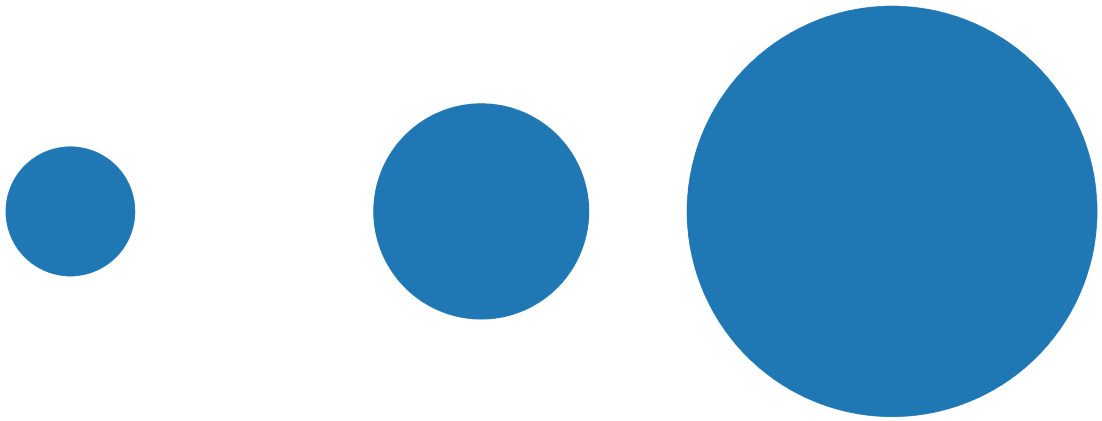
```
run_area_exp_once()
```



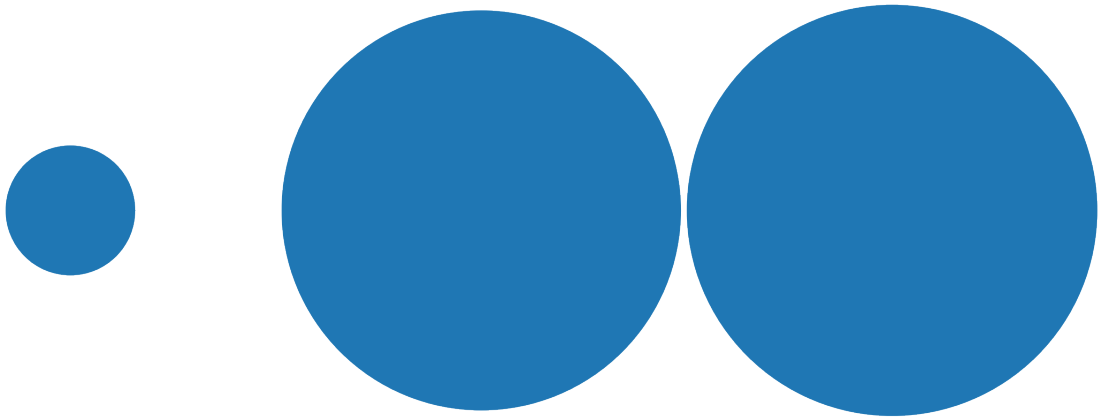
6



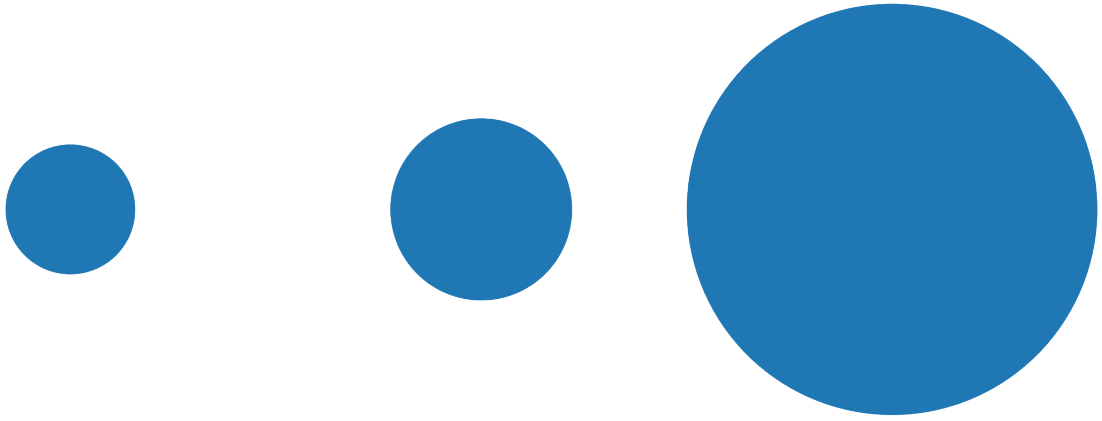
5



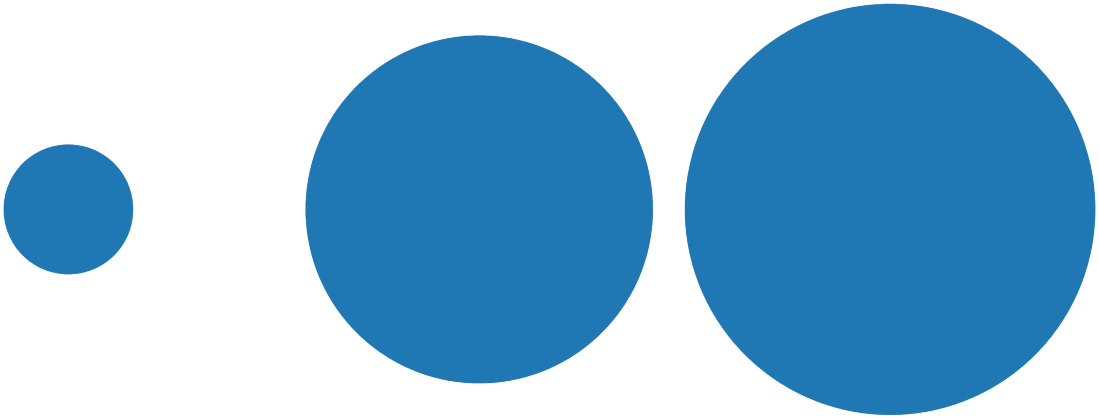
2



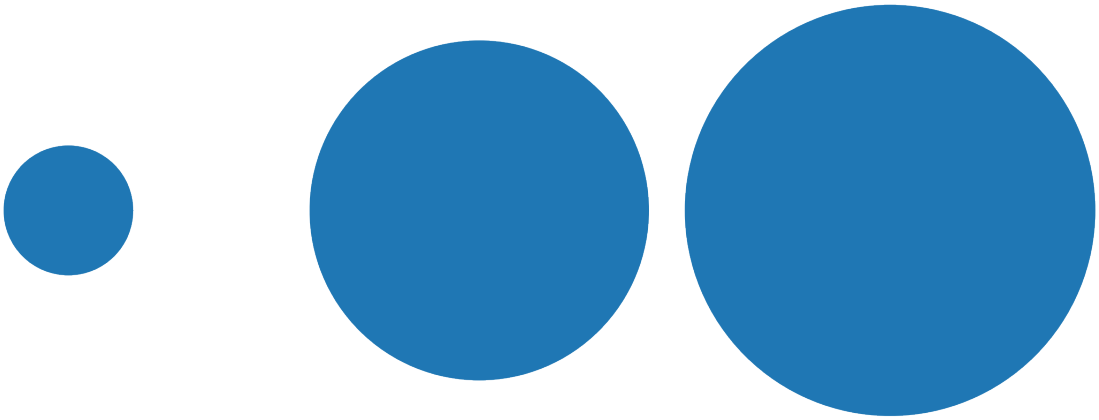
10



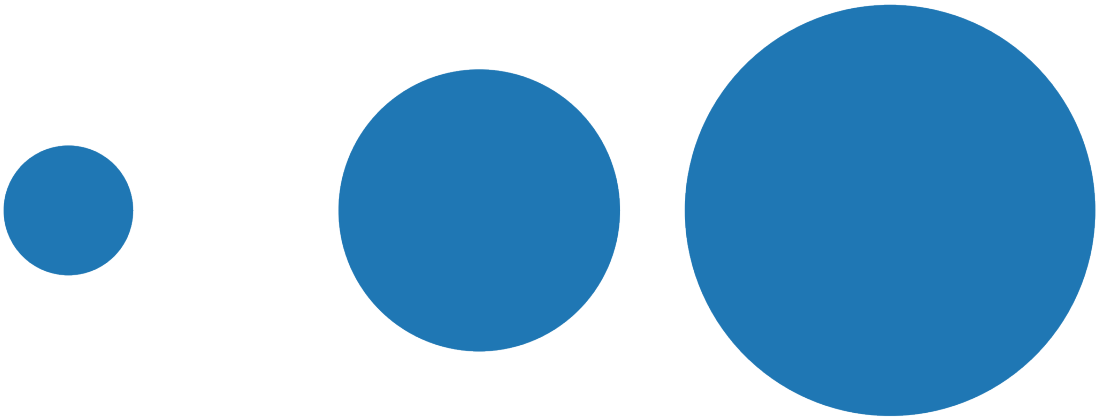
1.2



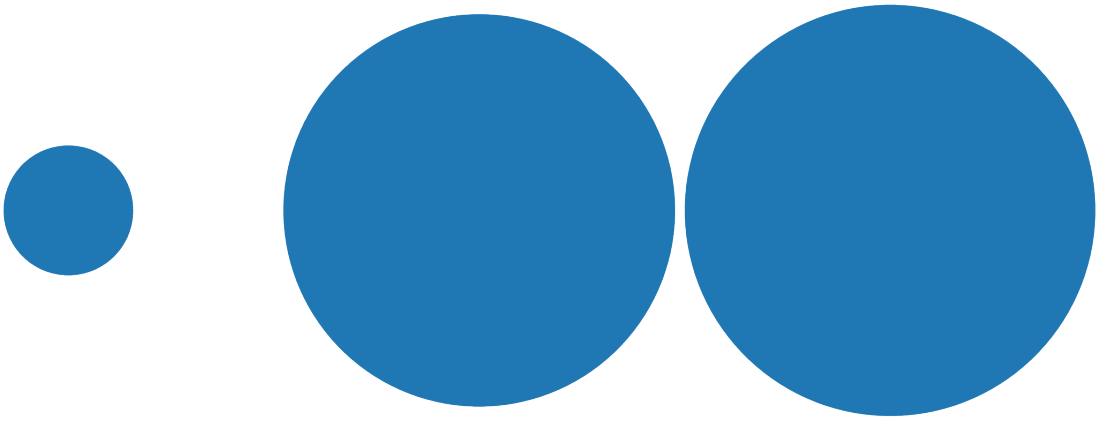
8



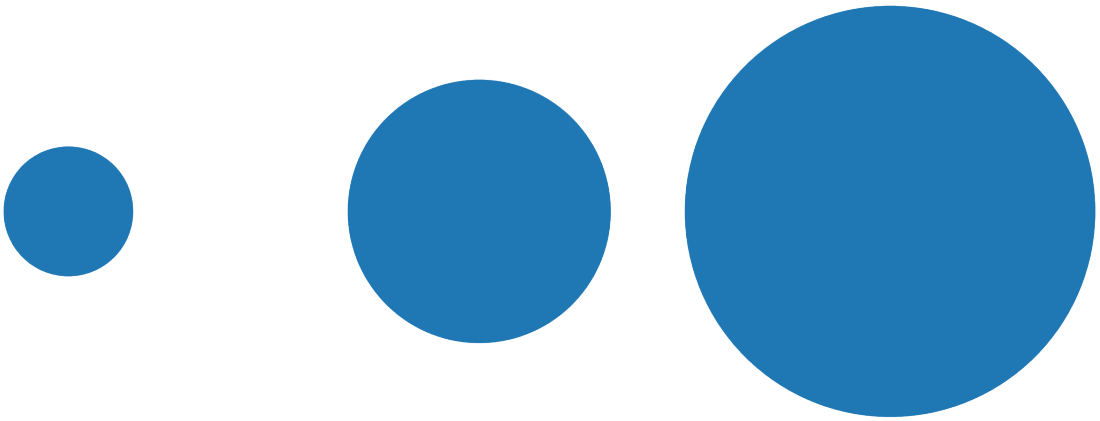
8



7



10



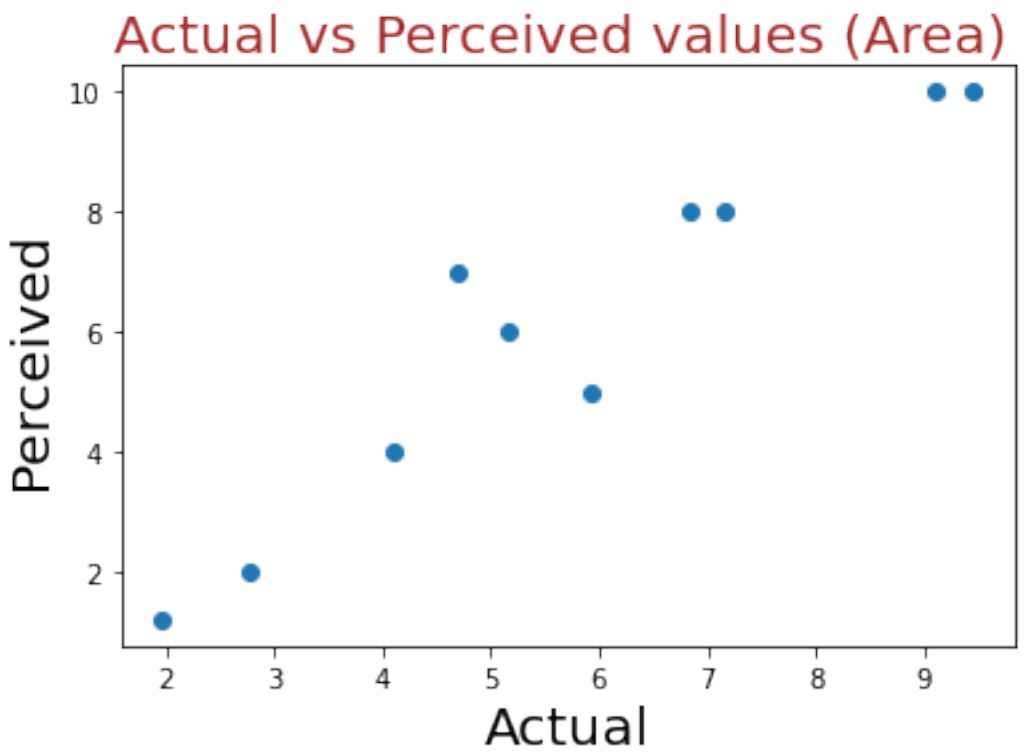
4

[51]:
```
print("Actual values : ",  np.round(actual_area_list, 2))
print("Perceived values : ", perceived_area_list)
```

```
Actual values :  [5.16 5.93 2.77 9.46 1.96 7.16 6.83 4.71 9.1  4.11]
Perceived values :  [6.0, 5.0, 2.0, 10.0, 1.2, 8.0, 8.0, 7.0, 10.0, 4.0]
```

[52]:
```
# Scatter plot

plt.scatter(x=actual_area_list, y=perceived_area_list)
plt.title("Actual vs Perceived values (Area) ", fontsize = 20, c = "Brown")
plt.xlabel("Actual",  fontsize = 20)
plt.ylabel("Perceived",  fontsize = 20)
```

[52]: Text(0, 0.5, 'Perceived')



[53]:
```
# Curve fit

from scipy.optimize import curve_fit

def func(x, a, b, c):
    return a * np.power(x, b) + c

popt, pcov = curve_fit(func, actual_area_list, perceived_area_list)
print('{:.2f} x^{:.2f} + {:.2f}'.format(*popt))
```

```
6.12 x^0.47 + -7.36
```

What is your result? How are the exponents different from each other?

The perception while comparing the lengths was much better than while comparing the area of a circle

1.5 Convert the notebook to HTML

[ ]:
```
%%shell
# jupyter nbconvert --to html /content/lab03_Ganapathy_Anitha.ipynb
```

```
[NbConvertApp] Converting notebook /content/lab03_Ganapathy_Anitha.ipynb to html
[NbConvertApp] Writing 1215468 bytes to /content/lab03_Ganapathy_Anitha.html
```

[ ]:

1.6 Convert the notebook to PDF

1.6.1 Install necessary plugins

https://stackoverflow.com/questions/52588552/google-co-laboratory-notebook-pdf-download

[54]:
```
%%time

!apt-get install texlive texlive-xetex texlive-latex-extra pandoc
!pip install pypandoc
```

```
Reading package lists… Done
Building dependency tree
Reading state information… Done
pandoc is already the newest version (1.19.2.4~dfsg-1build4).
pandoc set to manually installed.
The following package was automatically installed and is no longer required:
  libnvidia-common-460
Use 'apt autoremove' to remove it.
The following additional packages will be installed:
  fonts-droid-fallback fonts-lato fonts-lmodern fonts-noto-mono fonts-texgyre
  javascript-common libcupsfilters1 libcupsimage2 libgs9 libgs9-common
  libijs-0.35 libjbig2dec0 libjs-jquery libkpathsea6 libpotrace0 libptexenc1
  libruby2.5 libsynctex1 libtexlua52 libtexluajit2 libzzip-0-13 lmodern
  poppler-data preview-latex-style rake ruby ruby-did-you-mean ruby-minitest
  ruby-net-telnet ruby-power-assert ruby-test-unit ruby2.5
  rubygems-integration t1utils tex-common tex-gyre texlive-base
  texlive-binaries texlive-fonts-recommended texlive-latex-base
  texlive-latex-recommended texlive-pictures texlive-plain-generic tipa
Suggested packages:
  fonts-noto apache2 | lighttpd | httpd poppler-utils ghostscript
  fonts-japanese-mincho | fonts-ipafont-mincho fonts-japanese-gothic
  | fonts-ipafont-gothic fonts-arphic-ukai fonts-arphic-uming fonts-nanum ri
  ruby-dev bundler debhelper gv | postscript-viewer perl-tk xpdf-reader
  | pdf-viewer texlive-fonts-recommended-doc texlive-latex-base-doc
  python-pygments icc-profiles libfile-which-perl
  libspreadsheet-parseexcel-perl texlive-latex-extra-doc
```

```
  texlive-latex-recommended-doc texlive-pstricks dot2tex prerex ruby-tcltk
  | libtcltk-ruby texlive-pictures-doc vprerex
The following NEW packages will be installed:
  fonts-droid-fallback fonts-lato fonts-lmodern fonts-noto-mono fonts-texgyre
  javascript-common libcupsfilters1 libcupsimage2 libgs9 libgs9-common
  libijs-0.35 libjbig2dec0 libjs-jquery libkpathsea6 libpotrace0 libptexenc1
  libruby2.5 libsynctex1 libtexlua52 libtexluajit2 libzzip-0-13 lmodern
  poppler-data preview-latex-style rake ruby ruby-did-you-mean ruby-minitest
  ruby-net-telnet ruby-power-assert ruby-test-unit ruby2.5
  rubygems-integration t1utils tex-common tex-gyre texlive texlive-base
  texlive-binaries texlive-fonts-recommended texlive-latex-base
  texlive-latex-extra texlive-latex-recommended texlive-pictures
  texlive-plain-generic texlive-xetex tipa
0 upgraded, 47 newly installed, 0 to remove and 42 not upgraded.
Need to get 146 MB of archives.
After this operation, 460 MB of additional disk space will be used.
Get:1 http://archive.ubuntu.com/ubuntu bionic/main amd64 fonts-droid-fallback
all 1:6.0.1r16-1.1 [1,805 kB]
Get:2 http://archive.ubuntu.com/ubuntu bionic/main amd64 fonts-lato all 2.0-2
[2,698 kB]
Get:3 http://archive.ubuntu.com/ubuntu bionic/main amd64 poppler-data all
0.4.8-2 [1,479 kB]
Get:4 http://archive.ubuntu.com/ubuntu bionic/main amd64 tex-common all 6.09
[33.0 kB]
Get:5 http://archive.ubuntu.com/ubuntu bionic/main amd64 fonts-lmodern all
2.004.5-3 [4,551 kB]
Get:6 http://archive.ubuntu.com/ubuntu bionic/main amd64 fonts-noto-mono all
20171026-2 [75.5 kB]
Get:7 http://archive.ubuntu.com/ubuntu bionic/universe amd64 fonts-texgyre all
20160520-1 [8,761 kB]
Get:8 http://archive.ubuntu.com/ubuntu bionic/main amd64 javascript-common all
11 [6,066 B]
Get:9 http://archive.ubuntu.com/ubuntu bionic-updates/main amd64 libcupsfilters1
amd64 1.20.2-0ubuntu3.1 [108 kB]
Get:10 http://archive.ubuntu.com/ubuntu bionic-updates/main amd64 libcupsimage2
amd64 2.2.7-1ubuntu2.8 [18.6 kB]
Get:11 http://archive.ubuntu.com/ubuntu bionic/main amd64 libijs-0.35 amd64
0.35-13 [15.5 kB]
Get:12 http://archive.ubuntu.com/ubuntu bionic/main amd64 libjbig2dec0 amd64
0.13-6 [55.9 kB]
Get:13 http://archive.ubuntu.com/ubuntu bionic-updates/main amd64 libgs9-common
all 9.26~dfsg+0-0ubuntu0.18.04.16 [5,093 kB]
Get:14 http://archive.ubuntu.com/ubuntu bionic-updates/main amd64 libgs9 amd64
9.26~dfsg+0-0ubuntu0.18.04.16 [2,265 kB]
Get:15 http://archive.ubuntu.com/ubuntu bionic/main amd64 libjs-jquery all
3.2.1-1 [152 kB]
Get:16 http://archive.ubuntu.com/ubuntu bionic-updates/main amd64 libkpathsea6
amd64 2017.20170613.44572-8ubuntu0.1 [54.9 kB]
```

```
Get:17 http://archive.ubuntu.com/ubuntu bionic/main amd64 libpotrace0 amd64
1.14-2 [17.4 kB]
Get:18 http://archive.ubuntu.com/ubuntu bionic-updates/main amd64 libptexenc1
amd64 2017.20170613.44572-8ubuntu0.1 [34.5 kB]
Get:19 http://archive.ubuntu.com/ubuntu bionic/main amd64 rubygems-integration
all 1.11 [4,994 B]
Get:20 http://archive.ubuntu.com/ubuntu bionic-updates/main amd64 ruby2.5 amd64
2.5.1-1ubuntu1.11 [48.6 kB]
Get:21 http://archive.ubuntu.com/ubuntu bionic/main amd64 ruby amd64 1:2.5.1
[5,712 B]
Get:22 http://archive.ubuntu.com/ubuntu bionic-updates/main amd64 rake all
12.3.1-1ubuntu0.1 [44.9 kB]
Get:23 http://archive.ubuntu.com/ubuntu bionic/main amd64 ruby-did-you-mean all
1.2.0-2 [9,700 B]
Get:24 http://archive.ubuntu.com/ubuntu bionic/main amd64 ruby-minitest all
5.10.3-1 [38.6 kB]
Get:25 http://archive.ubuntu.com/ubuntu bionic/main amd64 ruby-net-telnet all
0.1.1-2 [12.6 kB]
Get:26 http://archive.ubuntu.com/ubuntu bionic/main amd64 ruby-power-assert all
0.3.0-1 [7,952 B]
Get:27 http://archive.ubuntu.com/ubuntu bionic/main amd64 ruby-test-unit all
3.2.5-1 [61.1 kB]
Get:28 http://archive.ubuntu.com/ubuntu bionic-updates/main amd64 libruby2.5
amd64 2.5.1-1ubuntu1.11 [3,072 kB]
Get:29 http://archive.ubuntu.com/ubuntu bionic-updates/main amd64 libsynctex1
amd64 2017.20170613.44572-8ubuntu0.1 [41.4 kB]
Get:30 http://archive.ubuntu.com/ubuntu bionic-updates/main amd64 libtexlua52
amd64 2017.20170613.44572-8ubuntu0.1 [91.2 kB]
Get:31 http://archive.ubuntu.com/ubuntu bionic-updates/main amd64 libtexluajit2
amd64 2017.20170613.44572-8ubuntu0.1 [230 kB]
Get:32 http://archive.ubuntu.com/ubuntu bionic-updates/main amd64 libzzip-0-13
amd64 0.13.62-3.1ubuntu0.18.04.1 [26.0 kB]
Get:33 http://archive.ubuntu.com/ubuntu bionic/main amd64 lmodern all 2.004.5-3
[9,631 kB]
Get:34 http://archive.ubuntu.com/ubuntu bionic/main amd64 preview-latex-style
all 11.91-1ubuntu1 [185 kB]
Get:35 http://archive.ubuntu.com/ubuntu bionic/main amd64 t1utils amd64 1.41-2
[56.0 kB]
Get:36 http://archive.ubuntu.com/ubuntu bionic/universe amd64 tex-gyre all
20160520-1 [4,998 kB]
Get:37 http://archive.ubuntu.com/ubuntu bionic-updates/main amd64 texlive-
binaries amd64 2017.20170613.44572-8ubuntu0.1 [8,179 kB]
Get:38 http://archive.ubuntu.com/ubuntu bionic/main amd64 texlive-base all
2017.20180305-1 [18.7 MB]
Get:39 http://archive.ubuntu.com/ubuntu bionic/universe amd64 texlive-fonts-
recommended all 2017.20180305-1 [5,262 kB]
Get:40 http://archive.ubuntu.com/ubuntu bionic/main amd64 texlive-latex-base all
2017.20180305-1 [951 kB]
```

```
Get:41 http://archive.ubuntu.com/ubuntu bionic/main amd64 texlive-latex-
recommended all 2017.20180305-1 [14.9 MB]
Get:42 http://archive.ubuntu.com/ubuntu bionic/universe amd64 texlive all
2017.20180305-1 [14.4 kB]
Get:43 http://archive.ubuntu.com/ubuntu bionic/universe amd64 texlive-pictures
all 2017.20180305-1 [4,026 kB]
Get:44 http://archive.ubuntu.com/ubuntu bionic/universe amd64 texlive-latex-
extra all 2017.20180305-2 [10.6 MB]
Get:45 http://archive.ubuntu.com/ubuntu bionic/universe amd64 texlive-plain-
generic all 2017.20180305-2 [23.6 MB]
Get:46 http://archive.ubuntu.com/ubuntu bionic/universe amd64 tipa all 2:1.3-20
[2,978 kB]
Get:47 http://archive.ubuntu.com/ubuntu bionic/universe amd64 texlive-xetex all
2017.20180305-1 [10.7 MB]
Fetched 146 MB in 5s (29.7 MB/s)
Extracting templates from packages: 100%
Preconfiguring packages …
Selecting previously unselected package fonts-droid-fallback.
(Reading database … 155629 files and directories currently installed.)
Preparing to unpack …/00-fonts-droid-fallback_1%3a6.0.1r16-1.1_all.deb …
Unpacking fonts-droid-fallback (1:6.0.1r16-1.1) …
Selecting previously unselected package fonts-lato.
Preparing to unpack …/01-fonts-lato_2.0-2_all.deb …
Unpacking fonts-lato (2.0-2) …
Selecting previously unselected package poppler-data.
Preparing to unpack …/02-poppler-data_0.4.8-2_all.deb …
Unpacking poppler-data (0.4.8-2) …
Selecting previously unselected package tex-common.
Preparing to unpack …/03-tex-common_6.09_all.deb …
Unpacking tex-common (6.09) …
Selecting previously unselected package fonts-lmodern.
Preparing to unpack …/04-fonts-lmodern_2.004.5-3_all.deb …
Unpacking fonts-lmodern (2.004.5-3) …
Selecting previously unselected package fonts-noto-mono.
Preparing to unpack …/05-fonts-noto-mono_20171026-2_all.deb …
Unpacking fonts-noto-mono (20171026-2) …
Selecting previously unselected package fonts-texgyre.
Preparing to unpack …/06-fonts-texgyre_20160520-1_all.deb …
Unpacking fonts-texgyre (20160520-1) …
Selecting previously unselected package javascript-common.
Preparing to unpack …/07-javascript-common_11_all.deb …
Unpacking javascript-common (11) …
Selecting previously unselected package libcupsfilters1:amd64.
Preparing to unpack …/08-libcupsfilters1_1.20.2-0ubuntu3.1_amd64.deb …
Unpacking libcupsfilters1:amd64 (1.20.2-0ubuntu3.1) …
Selecting previously unselected package libcupsimage2:amd64.
Preparing to unpack …/09-libcupsimage2_2.2.7-1ubuntu2.8_amd64.deb …
Unpacking libcupsimage2:amd64 (2.2.7-1ubuntu2.8) …
```

```
Selecting previously unselected package libijs-0.35:amd64.
Preparing to unpack …/10-libijs-0.35_0.35-13_amd64.deb …
Unpacking libijs-0.35:amd64 (0.35-13) …
Selecting previously unselected package libjbig2dec0:amd64.
Preparing to unpack …/11-libjbig2dec0_0.13-6_amd64.deb …
Unpacking libjbig2dec0:amd64 (0.13-6) …
Selecting previously unselected package libgs9-common.
Preparing to unpack …/12-libgs9-common_9.26~dfsg+0-0ubuntu0.18.04.16_all.deb
…
Unpacking libgs9-common (9.26~dfsg+0-0ubuntu0.18.04.16) …
Selecting previously unselected package libgs9:amd64.
Preparing to unpack …/13-libgs9_9.26~dfsg+0-0ubuntu0.18.04.16_amd64.deb …
Unpacking libgs9:amd64 (9.26~dfsg+0-0ubuntu0.18.04.16) …
Selecting previously unselected package libjs-jquery.
Preparing to unpack …/14-libjs-jquery_3.2.1-1_all.deb …
Unpacking libjs-jquery (3.2.1-1) …
Selecting previously unselected package libkpathsea6:amd64.
Preparing to unpack …/15-libkpathsea6_2017.20170613.44572-8ubuntu0.1_amd64.deb
…
Unpacking libkpathsea6:amd64 (2017.20170613.44572-8ubuntu0.1) …
Selecting previously unselected package libpotrace0.
Preparing to unpack …/16-libpotrace0_1.14-2_amd64.deb …
Unpacking libpotrace0 (1.14-2) …
Selecting previously unselected package libptexenc1:amd64.
Preparing to unpack …/17-libptexenc1_2017.20170613.44572-8ubuntu0.1_amd64.deb
…
Unpacking libptexenc1:amd64 (2017.20170613.44572-8ubuntu0.1) …
Selecting previously unselected package rubygems-integration.
Preparing to unpack …/18-rubygems-integration_1.11_all.deb …
Unpacking rubygems-integration (1.11) …
Selecting previously unselected package ruby2.5.
Preparing to unpack …/19-ruby2.5_2.5.1-1ubuntu1.11_amd64.deb …
Unpacking ruby2.5 (2.5.1-1ubuntu1.11) …
Selecting previously unselected package ruby.
Preparing to unpack …/20-ruby_1%3a2.5.1_amd64.deb …
Unpacking ruby (1:2.5.1) …
Selecting previously unselected package rake.
Preparing to unpack …/21-rake_12.3.1-1ubuntu0.1_all.deb …
Unpacking rake (12.3.1-1ubuntu0.1) …
Selecting previously unselected package ruby-did-you-mean.
Preparing to unpack …/22-ruby-did-you-mean_1.2.0-2_all.deb …
Unpacking ruby-did-you-mean (1.2.0-2) …
Selecting previously unselected package ruby-minitest.
Preparing to unpack …/23-ruby-minitest_5.10.3-1_all.deb …
Unpacking ruby-minitest (5.10.3-1) …
Selecting previously unselected package ruby-net-telnet.
Preparing to unpack …/24-ruby-net-telnet_0.1.1-2_all.deb …
Unpacking ruby-net-telnet (0.1.1-2) …
```

```
Selecting previously unselected package ruby-power-assert.
Preparing to unpack …/25-ruby-power-assert_0.3.0-1_all.deb …
Unpacking ruby-power-assert (0.3.0-1) …
Selecting previously unselected package ruby-test-unit.
Preparing to unpack …/26-ruby-test-unit_3.2.5-1_all.deb …
Unpacking ruby-test-unit (3.2.5-1) …
Selecting previously unselected package libruby2.5:amd64.
Preparing to unpack …/27-libruby2.5_2.5.1-1ubuntu1.11_amd64.deb …
Unpacking libruby2.5:amd64 (2.5.1-1ubuntu1.11) …
Selecting previously unselected package libsynctex1:amd64.
Preparing to unpack …/28-libsynctex1_2017.20170613.44572-8ubuntu0.1_amd64.deb
…
Unpacking libsynctex1:amd64 (2017.20170613.44572-8ubuntu0.1) …
Selecting previously unselected package libtexlua52:amd64.
Preparing to unpack …/29-libtexlua52_2017.20170613.44572-8ubuntu0.1_amd64.deb
…
Unpacking libtexlua52:amd64 (2017.20170613.44572-8ubuntu0.1) …
Selecting previously unselected package libtexluajit2:amd64.
Preparing to unpack
…/30-libtexluajit2_2017.20170613.44572-8ubuntu0.1_amd64.deb …
Unpacking libtexluajit2:amd64 (2017.20170613.44572-8ubuntu0.1) …
Selecting previously unselected package libzzip-0-13:amd64.
Preparing to unpack …/31-libzzip-0-13_0.13.62-3.1ubuntu0.18.04.1_amd64.deb …
Unpacking libzzip-0-13:amd64 (0.13.62-3.1ubuntu0.18.04.1) …
Selecting previously unselected package lmodern.
Preparing to unpack …/32-lmodern_2.004.5-3_all.deb …
Unpacking lmodern (2.004.5-3) …
Selecting previously unselected package preview-latex-style.
Preparing to unpack …/33-preview-latex-style_11.91-1ubuntu1_all.deb …
Unpacking preview-latex-style (11.91-1ubuntu1) …
Selecting previously unselected package t1utils.
Preparing to unpack …/34-t1utils_1.41-2_amd64.deb …
Unpacking t1utils (1.41-2) …
Selecting previously unselected package tex-gyre.
Preparing to unpack …/35-tex-gyre_20160520-1_all.deb …
Unpacking tex-gyre (20160520-1) …
Selecting previously unselected package texlive-binaries.
Preparing to unpack …/36-texlive-
binaries_2017.20170613.44572-8ubuntu0.1_amd64.deb …
Unpacking texlive-binaries (2017.20170613.44572-8ubuntu0.1) …
Selecting previously unselected package texlive-base.
Preparing to unpack …/37-texlive-base_2017.20180305-1_all.deb …
Unpacking texlive-base (2017.20180305-1) …
Selecting previously unselected package texlive-fonts-recommended.
Preparing to unpack …/38-texlive-fonts-recommended_2017.20180305-1_all.deb …
Unpacking texlive-fonts-recommended (2017.20180305-1) …
Selecting previously unselected package texlive-latex-base.
Preparing to unpack …/39-texlive-latex-base_2017.20180305-1_all.deb …
```

```
Unpacking texlive-latex-base (2017.20180305-1) …
Selecting previously unselected package texlive-latex-recommended.
Preparing to unpack …/40-texlive-latex-recommended_2017.20180305-1_all.deb …
Unpacking texlive-latex-recommended (2017.20180305-1) …
Selecting previously unselected package texlive.
Preparing to unpack …/41-texlive_2017.20180305-1_all.deb …
Unpacking texlive (2017.20180305-1) …
Selecting previously unselected package texlive-pictures.
Preparing to unpack …/42-texlive-pictures_2017.20180305-1_all.deb …
Unpacking texlive-pictures (2017.20180305-1) …
Selecting previously unselected package texlive-latex-extra.
Preparing to unpack …/43-texlive-latex-extra_2017.20180305-2_all.deb …
Unpacking texlive-latex-extra (2017.20180305-2) …
Selecting previously unselected package texlive-plain-generic.
Preparing to unpack …/44-texlive-plain-generic_2017.20180305-2_all.deb …
Unpacking texlive-plain-generic (2017.20180305-2) …
Selecting previously unselected package tipa.
Preparing to unpack …/45-tipa_2%3a1.3-20_all.deb …
Unpacking tipa (2:1.3-20) …
Selecting previously unselected package texlive-xetex.
Preparing to unpack …/46-texlive-xetex_2017.20180305-1_all.deb …
Unpacking texlive-xetex (2017.20180305-1) …
Setting up libgs9-common (9.26~dfsg+0-0ubuntu0.18.04.16) …
Setting up libkpathsea6:amd64 (2017.20170613.44572-8ubuntu0.1) …
Setting up libjs-jquery (3.2.1-1) …
Setting up libtexlua52:amd64 (2017.20170613.44572-8ubuntu0.1) …
Setting up fonts-droid-fallback (1:6.0.1r16-1.1) …
Setting up libsynctex1:amd64 (2017.20170613.44572-8ubuntu0.1) …
Setting up libptexenc1:amd64 (2017.20170613.44572-8ubuntu0.1) …
Setting up tex-common (6.09) …
update-language: texlive-base not installed and configured, doing nothing!
Setting up poppler-data (0.4.8-2) …
Setting up tex-gyre (20160520-1) …
Setting up preview-latex-style (11.91-1ubuntu1) …
Setting up fonts-texgyre (20160520-1) …
Setting up fonts-noto-mono (20171026-2) …
Setting up fonts-lato (2.0-2) …
Setting up libcupsfilters1:amd64 (1.20.2-0ubuntu3.1) …
Setting up libcupsimage2:amd64 (2.2.7-1ubuntu2.8) …
Setting up libjbig2dec0:amd64 (0.13-6) …
Setting up ruby-did-you-mean (1.2.0-2) …
Setting up t1utils (1.41-2) …
Setting up ruby-net-telnet (0.1.1-2) …
Setting up libijs-0.35:amd64 (0.35-13) …
Setting up rubygems-integration (1.11) …
Setting up libpotrace0 (1.14-2) …
Setting up javascript-common (11) …
Setting up ruby-minitest (5.10.3-1) …
```

```
Setting up libzzip-0-13:amd64 (0.13.62-3.1ubuntu0.18.04.1) …
Setting up libgs9:amd64 (9.26~dfsg+0-0ubuntu0.18.04.16) …
Setting up libtexluajit2:amd64 (2017.20170613.44572-8ubuntu0.1) …
Setting up fonts-lmodern (2.004.5-3) …
Setting up ruby-power-assert (0.3.0-1) …
Setting up texlive-binaries (2017.20170613.44572-8ubuntu0.1) …
update-alternatives: using /usr/bin/xdvi-xaw to provide /usr/bin/xdvi.bin
(xdvi.bin) in auto mode
update-alternatives: using /usr/bin/bibtex.original to provide /usr/bin/bibtex
(bibtex) in auto mode
Setting up texlive-base (2017.20180305-1) …
mktexlsr: Updating /var/lib/texmf/ls-R-TEXLIVEDIST…
mktexlsr: Updating /var/lib/texmf/ls-R-TEXMFMAIN…
mktexlsr: Updating /var/lib/texmf/ls-R…
mktexlsr: Done.
tl-paper: setting paper size for dvips to a4:
/var/lib/texmf/dvips/config/config-paper.ps
tl-paper: setting paper size for dvipdfmx to a4:
/var/lib/texmf/dvipdfmx/dvipdfmx-paper.cfg
tl-paper: setting paper size for xdvi to a4: /var/lib/texmf/xdvi/XDvi-paper
tl-paper: setting paper size for pdftex to a4:
/var/lib/texmf/tex/generic/config/pdftexconfig.tex
Setting up texlive-fonts-recommended (2017.20180305-1) …
Setting up texlive-plain-generic (2017.20180305-2) …
Setting up texlive-latex-base (2017.20180305-1) …
Setting up lmodern (2.004.5-3) …
Setting up texlive-latex-recommended (2017.20180305-1) …
Setting up texlive-pictures (2017.20180305-1) …
Setting up tipa (2:1.3-20) …
Regenerating '/var/lib/texmf/fmtutil.cnf-DEBIAN'… done.
Regenerating '/var/lib/texmf/fmtutil.cnf-TEXLIVEDIST'… done.
update-fmtutil has updated the following file(s):
        /var/lib/texmf/fmtutil.cnf-DEBIAN
        /var/lib/texmf/fmtutil.cnf-TEXLIVEDIST
If you want to activate the changes in the above file(s),
you should run fmtutil-sys or fmtutil.
Setting up texlive (2017.20180305-1) …
Setting up texlive-latex-extra (2017.20180305-2) …
Setting up texlive-xetex (2017.20180305-1) …
Setting up ruby2.5 (2.5.1-1ubuntu1.11) …
Setting up ruby (1:2.5.1) …
Setting up ruby-test-unit (3.2.5-1) …
Setting up rake (12.3.1-1ubuntu0.1) …
Setting up libruby2.5:amd64 (2.5.1-1ubuntu1.11) …
Processing triggers for mime-support (3.60ubuntu1) …
Processing triggers for libc-bin (2.27-3ubuntu1.3) …
/sbin/ldconfig.real: /usr/local/lib/python3.7/dist-
packages/ideep4py/lib/libmkldnn.so.0 is not a symbolic link
```

```
Processing triggers for man-db (2.8.3-2ubuntu0.1) …
Processing triggers for fontconfig (2.12.6-0ubuntu2) …
Processing triggers for tex-common (6.09) …
Running updmap-sys. This may take some time… done.
Running mktexlsr /var/lib/texmf … done.
Building format(s) --all.
        This may take some time… done.
Looking in indexes: https://pypi.org/simple, https://us-python.pkg.dev/colab-
wheels/public/simple/
Collecting pypandoc
  Downloading pypandoc-1.8.1-py3-none-any.whl (20 kB)
Installing collected packages: pypandoc
Successfully installed pypandoc-1.8.1
```

1.6.2 PDF conversion command

[ ]:
```
%%shell
# jupyter nbconvert --to PDF /content/lab03_Ganapathy_Anitha.ipynb
```

```
[NbConvertApp] Converting notebook /content/lab03_Ganapathy_Anitha.ipynb to PDF
[NbConvertApp] Support files will be in lab03_Ganapathy_Anitha_files/
[NbConvertApp] Making directory ./lab03_Ganapathy_Anitha_files
[NbConvertApp] Making directory ./lab03_Ganapathy_Anitha_files
[NbConvertApp] Making directory ./lab03_Ganapathy_Anitha_files
[NbConvertApp] Making directory ./lab03_Ganapathy_Anitha_files
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[NbConvertApp] Making directory ./lab03_Ganapathy_Anitha_files
[NbConvertApp] Making directory ./lab03_Ganapathy_Anitha_files
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[NbConvertApp] Making directory ./lab03_Ganapathy_Anitha_files
[NbConvertApp] Making directory ./lab03_Ganapathy_Anitha_files
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[NbConvertApp] Making directory ./lab03_Ganapathy_Anitha_files
[NbConvertApp] Making directory ./lab03_Ganapathy_Anitha_files
[NbConvertApp] Writing 69710 bytes to ./notebook.tex
[NbConvertApp] Building PDF
[NbConvertApp] Running xelatex 3 times: ['xelatex', './notebook.tex', '-quiet']
[NbConvertApp] Running bibtex 1 time: ['bibtex', './notebook']
[NbConvertApp] WARNING | bibtex had problems, most likely because there were no
citations
[NbConvertApp] PDF successfully created
[NbConvertApp] Writing 659191 bytes to /content/lab03_Ganapathy_Anitha.pdf
```

[ ]: