System of Linear Equation

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Requirements:

1. Provide one (1) system of linear equations WORD problem and provide the source (i.e., book, website, online course, etc.): Make sure that the variables should be three (3), and a minimum of three (3) equations.
2. Represent a system of linear equations in the following ways: Standard bracketed form Linear Combination form (Matrix) Vector Visualization
3. A programmed algorithm for solving the problem.

Word Problem

Axel bought 1 book, 2 color pencils, 4 sharpie pens total of 2,840 php, Jack 3 books 2 prism color pencils , 7 sharpie pens total of 4,370 and Leslie bought 4 books , 1 prism color pencils and 12 sharpie pens total of 4,620 at National Bookstor. Since they spent their money on each item, Axel and his friends wants to know how much is the price of each item.

Standard Bracketed Form

$Let:$
$a = book\ , b = prism\ color\ pencil\ , c = sharpie\ pens$

$$Axel = \{\, a + 2b + 4c = 2840$$

$$Jack = \{\, 3a + 2b + 7c = 4370$$

$$Leslie = \{\, 4a + y + 12c = 4620$$

Linear Combination Form (Matrix) .

$$\begin{bmatrix} 1 & 2 & 4 \\ 3 & 2 & 7 \\ 4 & 1 & 12 \end{bmatrix} \cdot \begin{bmatrix} a \\ b \\ c \end{bmatrix} = \begin{bmatrix} 2840 \\ 4370 \\ 4620 \end{bmatrix}$$

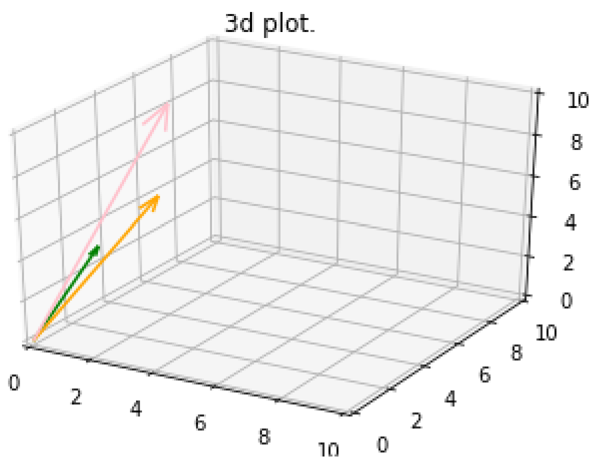
Visualization of Vectors

```
import numpy as np
import matplotlib.pyplot as plt
%matplotlib inline
A = np.array([
              [1,2,4],
```

```
                 [3,2,7],
                 [4,1,12]
                  ])
fig = plt.figure()
ax = fig.gca(projection='3d')
ax.set_xlim([0,10])
ax.set_ylim([0,10])
ax.set_zlim([0, 10])

ax.quiver(0, 0, 0, A[0,0], A[0,1], A[0,2], arrow_length_ratio=0.10, colors='green')
ax.quiver(0, 0, 0, A[1,0], A[1,1], A[1,2], arrow_length_ratio=0.10, colors='orange')
ax.quiver(0, 0, 0, A[2,0], A[2,1], A[2,2], arrow_length_ratio=0.10, colors='pink')
plt.title("3d plot.")
```

```
Text(0.5, 0.92, '3d plot.')
```

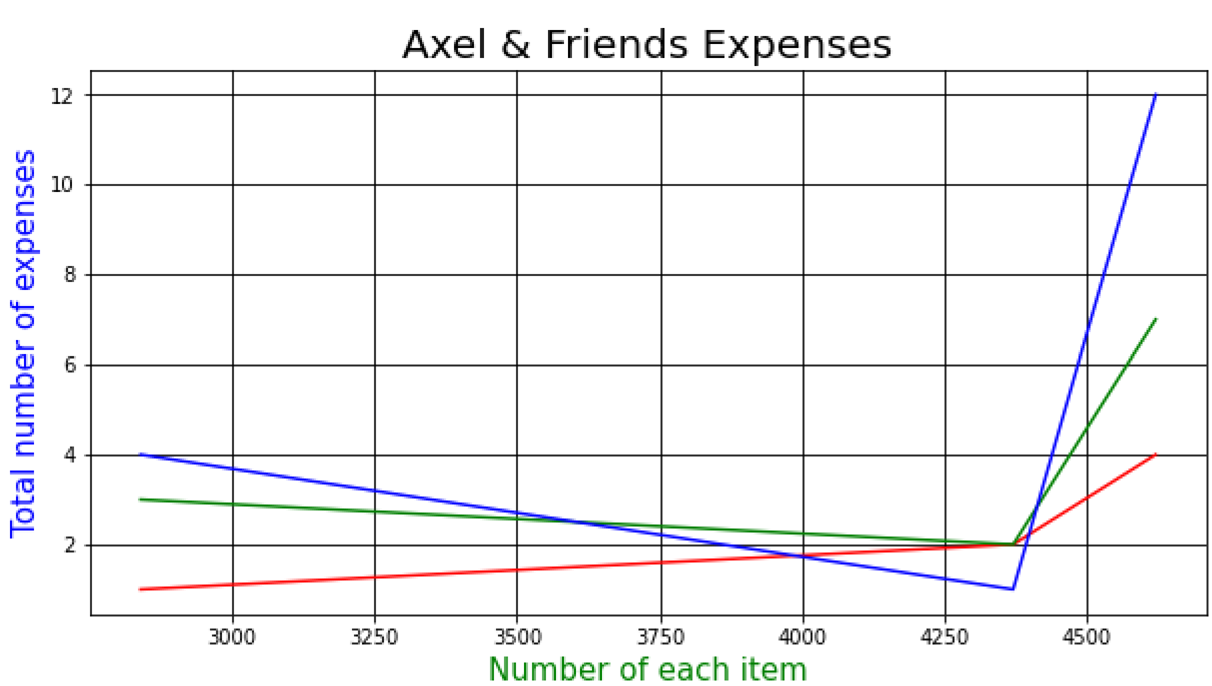



```
ax= np.array([1,2,4])
jk= np.array([3,2,7])
ls = np.array([4,1,12])
ts = np.array([2840,4370,4620])

plt.figure(figsize=(10,5))
plt.title('Axel & Friends Expenses', fontdict={'fontsize':20}, color= 'Black')

plt.plot(ts, ax, color = 'red')
plt.plot(ts, jk, color = 'green')
plt.plot(ts, ls, color = 'blue')
plt.xlabel('Number of each item', fontdict={'fontsize':15}, color='green')
plt.ylabel('Total number of expenses', fontdict={'fontsize':15},  color='blue')

plt.grid(color = 'black')
plt.show()
```



Solving the System of Linear System

```
qty = np.array([
               [1,2,4],
               [3,2,7],
               [4,1,12]
                ])
total_spent = np.array([
                        [2840],
                        [4370],
                        [4620]
                       ])
X = np.linalg.solve(qty, total_spent)
print (X)
```

```
[[600.]
 [900.]
 [110.]]
```

```
prices = np.linalg.inv(qty) @ total_spent
print(' the price of each book is: PHP {:2f}'.format(float(prices[0])))
print(' the price of each prism color pencil is: PHP {:2f}'.format(float(prices[1])))
print(' the price of each sharpie pens is: PHP {:2f}'.format(float(prices[2])))
```

```
 the price of each book is: PHP 600.000000
 the price of each prism color pencil is: PHP 900.000000
 the price of each sharpie pens is: PHP 110.000000
```

therefore the values of a = 600 , b = 900, c = 110 .

Reference

[1] “numeth2021/NuMeth_3_System_of_Linear_Equations.ipynb at main · dyjdlopez/numeth2021 · GitHub.” https://github.com/dyjdlopez/numeth2021/blob/main/Week%207-9%20-%20Solving%20System%20of%20Linear%20Equations/NuMeth_3_System_of_Linear_Equations.ipynb (accessed May 05, 2021).

Curve Fitting

Requirements

1. Provide one (1) regression data problem: The problem should have more than 1 feature and data records should be greater than 30 lines. Use the Diabetes dataset from sklearn.
2. A programmed regression routine for solving the problem.

   Implement using sklearn's Multiple Linear Regression, Polynomial Curve, and the Normal Equation.

```
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import seaborn as sns
from sklearn.model_selection import train_test_split
from sklearn import datasets
from sklearn.linear_model import LinearRegression
from sklearn import metrics
```

```
# Data Preparation
# importing data set from sklearn diabetes
db_data = datasets.load_diabetes()
```

```
diabetes_data = pd.DataFrame(db_data.data, columns=db_data.feature_names)
diabetes_data.describe()
```

	age	sex	bmi	bp	s1	s2
count	4.420000e+02	4.420000e+02	4.420000e+02	4.420000e+02	4.420000e+02	4.420000e+02
mean	-3.634285e-16	1.308343e-16	-8.045349e-16	1.281655e-16	-8.835316e-17	1.327024e-16
std	4.761905e-02	4.761905e-02	4.761905e-02	4.761905e-02	4.761905e-02	4.761905e-02
min	-1.072256e-01	-4.464164e-02	-9.027530e-02	-1.123996e-01	-1.267807e-01	-1.156131e-01
25%	-3.729927e-02	-4.464164e-02	-3.422907e-02	-3.665645e-02	-3.424784e-02	-3.035840e-02
50%	5.383060e-03	-4.464164e-02	-7.283766e-03	-5.670611e-03	-4.320866e-03	-3.819065e-03

```
# checking its rows and columns
diabetes_data.shape
```

```
(442, 10)
```

```
# target refers to y-axis. setting target as the data of disease progression
diabetes_data['disease progression'] = db_data.target
diabetes_data['disease progression'].head()
```

```
0    151.0
1     75.0
2    141.0
3    206.0
4    135.0
Name: disease progression, dtype: float64
```

```
#cheking the updated rows and columns of the data
diabetes_data.shape
```

```
(442, 11)
```

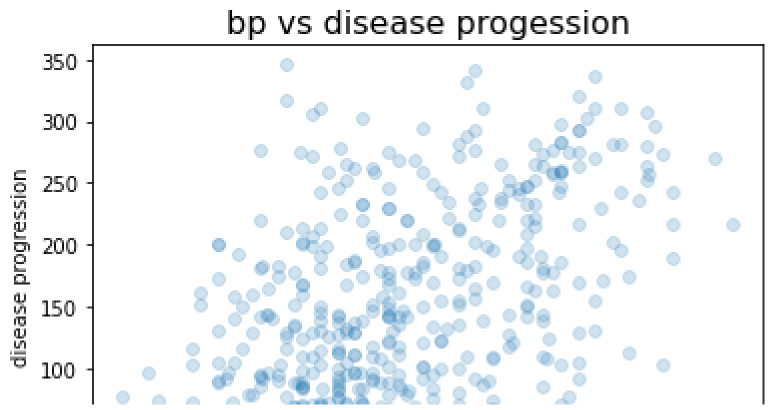
Visualization of percentage related on the following bp = average blood pressure

s4= total cholesterol / HDL (tch)

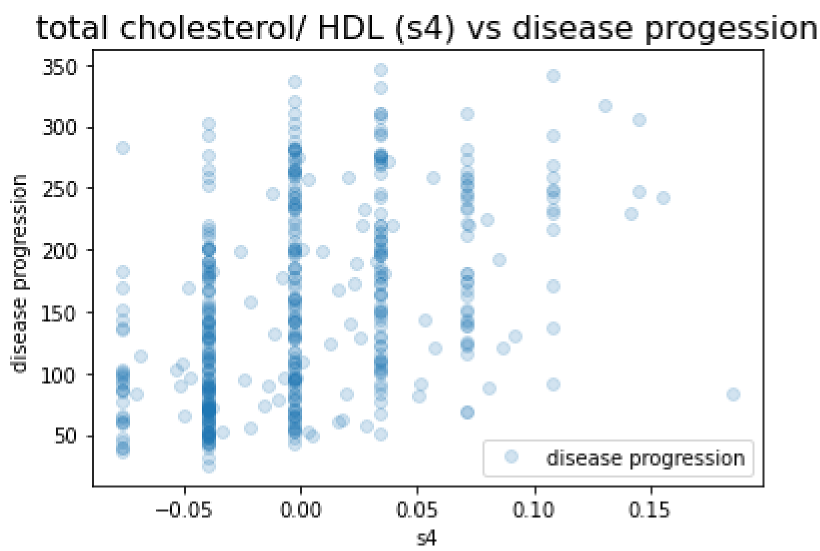
s6 = blood sugar level

which measure of disease progression one year after baseline [1]

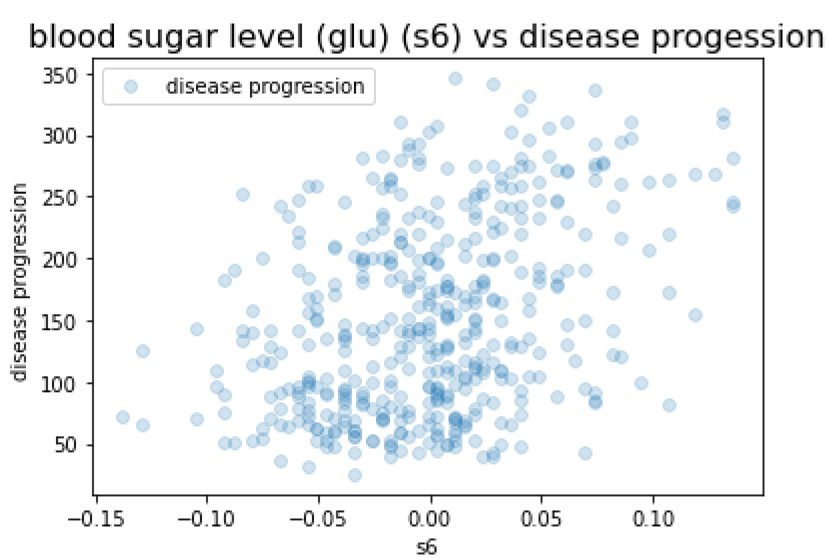
```
# Visualizing the average blood pressure and disease progression
diabetes_data.plot(x='bp', y='disease progression', style='o', alpha=0.2)
plt.title('bp vs disease progession', fontsize=16)
plt.xlabel('bp')
plt.ylabel('disease progression ')
plt.show()
```




```
diabetes_data.plot(x='s4', y='disease progression', style='o', alpha=0.2)
plt.title('total cholesterol/ HDL (s4) vs disease progession', fontsize=16)
plt.xlabel('s4')
plt.ylabel('disease progression ')
plt.show()
```




```
diabetes_data.plot(x='s6', y='disease progression', style='o', alpha=0.2)
plt.title('blood sugar level (glu) (s6) vs disease progession', fontsize=16)
plt.xlabel('s6')
plt.ylabel('disease progression ')
plt.show()
```



Multiple Linear Regression

```
# Multiple Regreesion
X = pd.DataFrame(np.c_[diabetes_data['s4'], diabetes_data['bp'], diabetes_data['s6']], col
y = diabetes_data['disease progression']
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size = 0.2, random_state=1)
```

```
# Fitting a Multiple Linear Model
```

```
l_reg= LinearRegression()
l_reg.fit(X_train, y_train)
```

```
LinearRegression(copy_X=True, fit_intercept=True, n_jobs=None, normalize=False)
```

```
# Summary of modelling
l_reg_sum =  pd.DataFrame(X.columns, columns=['Features'])
l_reg_sum['Weights Raw'] = l_reg.coef_.reshape(3,1)
l_reg_sum = l_reg_sum.append({'Features':'Intercept', 'Weights Raw':float(l_reg.intercept_
l_reg_sum
```

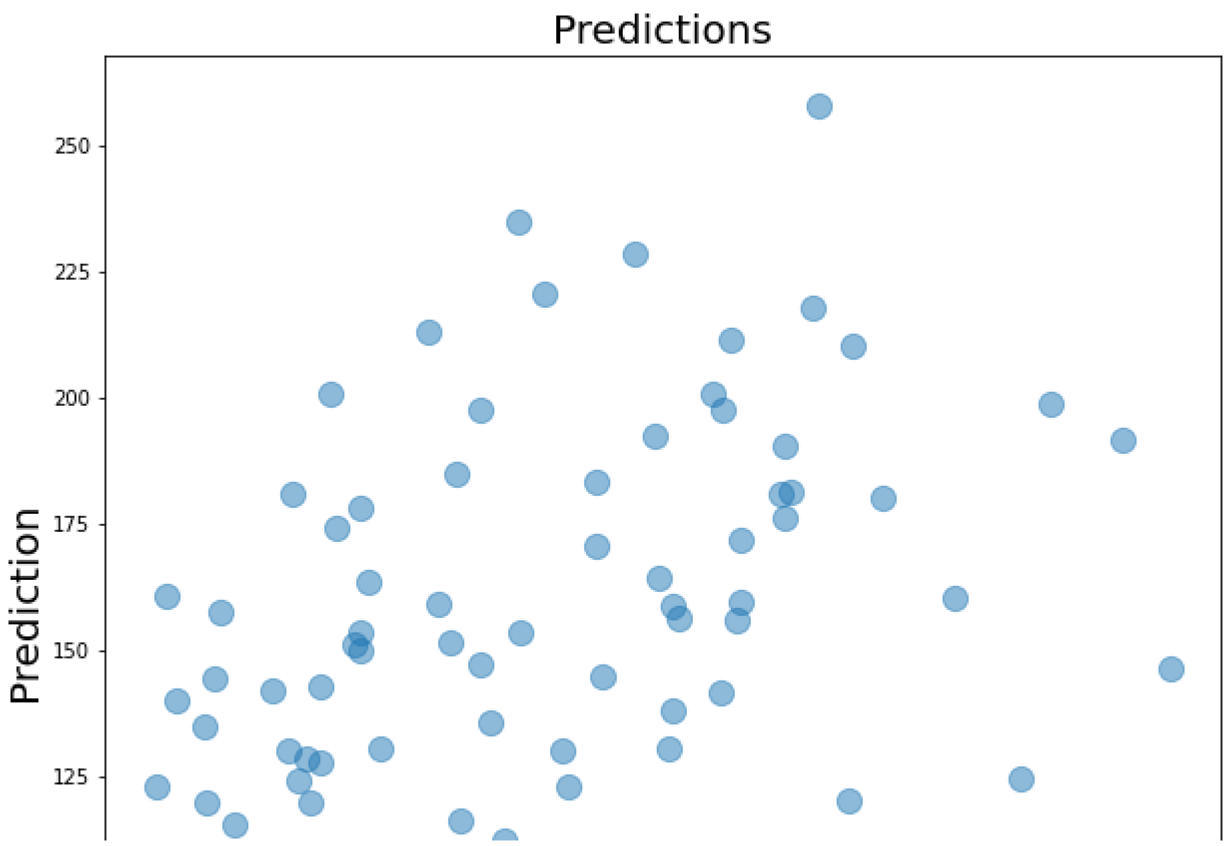
	Features	Weights Raw
0	s4	476.371697
1	bp	520.717573
2	s6	223.540217
3	Intercept	152.003079

```
# prediction model
preds = l_reg.predict(X_test)
res = pd.DataFrame({'Actual': y_test, 'Predicted': preds})
res
```

	Actual	Predicted
246	78.0	101.813989
425	152.0	61.865283
293	200.0	158.542200
31	59.0	63.717138
359	311.0	198.762461
...	...	...
277	64.0	119.706441
132	107.0	151.337305
213	49.0	122.883893
286	60.0	73.843248
256	346.0	146.417776

89 rows × 2 columns

```
plt.figure(figsize=(10,10))
plt.title('Predictions', fontsize=20)
plt.scatter(y_test, preds, s = 150,  alpha=0.5)
plt.xlabel('Ground Truth', fontsize=20)
plt.ylabel('Prediction', fontsize=20)
plt.show()
```




```
# Metrics
# adjusted r squared as per lecture

def adjr2(r2,x):
    n = x.shape[0]
    p = x.shape[1]
    adjusted_r2 = 1-(1-r2)*(n-1)/(n-p-1)
    return adjusted_r2
```


```
MSE = metrics.mean_squared_error(y_test, preds)
RMSE = np.sqrt(MSE)
R2 = metrics.r2_score(y_test, preds)
AR2 = adjr2(R2,X_train)
model_metrics = pd.DataFrame([['MSE'],['RMSE'],['R^2'],
                              ['Adjusted R^2']],
                             columns=['Metrics'])
model_metrics['Multiple Regression'] = MSE, RMSE, R2, AR2
model_metrics
```

	Metrics	Multiple Regression
0	MSE	3834.449487
1	RMSE	61.922932
2	R^2	0.280452
3	Adjusted R^2	0.274267

Polynomial Regression

```
# POLYNOMIAL REGRESSION
from sklearn.preprocessing import PolynomialFeatures
X = pd.DataFrame(np.c_[diabetes_data['s4'], diabetes_data['bp'], diabetes_data['s6'],diabe
y = diabetes_data['disease progression']
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size = 0.2, random_state=1)
```

```
poly_reg = PolynomialFeatures(degree=2)
X_poly = poly_reg.fit_transform(X_train)
```

```
print(X_poly)
```

```
[[ 1.00000000e+00  3.43088589e-02 -6.76422830e-02 ...  1.97895780e-03
   2.19497116e-03  2.43456348e-03]
 [ 1.00000000e+00  5.60805202e-02 -1.14087284e-02 ...  1.02778960e-03
   1.27305716e-03  1.57685439e-03]
 [ 1.00000000e+00 -2.59226200e-03  4.25295792e-02 ...  2.72463581e-05
  -3.72467191e-04  5.09175604e-03]
 ...
 [ 1.00000000e+00 -3.94933829e-02 -2.28849640e-02 ...  1.17063562e-03
   2.17217379e-03  4.03057866e-03]
 [ 1.00000000e+00  1.29062088e-02  5.85963092e-02 ...  2.36464207e-03
  -2.88648387e-03  3.52348849e-03]
 [ 1.00000000e+00 -3.94933829e-02 -5.73136710e-02 ...  2.72463581e-05
   1.30287145e-04  6.23009508e-04]]
```

```
# Fitting a Multiple Linear Model
l_reg2 = LinearRegression()
l_reg2.fit(X_poly, y_train)
```

```
LinearRegression(copy_X=True, fit_intercept=True, n_jobs=None, normalize=False)
```

```
preds = l_reg2.predict(poly_reg.fit_transform(X_test))
```

```
poly_MSE = metrics.mean_squared_error(y_test,preds)
poly_RMSE = np.sqrt(poly_MSE)
poly_R2 = metrics.r2_score(y_test,preds)
poly_AR2 = adjr2(poly_R2,X_train)
model_metrics = pd.DataFrame([['MSE'],['RMSE'],['R^2'],
                              ['Adjusted R^2']],
                             columns=['Metrics'])
model_metrics['Polynomial Regression'] = poly_MSE, poly_RMSE, poly_R2, poly_AR2
model_metrics
```

	Metrics	Polynomial Regression
0	MSE	4219.197941
1	RMSE	64.955353
2	R^2	0.208253
3	Adjusted R^2	0.199152

Normal Equation

```
X = diabetes_data['s4'].values.reshape(-1,1)
y = diabetes_data['disease progression'].values.reshape(-1,1)

n = len(diabetes_data['s4']) #no. rows
bias = np.ones((n,1)) #column-1 of Matrix X
xnew = np.reshape(X,(n,1)) #reshaping the data
xnew1 =np.append(bias,xnew,axis=1) #forming Matrix X
xnew1_t = np.transpose(xnew1) #transpose
xnew_t_dot_x_new = xnew1_t.dot(xnew1) #matrix multiplication
temp_1 = np.linalg.inv(xnew_t_dot_x_new) #inverse of a matrix
temp_2 = xnew1_t.dot(y)
```

```
#Finding coefficients:

theta = temp_1.dot(temp_2)
Intercept = theta[0]
Slope = theta[1]
print("Intercept:",Intercept)
```

```
print("Slope:",Slope)
```

```
Intercept: [152.13348416]
Slope: [696.88303009]
```

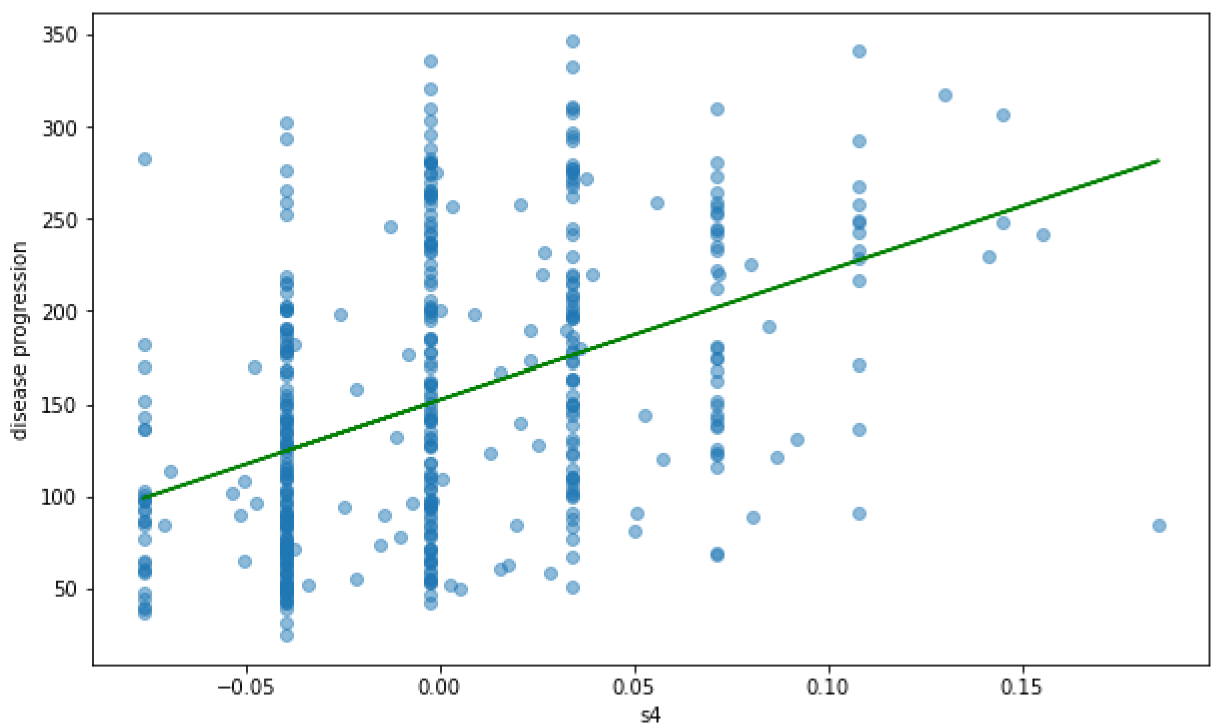
```
#Predicting values:
def predict_value(input_feature,slope,intercept):
    return slope*input_feature+intercept
```

```
s4 = 4
prediction = predict_value(s4,Slope,Intercept)
print(prediction)
```

```
[2939.66560453]
```

```
#Plotting the regression Line:
plt.figure(figsize=(5*2,3*2))
plt.scatter(X,y, alpha=0.5)
plt.xlabel('s4')
plt.ylabel('disease progression')
plt.plot(X,Slope*X+Intercept, color="green")
```

```
[<matplotlib.lines.Line2D at 0x7f1413ef5750>]
```



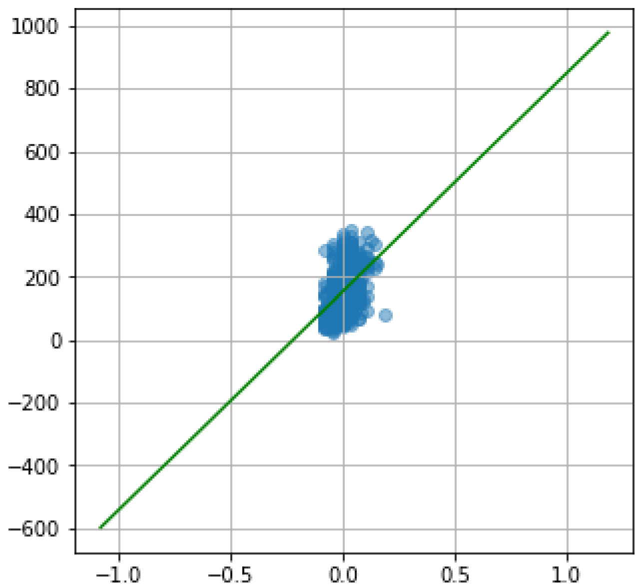
Polynomial Curve

```
def linear_regressor(X,y):
  X = np.array(X)
  y = np.array(y)
  n = X.size
  w0 = (y.mean()*np.sum(X**2)-X.mean()*np.sum(X*y)) / (np.sum(X**2) - n*X.mean()**2)
  w1 = (np.sum(X*y) - X.mean()*np.sum(y)) / (np.sum(X**2) - n*X.mean()**2)
  return w0,w1
w0,w1 = linear_regressor(X,y)
print("Linear Regression Equation: y = {:.3f}x + {:.3f}".format(w1, w0))
```

```
Linear Regression Equation: y = 696.883x + 152.133
```

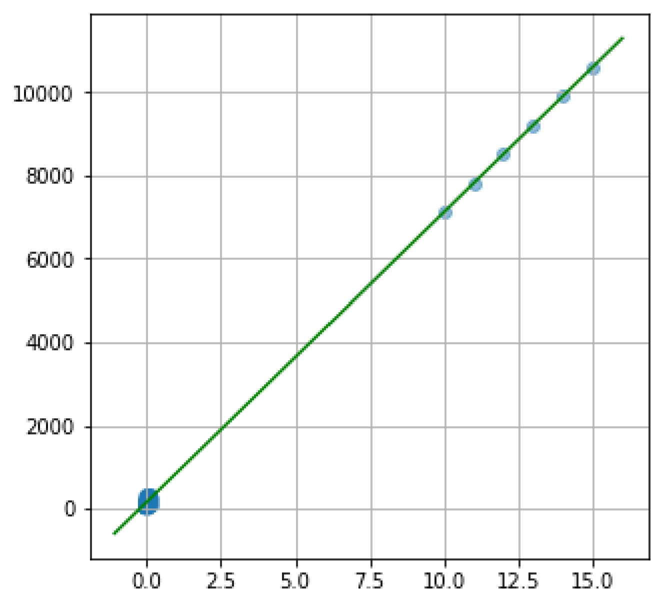
```
def show_regline(X,y,w1,w0):
  x_min, x_max = X.min() - 1, X.max() + 1
  linex = np.linspace(x_min, x_max)
  liney = w1*linex+w0
  plt.figure(figsize=(5,5))
```

```
  plt.grid()
  plt.scatter(X,y, alpha=0.5)
  plt.plot(linex, liney, c='green')
  plt.show()
show_regline(X,y,w1,w0)
```




```
def lin_reg(val,w0,w1):
  return w1*val + w0 #model
print(lin_reg(10, w0, w1))
X_new, y_new = X.copy(), y.copy()
for i in range(10,16):
  X_new = np.insert(X_new,-1, i)
  y_new = np.insert(y_new,-1, lin_reg(i,w0,w1))
show_regline(X_new, y_new, w1, w0)
```

```
7120.963785085329
```



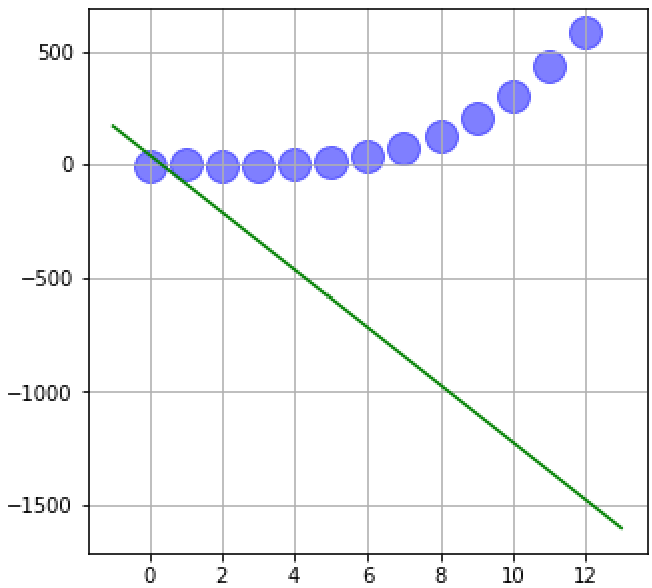

```
X_1 = np.arange(0, 13,1)
y_1 = X_1 - 2 * (X_1 ** 2) + 0.5 * (X_1 ** 3) + np.random.normal(-3, 3, 13)
```

```
def show_regline(X,y,w1,w0):
  x_min, x_max = X.min() - 1, X.max() + 1
  linex = np.linspace(x_min, x_max)
  liney = w1*linex+w0
  plt.figure(figsize=(5,5))
  plt.grid()
  plt.scatter(X_1,y_1, s = 256, color='blue', alpha=0.5)
  plt.plot(linex, liney, c='green')
  plt.show()
```

```
def linear_regressor(X,y):
```

```
  X = np.array(X)
  y = np.array(y)
  n = X.size
  w0 = (y.mean()*np.sum(X**2)-X.mean()*np.sum(X*y)) / (np.sum(X**2) - n*X.mean()**2)
  w1 = (np.sum(X*y) - X.mean()*np.sum(y)) / (np.sum(X**2) - n*X.mean()**2)
  return w0,w1
w0,w1 = linear_regressor(X,y)
```

```
w0_q,w1_q = linear_regressor(X_1, y_1)
show_regline(X_1,y_1,w0_q,w1_q)
```



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