동국대학교
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# Numpy, Pandas, Matplotlib

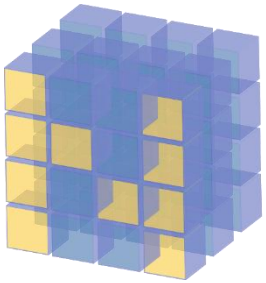
Machine Learning

# Numpy, Pandas, Matplotlib

- Contents
  - Numpy
  - Pandas
  - Matplotlib
  - Scikit-learn

# What is Numpy?

- Numpy
  - One of the library that provides efficient  and easy operation of the large-scale and multi-dimensional matrix in the python
  - It can make us to implement matrix operation, generate random numbers and fourier transform more easily than C, C++, Fortran
  - It is partially implemented in C, Fortran internally so, its speed of running is fast
  - Mostly, it is used with other python libraries (Scipy, Sympy, Matplotlib, Pandas)  to implement various statistical and  numerical analysis techniques



NumPy

# Array Creation

- array()
  - Example Code

```
from IPython.core.interactiveshell import InteractiveShell
InteractiveShell.ast_node_interactivity = "all"
```

→ Display full output in Jupyter cell, not only last result.

```
import numpy as np

a = np.array([[0, 1, 2, 3],
              [5, 6, 7, 8],
              [10, 11, 12, 13]])
a

a.ndim # 2 dimensions
a.shape # 3x4
```

```
array([[ 0, 1, 2, 3],
       [ 5, 6, 7, 8],
       [10, 11, 12, 13]])

2

(3, 4)
```

https://docs.scipy.org/doc/numpy/user/quickstart.html

# Array Creation

## 1. np.arange() & np.reshape()

```
a = np.arange(6)
a # np.array([0, 1, 2, 3, 4, 5])
```

```
array([0, 1, 2, 3, 4, 5])
```

```
b = a.reshape(2,3)
b # np.array([[0, 1, 2], [3, 4, 5]])
```

```
array([[0, 1, 2],
       [3, 4, 5]])
```

## 2. np.zeros()

```
# initialized all 0
x = np.zeros((3, 4))
x
```

```
array([[ 0., 0., 0., 0.],
       [ 0., 0., 0., 0.],
       [ 0., 0., 0., 0.]])
```

## 3. np.ones()

```
# initialized all 1
y = np.ones((2, 3, 4), dtype = np.float64)
y
```

```
array([[[ 1., 1., 1., 1.],
        [ 1., 1., 1., 1.],
        [ 1., 1., 1., 1.]],
       [[ 1., 1., 1., 1.],
        [ 1., 1., 1., 1.],
        [ 1., 1., 1., 1.]]])
```

https://docs.scipy.org/doc/numpy/user/quickstart.html

# Array Creation

## 4. np.identity()

```
# identity matrix of size 3 x 3
i = np.identity(n=3)
i
```

```
array([[ 1., 0., 0.],
       [ 0., 1., 0.],
       [ 0., 0., 1.]])
```

## 5. np.random.randn()

```
# Return samples from the "standard normal" distribution.
r = np.random.randn(3,3)
r
```

```
array([[-0.03318424, 0.07825921, -0.59816703],
       [-0.91686982, -0.18075674, 1.92220989],
       [ 0.84470512, -1.42788256, 0.44475968]])
```

https://docs.scipy.org/doc/numpy/user/quickstart.html

# Array Operations

- +, -, *, matrix multiplication, matrix transpose

```
a = np.array([[1, 1], [0, 1]])
b = np.array([[2, 0], [3, 4]])

a
b

a * 10 # matrix * scalar
a + b # elementwise addition
a * b # elementwise product
```

```
array([[1, 1],
       [0, 1]])

array([[2, 0],
       [3, 4]])

array([[10, 10],
       [ 0, 10]])

array([[3, 1],
       [3, 5]])

array([[2, 0],
       [0, 4]])
```

https://docs.scipy.org/doc/numpy/user/quickstart.html

# Array Operations

- +, -, *, matrix multiplication, matrix transpose

```
a @ b    # matrix product
a.dot(b) # matrix product

a.T      # matrix transpose
```

```
array([[5, 4],
       [3, 4]])

array([[5, 4],
       [3, 4]])

array([[1, 0],
       [1, 1]])
```

https://docs.scipy.org/doc/numpy/user/quickstart.html

# Indexing

- Indexing, slicing

```
a = np.arange(20).reshape(4, 5)
a
```

```
array([[ 0, 1, 2, 3, 4],
       [ 5, 6, 7, 8, 9],
       [10, 11, 12, 13, 14],
       [15, 16, 17, 18, 19]])
```

```
# indexing
a[2, 2]

# slicing
a[0:2, 0:2]
a[0:2, :]
a[:, 0:2]
```

```
12

array([[0, 1],
       [5, 6]])
array([[0, 1, 2, 3, 4],
       [5, 6, 7, 8, 9]])
array([[ 0, 1],
       [ 5, 6],
       [10, 11],
       [15, 16]])
```

https://docs.scipy.org/doc/numpy/user/quickstart.html

# Stacking

- vstack(), hstack()

```
a = np.array([[1, 1],[0, 1]])
b = np.array(10*np.random.random((2, 2)))
a
B

np.vstack((a, b)) # append row
np.hstack((a, b)) # append column
```

```
array([[1, 1],
       [0, 1]])
array([[ 8.95081961, 8.17967375],
       [ 8.91370118, 6.80621455]])


array([[ 1. , 1. ],
       [ 0. , 1. ],
       [ 8.95081961, 8.17967375],
       [ 8.91370118, 6.80621455]])
array([[ 1. , 1. , 8.95081961, 8.17967375],
       [ 0. , 1. , 8.91370118, 6.80621455]])
```

https://docs.scipy.org/doc/numpy/user/quickstart.html

# Axis

- For array of shape M x N,
  - axis = 0 : M rows
  - axis = 1 : N columns

```
a = np.arange(6).reshape(2,3)
a
a.sum(axis = 0) # axis = 0, x axis(row)
a.sum(axis = 1) # axis = 1, y axis(colum)
```

```
array([[0, 1, 2],
       [3, 4, 5]])

array([3, 5, 7])

array([ 3, 12])
```

```
a = np.array([[20, 10], [2, 1]])
a
np.sort(a, axis = 0)
np.sort(a, axis = 1)
```

```
array([[20, 10],
       [ 2, 1]])

array([[ 2, 1],
       [20, 10]])

array([[10, 20],
       [ 1, 2]])
```

https://docs.scipy.org/doc/numpy/user/quickstart.html

# Basic Statistics

- max(), min()

```
a = np.array([[1, 2], [3, 4]])
a

np.max(a) # max
np.min(a) # min
```

```
array([[1, 2],
       [3, 4]])
4
1
```

- mean(), std(), var(), …

```
np.mean(a) # mean
np.mean(a, axis=0)
np.mean(a, axis=1)

np.std(a) # standard deviation
np.std(a, axis=0)
np.std(a, axis=1)

np.var(a) # variance
np.var(a, axis=0)
np.var(a, axis=1)
```

```
0.75
array([0.5, 1. ])
array([1. , 0.5])

0.4330127018922193
array([0.5, 0. ])
array([0. , 0.5])

0.1875
array([0.25, 0. ])
array([0. , 0.25])
```

https://docs.scipy.org/doc/numpy/user/quickstart.html

# What is Pandas?

- Pandas
  - One of the python libraries in python to analyze data
  - It provides data structure ‘Dataframe’, so that it makes data analysis efficiently by the various operation
  - It provides a variety of data structure to sort data by the name of the axis
  - It can make us to handle both time series and non-time series data
  - It provides flexible handling of missing data(NA, etc.)
  - It is also able to perform relation calculation in SQL

# Object Creation

- Series, DataFrame

```
import numpy as np
import pandas as pd

s = pd.Series([1, 3, 5, 7, 9])
s
```

```
0 1
1 3
2 5
3 7
4 9
dtype: int64
```

```
data = {'Name':['John', 'Bill', 'Tom'],
        'height':[172, 168, 185],
        'weight':[67, 72, 88]}
df = pd.DataFrame(data)
df
```

| | Name | height | weight |
|---|---|---|---|
| **0** | John | 172 | 67 |
| **1** | Bill | 168 | 72 |
| **2** | Tom | 185 | 88 |

https://pandas.pydata.org/pandas-docs/stable/getting_started/10min.html#min

# Getting Data In

- read_csv()

```
# Read data from csv file
toycars = pd.read_csv('toycars.csv')
toycars
```

| | angle | distance | car |
|---|---|---|---|
| 0 | 1.3 | 0.43 | 1 |
| 1 | 1.3 | 0.37 | 2 |
| 2 | 1.3 | 0.27 | 3 |
| 3 | 4.0 | 0.84 | 1 |
| 4 | 4.0 | 0.92 | 2 |
| 5 | 4.0 | 0.69 | 3 |
| 6 | 2.7 | 0.58 | 1 |
| 7 | 2.7 | 0.64 | 2 |
| 8 | 2.7 | 0.55 | 3 |

https://pandas.pydata.org/pandas-docs/stable/getting_started/10min.html#min

# Viewing Data

- head() & tail()

```
# head() & tail()
toycars.head(2)
toycars.tail(2)
```

| | angle | distance | car |
|---|---|---|---|
| 0 | 1.3 | 0.43 | 1 |
| 1 | 1.3 | 0.37 | 2 |

| | angle | distance | car |
|---|---|---|---|
| 7 | 2.7 | 0.64 | 2 |
| 8 | 2.7 | 0.55 | 3 |

- index & columns

```
# index & columns
toycars.index
toycars.columns
```

```
RangeIndex(start=0, stop=9, step=1)
Index(['angle', 'distance', 'car'], dtype='object')
```

https://pandas.pydata.org/pandas-docs/stable/getting_started/10min.html#min

# Viewing Data

- describe()

```
# describe()
toycars.describe()
```

| | angle | distance | car |
|---|---|---|---|
| count | 9.000000 | 9.000000 | 9.000000 |
| mean | 2.666667 | 0.587778 | 2.000000 |
| std | 1.169402 | 0.212707 | 0.866025 |
| min | 1.300000 | 0.270000 | 1.000000 |
| 25% | 1.300000 | 0.430000 | 1.000000 |
| 50% | 2.700000 | 0.580000 | 2.000000 |
| 75% | 4.000000 | 0.690000 | 3.000000 |
| max | 4.000000 | 0.920000 | 3.000000 |

https://pandas.pydata.org/pandas-docs/stable/getting_started/10min.html#min

# Selection

- by labels

```
# 'loc'ation : [row index, [column name]]
toycars.loc[0:3, ['angle', 'distance']]
```

| | angle | distance |
|---|---|---|
| **0** | 1.3 | 0.43 |
| **1** | 1.3 | 0.37 |
| **2** | 1.3 | 0.27 |
| **3** | 4.0 | 0.84 |

- by position

```
# 'i'nteger 'loc'ation : select via position, numpy style
toycars.iloc[[2, 4, 6], [1, 2]]
```

| | distance | car |
|---|---|---|
| **2** | 0.27 | 3 |
| **4** | 0.92 | 2 |
| **6** | 0.58 | 1 |

https://pandas.pydata.org/pandas-docs/stable/getting_started/10min.html#min

# Selection

- Boolean indexing

```
# Select only samples with anlgle value more than 0.6
toycars[toycars.angle > 0.6]
```

| | angle | distance | car |
|---|---|---|---|
| **0** | 1.3 | 0.43 | 1 |
| **1** | 1.3 | 0.37 | 2 |
| **2** | 1.3 | 0.27 | 3 |
| **3** | 4.0 | 0.84 | 1 |
| **4** | 4.0 | 0.92 | 2 |
| **5** | 4.0 | 0.69 | 3 |
| **6** | 2.7 | 0.58 | 1 |
| **7** | 2.7 | 0.64 | 2 |
| **8** | 2.7 | 0.55 | 3 |

https://pandas.pydata.org/pandas-docs/stable/getting_started/10min.html#min

# What is Matplotlib?

- Matplotlib
  - One of the library in the python to visualize the data
  - It provides Object-Oriented API that can embed various data an numerical data in application through general GUI-toolkits
  - Pylab in Matplotlib includes most of interfaces provided in MATLAB
  - Usually, it is utilized with Scipy, Numpy and Pandas as well as to visualize the results of training of the data from Scikit-learn and Tensorflow

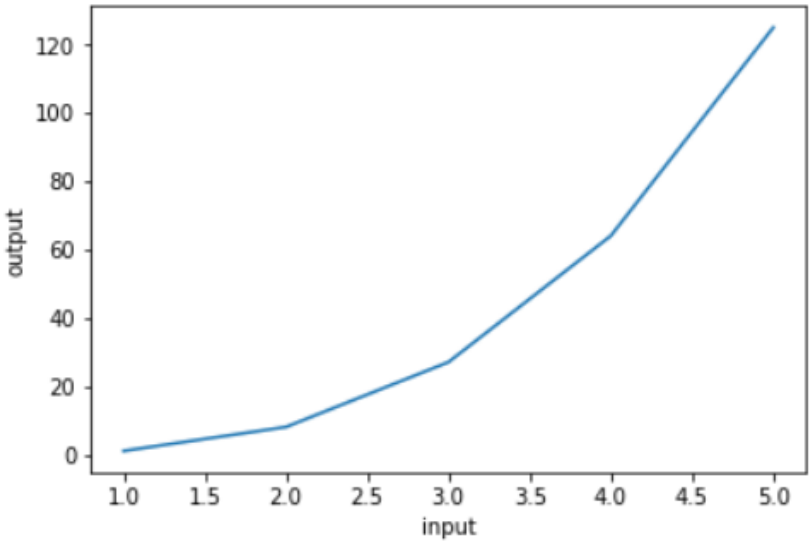
# Plot

- plt.plot(x, y)

```
import matplotlib.pyplot as plt
import numpy as np
%pylab inline
%matplotlib inline

x = [1, 2, 3, 4, 5]
y = [1, 8, 27, 64, 125]

plt.plot(x, y)
plt.ylabel('output')
plt.xlabel('input')
plt.show()
```



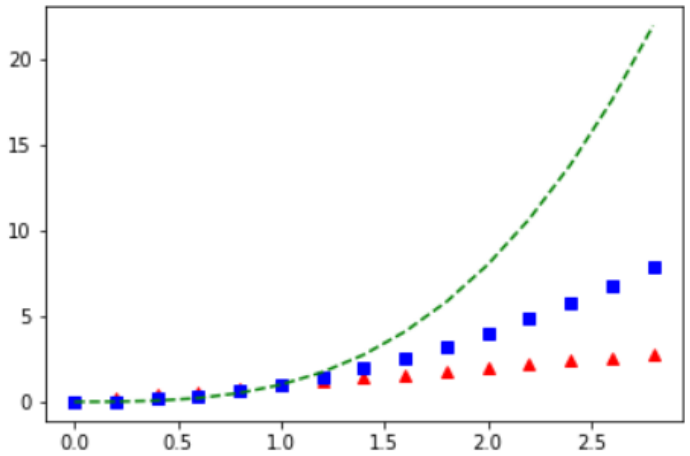

https://matplotlib.org/tutorials/index.html

# Plot

- Color & shapes
  - Colors(c=)
    - Red : r
    - Green : g
    - Blue : b
  - Marker Shapes(marker=)
    - Triangle : ^
    - Circle : o
    - Star : *
    - Square : s
  - Line Styles(linestyle=)
    - Normal line : -
    - Dashed line : --

```
# evenly sampled time at 200ms intervals
t = np.arange(0, 3, 0.2)
t
# red triangles, blue squares and green dashes
plt.plot(t, t, 'r^', t, t**2, 'bs', t, t**3, 'g--')
plt.show()
```

```
[0.  0.2 0.4 0.6 0.8 1.  1.2 1.4 1.6 1.8 2.  2.2 2.4 2.6 2.8]
```



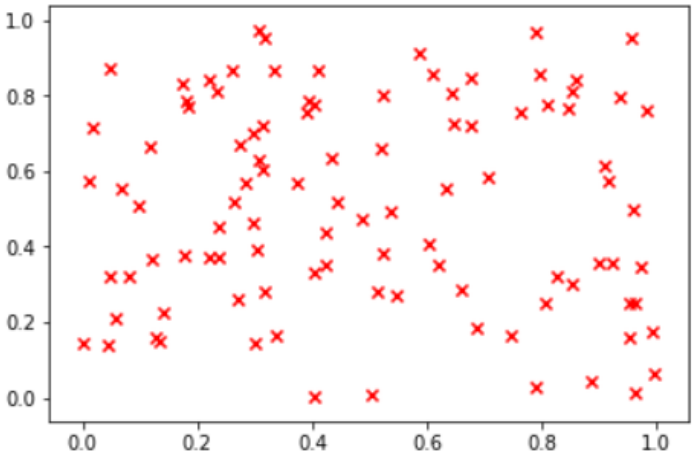

https://python-graph-gallery.com/cheat-sheets/
https://matplotlib.org/tutorials/index.html

# Scatter Plot

- plt.scatter(x, y)

```
data = np.random.rand(100, 2)

plt.scatter(data[:,0], data[:,1],
            color='red', marker='x')
plt.show()
```



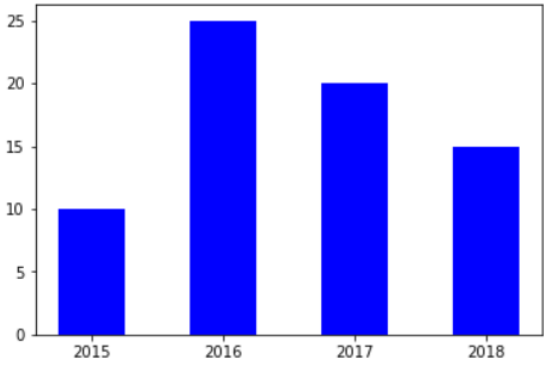

https://matplotlib.org/tutorials/index.html

# Bar Plot

- plt.bar()

```
# old version
x = range(4)
data = [10.0, 25.0, 20.0, 15.0]
index = ['2015','2016','2017', '2018']

plt.bar(x, data, color='b', width=0.5)
plt.xticks(x, index)
plt.show()
```




```
# current version (without xticks)
data = [10.0, 25.0, 20.0, 15.0]
index = ['2015','2016','2017', '2018']

plt.bar(index, data, color='b', width=0.5)
plt.show()
```

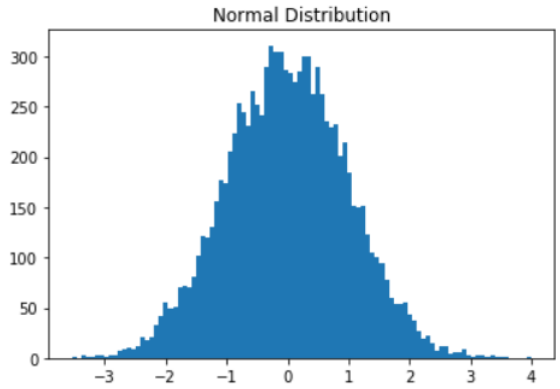
https://matplotlib.org/tutorials/index.html

# Histogram

- plt.hist()

```
x = np.random.randn(10000)

plt.hist(x, bins=100)
plt.title('Normal Distribution')
plt.show()
```




https://matplotlib.org/tutorials/index.html

# Matplotlib

- Too many tutorials. See the documents!


https://matplotlib.org/tutorials/index.html

# Scikit-learn

- Scikit-learn
  - Simple and efficient python library for Datamining, Data Analysis, and Machine Learning
  - It does not deal with large-scale deep learning or reinforcement learning, but provides various algorithms necessary for machine learning such as classification, regression, clustering, and dimension reduction.
  - It provides various machine learning methods such as hyper-parameter tuning and model optimization.
  - It is very easy to learn because it is compatible with other libraries in Python and has an internally unified interface
  - Optimal framework for beginner of machine learning


https://scikit-learn.org/stable/

# Training a Model

- Task
  - Classify x = [x1, x2, x3] to y = 1 or 0
- Training datatset
  - 5 instances (example data) with known labels

```
X = np.array([[0, 1, 1],
              [1, 0, 1],
              [1, 1, 1],
              [0, 1, 1],
              [0, 0, 1]])

y = np.array([1, 0, 1, 1, 0])
```

5 instances

| features | | | label |
|---|---|---|---|
| x1 | x2 | x3 | y |
| 0 | 1 | 1 | 1 |
| 1 | 0 | 1 | 0 |
| 1 | 1 | 1 | 1 |
| 0 | 1 | 1 | 1 |
| 0 | 0 | 1 | 0 |

# Training a Model

- Training (learning) – fit
  - Learning Decision Tree Classifier model with training dataset

```
from sklearn.tree import DecisionTreeClassifier
clf = DecisionTreeClassifier()
clf = clf.fit(X, y)
clf
```

```
DecisionTreeClassifier(class_weight=None, criterion='gini', max_depth=None,
      max_features=None, max_leaf_nodes=None,
      min_impurity_decrease=0.0, min_impurity_split=None,
      min_samples_leaf=1, min_samples_split=2,
      min_weight_fraction_leaf=0.0, presort=False, random_state=None,
      splitter='best')
```

# Predicting using the Model

- Test dataset
  - 2 new instances

```
X_test = np.array([[0, 0, 0],
                   [1, 1, 0]])

y_test = np.array([0, 1])
```

new instances

| x1 | x2 | x3 | y |
|---|---|---|---|
| 0 | 0 | 0 | |
| 1 | 1 | 0 | |

# Predicting using the Model

- Predicting labels – predict
  - Predict the label of new x using the learned model

```
predicted = clf.predict(X_test)
predicted
```

```
array([0, 1])
```

- Evaluation : Accuracy

```
# Accuracy
acc = 100 * np.sum(y_test == predicted)/len(y_test)
acc
```

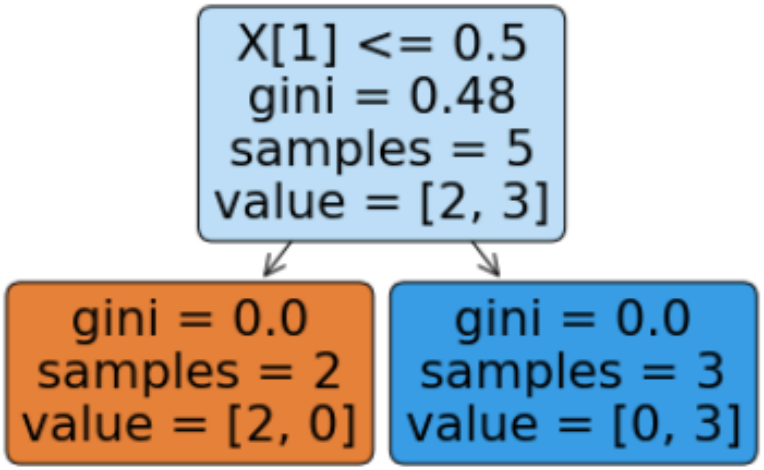
```
100.0
```

# Visualize the Model

- Visualizing Decision Tree model using graphviz

```
from sklearn.tree import plot_tree

plot_tree(clf, filled = True, rounded = True)
```



# Submit

- To make sure if you have completed this practice,
  Submit your practice file(Week03_givencode.ipynb) to e-class.
- **Deadline : tomorrow 11:59pm**
- Modify your ipynb file name as “Week03_StudentNum_Name.ipynb”
  Ex) **Week03_2020123456_홍길동.ipynb**
- You can upload this file without taking the quiz, but homework will be provided like a quiz every three weeks, so it is recommended to take the quiz as well.

# Quiz 1

- 2D array
  - Make 10 x 10 matrix A using arange(1,101), and print A
  - Make 2 x 6 matrix B by slicing 0-1 rows 0-5 columns of A, and print B, B transpose
  - Compute matrix C = 0.1 (B x B transpose) (x : dot product)
- Desired Output

Matrix A →

```
[[  1  2  3  4  5  6  7  8  9 10]
 [ 11 12 13 14 15 16 17 18 19 20]
 [ 21 22 23 24 25 26 27 28 29 30]
 [ 31 32 33 34 35 36 37 38 39 40]
 [ 41 42 43 44 45 46 47 48 49 50]
 [ 51 52 53 54 55 56 57 58 59 60]
 [ 61 62 63 64 65 66 67 68 69 70]
 [ 71 72 73 74 75 76 77 78 79 80]
 [ 81 82 83 84 85 86 87 88 89 90]
 [ 91 92 93 94 95 96 97 98 99 100]]
```

Matrix B →

```
[[ 1  2  3  4  5  6]
 [11 12 13 14 15 16]]
```

```
[[ 1 11]
 [ 2 12]
 [ 3 13]
 [ 4 14]
 [ 5 15]
 [ 6 16]]
```

← Transposed matrix of B

```
[[  9.1  30.1]
 [ 30.1 111.1]]
```

← Matrix C

# Quiz 2

- Vector computation
  - From $\mathbf{x}$ =[$x1$,$x2$,$x3$] and $w$=[$w1$,$w2$,$w3$] and $b$, $y$ is computed as follows:

$$y=\mathbf{w}\cdot\mathbf{x}+b=w1x1+w2x2+w3x3+b$$

  - For following $w$, $b$ and $X$, compute $y$ for each row of $X$

- Desired Output

```
[10.1 20.1 30.1 40.1 50.1]
```

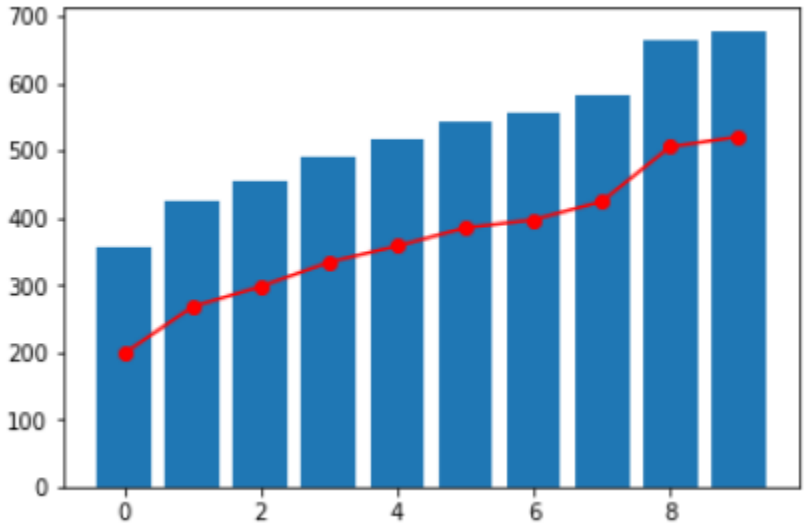
# Quiz 3

- DataFrame and plot
  - The temperature (temp) and iced americano sales (sale) have the following relation
    - sale = 30.08 * temp - 159.47
  - Make a 1D array X from following 'temps' list
  - Compute 1D array Y for sales using above equation
  - Make 2D array C such that fist column is X, second column is Y, using vstack() and transpose
  - Make a DataFrame from C with column names "Temp" and "Sale" (use column = ["Temp", "Sale"])
  - Bar plot 30 * Temp values, and plot Sale values on it as a red line and marker "o" (use color="red", marker="o")

# Quiz 3

- Desired output

| | Temp | Sale |
|---|---|---|
| **0** | 11.9 | 198.482 |
| **1** | 14.2 | 267.666 |
| **2** | 15.2 | 297.746 |
| **3** | 16.4 | 333.842 |
| **4** | 17.2 | 357.906 |
| **5** | 18.1 | 384.978 |
| **6** | 18.5 | 397.010 |
| **7** | 19.4 | 424.082 |
| **8** | 22.1 | 505.298 |
| **9** | 22.6 | 520.338 |



# Quiz 4

- Visualizing Boston Housing Price Dataset
  - Load the dataset as a DataFrame (given)
  - Visualize the relationship between two variables using scatter plot
    - RM and MEDV
    - CRIM and MEDV
- Desired output