In [ ]:

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

In [ ]:

```
# Read CSV
df = pd.read_csv('D3.csv')
# Initialize inputs outputs and the number of data points
x_1 = df.values[:,0]
x_2 = df.values[:,1]
x_3 = df.values[:,2]
Y = df.values[:,3]
m = len(Y)
x_0 = np.ones((m,1))
# put in list for automation
x_i_old = [x_1,x_2,x_3]
x_i = [x_1,x_2,x_3]
# Initialize Results
final_thetas = np.zeros((3,2))
costhistorys = [[]] * 3
# Initialize Value for terms to change
alpha = .01
iterations = 1500
theta = np.zeros(2)
```

In [ ]:

```
def compute_cost(X, y, theta):
  """
  Compute cost for linear regression.

  Input Parameters
  ----------------
  X : 2D array where each row represent the training example and each column represent
      m= number of training examples
      n= number of features (including X_0 column of ones)
  y : 1D array of labels/target value for each traing example. dimension(1 x m)

  theta : 1D array of fitting parameters or weights. Dimension (1 x n)

  Output Parameters
  -----------------
  J : Scalar value.
  """
  predictions = X.dot(theta)
  errors = np.subtract(predictions, y)
  sqrErrors = np.square(errors)
  J = 1 / (2 * m) * np.sum(sqrErrors)

  return J
```

In [ ]:

```
def gradient_descent(X, y, theta, alpha, iterations):
  """
  Compute cost for linear regression.

  Input Parameters
```

```
    -----------------
    X : 2D array where each row represent the training example and each column represent
        m= number of training examples
        n= number of features (including X_0 column of ones)
    y : 1D array of labels/target value for each traing example. dimension(m x 1)
    theta : 1D array of fitting parameters or weights. Dimension (1 x n)
    alpha : Learning rate. Scalar value
    iterations: No of iterations. Scalar value.

    Output Parameters
    -----------------
    theta : Final Value. 1D array of fitting parameters or weights. Dimension (1 x n)
    cost_history: Conatins value of cost for each iteration. 1D array. Dimansion(m x 1)
    """
    cost_history = np.zeros(iterations)

    for i in range(iterations):
      predictions = X.dot(theta)
      errors = np.subtract(predictions, y)
      sum_delta = (alpha / m) * X.transpose().dot(errors);
      theta = theta - sum_delta;
      cost_history[i] = compute_cost(X, y, theta)

    return theta, cost_history
```

In [ ]:

```
# Preform the linear regression then store
for i in range(len(costhistorys)):
    # Reshape for linear algebra
    x_i[i] = x_i[i].reshape(m,1)
    # Add x_0 term to each X value
    x_i[i] = np.hstack((x_0,x_i[i]))
    # preform the calculations
    final_thetas[i,:], costhistorys[i] = gradient_descent(x_i[i], Y, theta, alpha, iter
```

In [ ]:

```
for i in range(final_thetas.shape[0]):
    print('Model for x_' + str(i) + ':',final_thetas[i,:])
```

```
Model for x_0: [ 5.71850653 -1.9568206 ]
Model for x_1: [0.71988473 0.56390334]
Model for x_2: [ 2.78048129 -0.48451631]
```

In [ ]:

```
compute_cost(x_i[0], Y, final_thetas[0,:])
```

Out[ ]:

```
0.9905894438682062
```

In [ ]:

```
# Plot Linear Regression and Cost Plot
for i in range(len(x_i)):
    plt.scatter(x_i_old[i], Y, color='red', marker= '+', label= 'Training Data')
    plt.plot(x_i[i][:,1], x_i[i].dot(final_thetas[i,:]), color='green', label='Linear R

    plt.rcParams["figure.figsize"] = (10,6)
    plt.grid()
    plt.xlabel('x_' + str(i + 1) + ' Values')
    plt.ylabel('Y Values')
```

```
    plt.title('Linear Regression Fit')
    plt.legend()
    plt.savefig('output'+ str(i) + '.jpg')
    plt.clf()


    plt.plot(range(1, iterations + 1),costhistorys[i], color='blue')
    plt.rcParams["figure.figsize"] = (10,6)
    plt.grid()
    plt.xlabel('Number of iterations')
    plt.ylabel('Cost (J)')
    plt.title('Convergence of gradient descent for x_' + str(i + 1))
    plt.savefig('convergence' + str(i) + '.jpg')
    plt.clf()
```

```
<Figure size 720x432 with 0 Axes>
```

Problem 2

In [ ]:

```
df2 = pd.read_csv('D3.csv')
```

In [ ]:

```
# Initialize Variables
iterations2 = 1500
alpha2 = .01
# Add Column of ones to the begining of the data
df2 =  pd.concat([pd.Series(1, index=df.index, name='x_0'), df], axis=1)
# Get the inputs
X = df2.drop(columns='Y')
# Get the outputs
Y = df2.values[:,4]
# Declare theta
theta = np.array([0]*len(X.columns))
```

In [ ]:

```
# Run the linear regression algorithm
model, cost_func = gradient_descent(X,Y,theta,alpha2,iterations2)
temp = 0
for i in model:
    print('Theta_' + str(temp) + ' =', i)
    temp += 1
```

```
Theta_0 = 4.151187282528127
Theta_1 = -1.839429097710375
Theta_2 = 0.7247385609338923
Theta_3 = -0.09513266408711538
```

In [ ]:

```
plt.plot(range(1, iterations2 + 1),cost_func, color='blue')
plt.rcParams["figure.figsize"] = (10,6)
plt.grid()
plt.xlabel('Number of iterations')
plt.ylabel('Cost (J)')
plt.title('Convergence of gradient descent for entire model')
plt.savefig('convergence_part2.jpg')
plt.clf()
```

```
<Figure size 720x432 with 0 Axes>
```

In [ ]:

```python
# Create New dataframe for new data
data = {'x1New' : [1,2,3], 'x2New' : [1,0,2], 'x3New' : [1,4,1]}
newDf = pd.DataFrame(data)
newDf =  pd.concat([pd.Series(1, index=newDf.index, name='x0New'), newDf], axis=1)
newDf = newDf.to_numpy() # Needs to be a numpy array to do the dot module
# dot new data with model to predict the output
Hypothosis = newDf.dot(model)
for i in range(len(Hypothosis)):
    print('Predicted Value ' + str(i+1) + ':', Hypothosis[i])
```

```
Predicted Value 1: 2.9413640816645295
Predicted Value 2: 0.09179843075891558
Predicted Value 3: -0.012755552822328736
```

Display Graphs

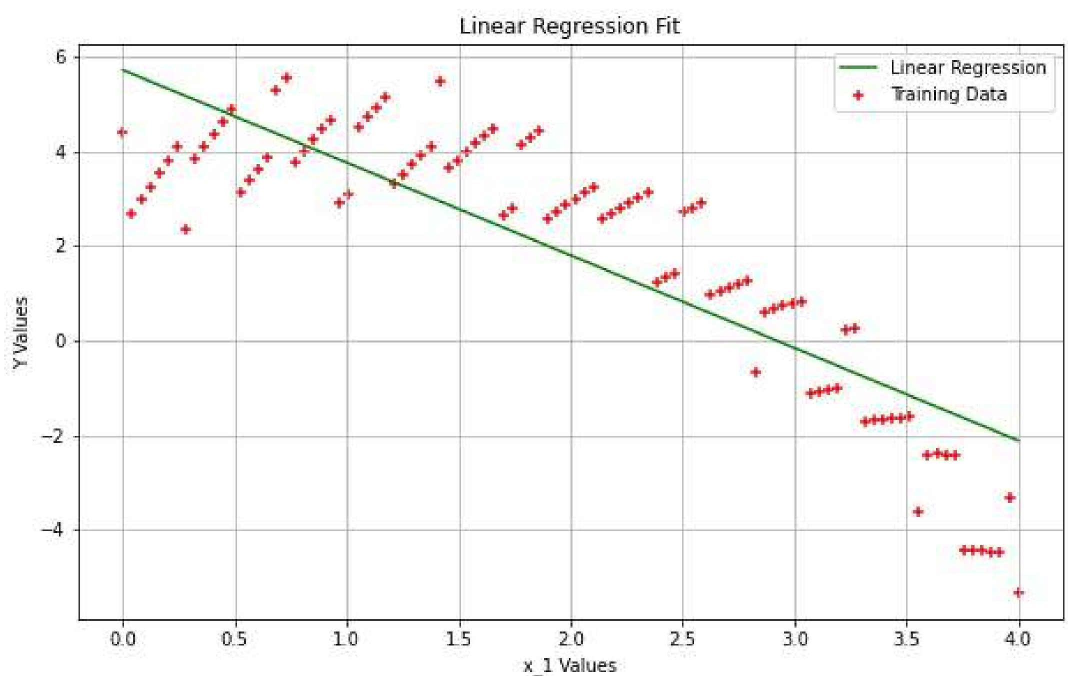
In [ ]:

```python
from PIL import Image
```

In [ ]:

```python
Image.open('output0.jpg')
```

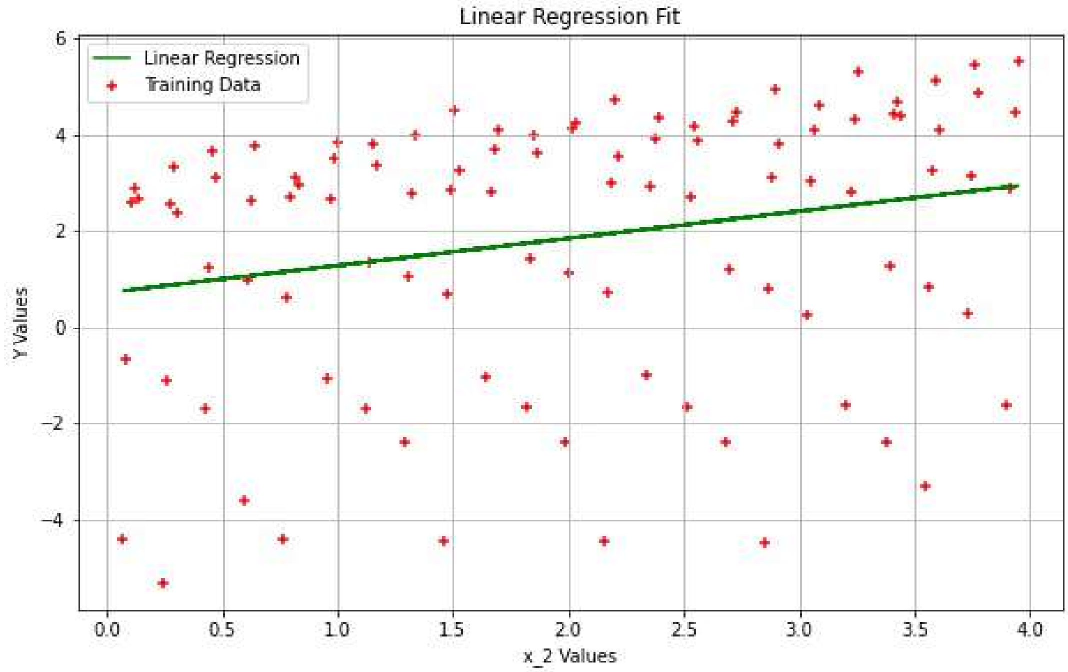
Out[ ]:



In [ ]:

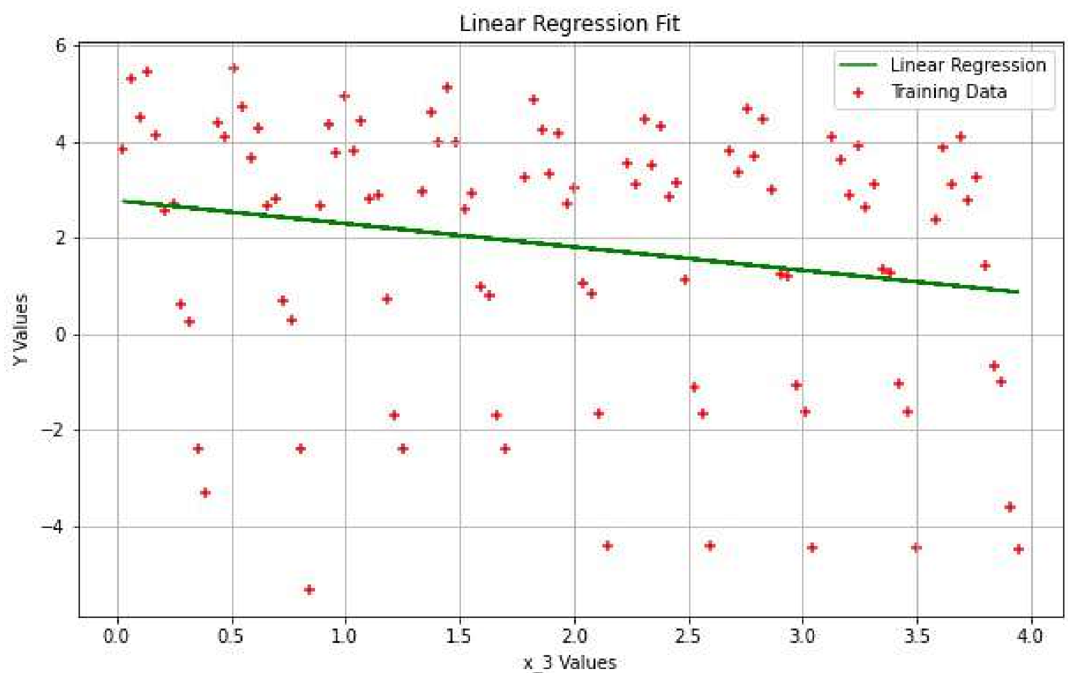
```python
Image.open('output1.jpg')
```

Out[ ]:



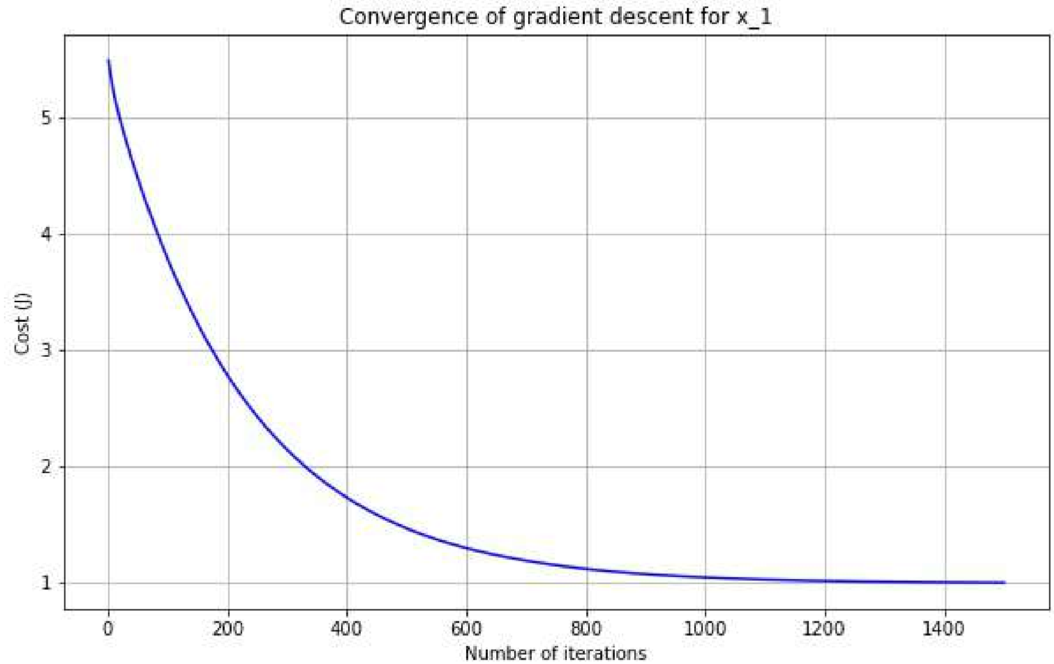
In [ ]:
```
Image.open('output2.jpg')
```

Out[ ]:



In [ ]:
```
Image.open('convergence0.jpg')
```

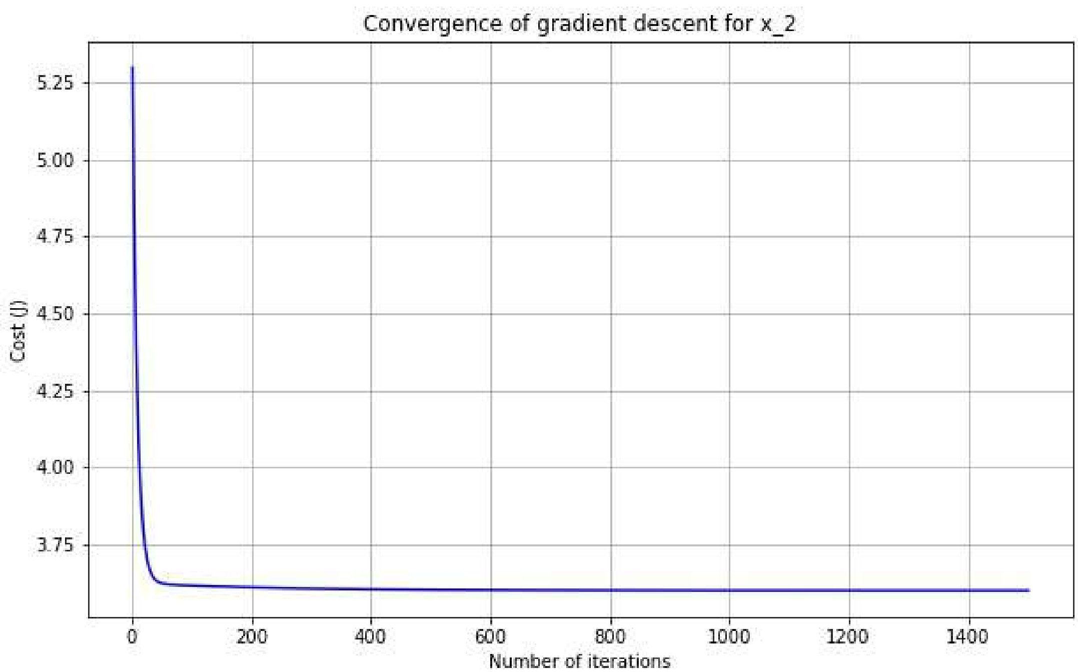
Out[ ]:



In [ ]:

```
Image.open('convergence1.jpg')
```

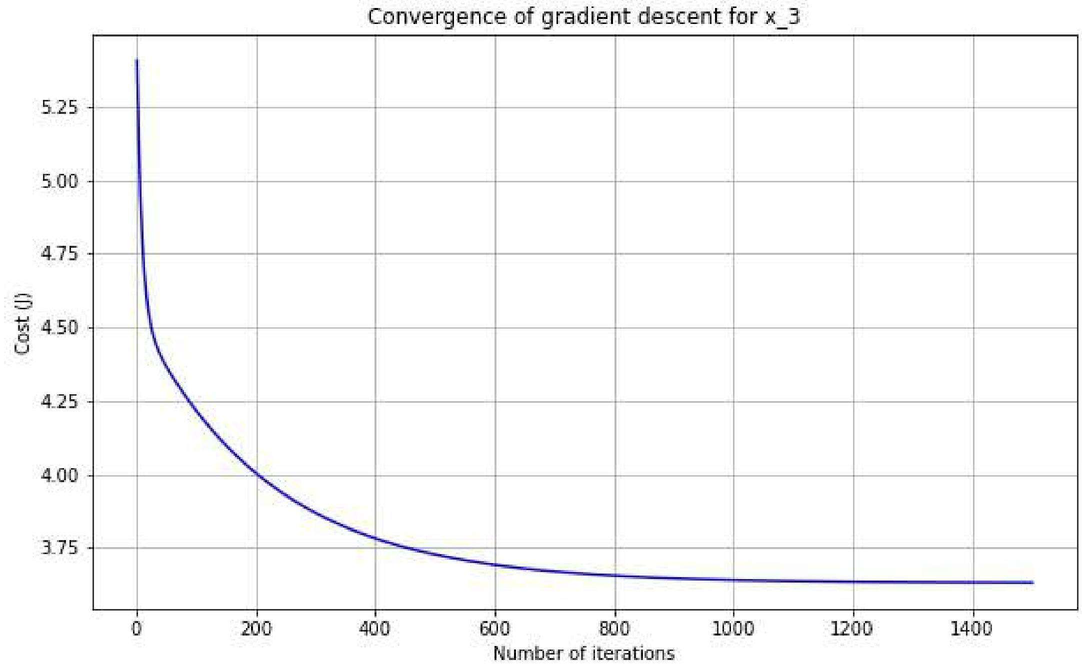
Out[ ]:



In [ ]:

```
Image.open('convergence2.jpg')
```

Out[ ]:



In [ ]:

```
Image.open('convergence_part2.jpg')
```

Out[ ]: