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# HOMEWORK #1
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import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
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```
url = "https://raw.githubusercontent.com/HamedTabkhi/Intro-to-ML/main/Dataset/D3.csv"
df = pd.read_csv(url)
display(df.head())
```

```
X1 = df.values[:,0]
X2 = df.values[:,1]
X3 = df.values[:,2]
y = df.values[:,3]
```

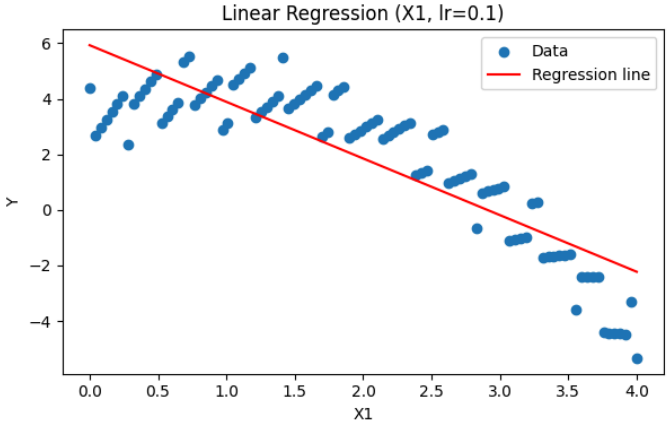
```
#problem 1

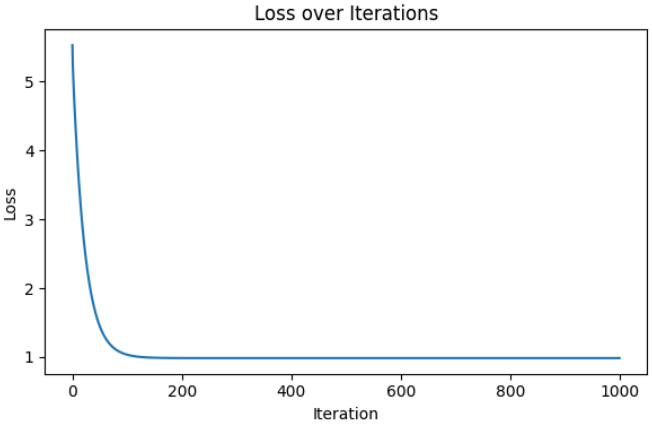
def run_and_plot(X, y, feature_name): #functionalized pltting to reduce reppetitive code
    theta0, theta1, loss_history = gradient_descent(X, y, lr=0.1, epochs=1000)
    print(f"Feature: {feature_name}")
    print(f"Model: y = {theta0:.4f} + {theta1:.4f}*{feature_name}")
    print(f"Final loss: {loss_history[-1]:.4f}\n")
    plt.figure(figsize=(12,4))
    plt.subplot(1,2,1)
    plt.scatter(X, y, label='Data')
    plt.plot(X, theta0 + theta1*X, color='red', label='Regression line')
    plt.xlabel(feature_name)
    plt.ylabel('Y')
    plt.title(f'Linear Regression ({feature_name}, lr=0.1)')
    plt.legend()
    plt.subplot(1,2,2)
    plt.plot(loss_history)
    plt.xlabel('Iteration')
    plt.ylabel('Loss')
    plt.title('Loss over Iterations')
    plt.tight_layout()
    plt.show()

#run for all three values
run_and_plot(X1, y, 'X1')
run_and_plot(X2, y, 'X2')
run_and_plot(X3, y, 'X3')

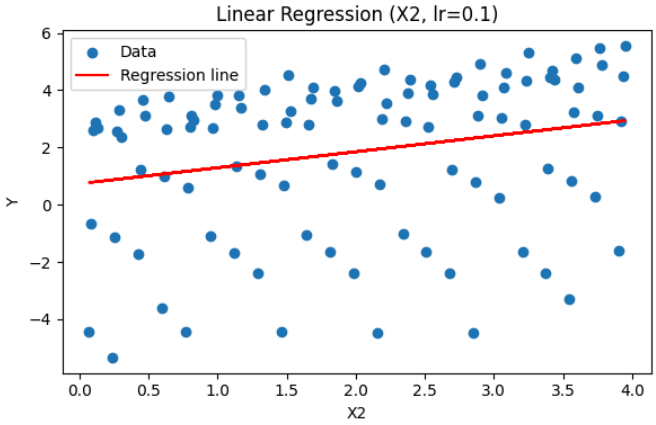
def gradient_descent(X, y, lr=0.1, epochs=1000):
    m = len(y)
    theta0 = 0.0
    theta1 = 0.0
    loss_history = []
    for i in range(epochs):
        y_pred = theta0 + theta1 * X
        error = y_pred - y
        loss = (1/(2*m)) * np.sum(error ** 2)
        loss_history.append(loss)
        #gradients
        d_theta0 = (1/m) * np.sum(error)
        d_theta1 = (1/m) * np.sum(error * X)
        #update
        theta0 -= lr * d_theta0
        theta1 -= lr * d_theta1
    return theta0, theta1, loss_history
```

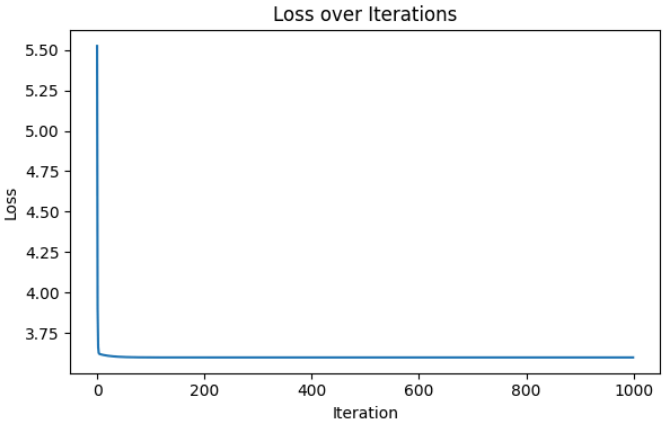
```
Feature: X1
Model: y = 5.9279 + -2.0383*X1
Final loss: 0.9850
```






```
Feature: X2
Model: y = 0.7361 + 0.5576*X2
Final loss: 3.5994
```



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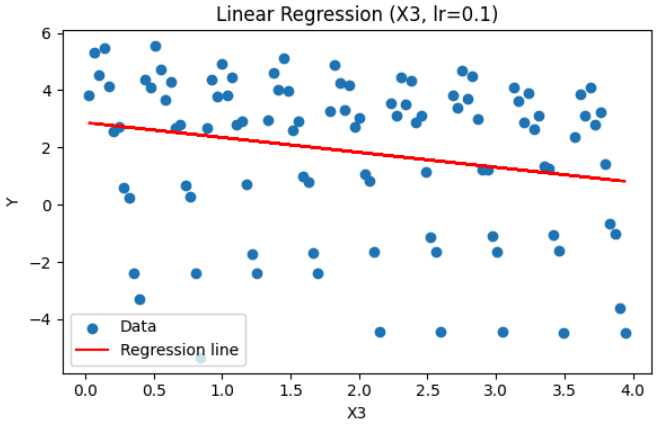
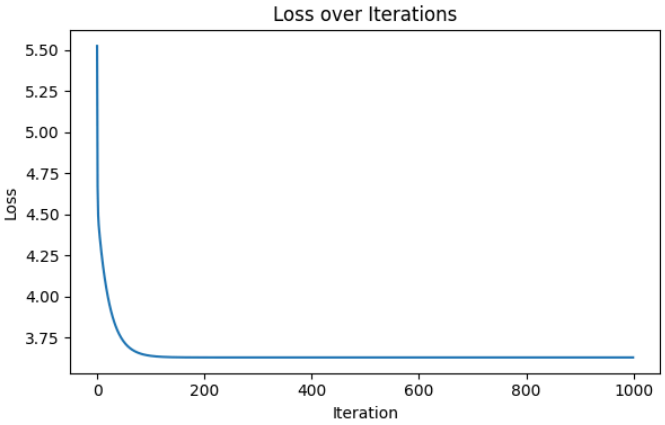
Feature: X3
Model: y = 2.8714 + -0.5205*X3
Final loss: 3.6295
```





```
#problem2

def gradient_descent_multi(X, y, lr=0.1, epochs=1000):
  m, n = X.shape
  theta = np.zeros(n)
  loss_history = []
  for i in range(epochs):
    y_pred = X @ theta
    error = y_pred - y
    loss = (1/(2*m)) * np.sum(error ** 2)
    loss_history.append(loss)
    grad = (1/m) * (X.T @ error)
    theta -= lr * grad
  return theta, loss_history

#prepare x matrix with the bias terms 1
X = np.column_stack((np.ones(len(X1)), X1, X2, X3))

#run the gradient descent with new X
theta, loss_history = gradient_descent_multi(X, y, lr=0.1, epochs=1000)

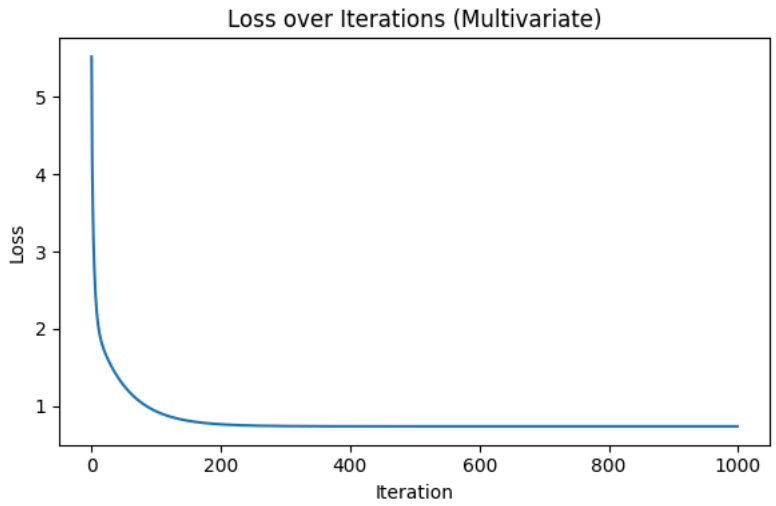
print("Model (learning rate=0.1):")
print(f"y = {theta[0]:.4f} + {theta[1]:.4f}*X1 + {theta[2]:.4f}*X2 + {theta[3]:.4f}*X3")
print(f"Final loss: {loss_history[-1]:.4f}\n")

#plot loss
plt.figure(figsize=(6,4))
plt.plot(loss_history)
plt.xlabel('Iteration')
plt.ylabel('Loss')
plt.title('Loss over Iterations (Multivariate)')
plt.tight_layout()
plt.show()

#predict
def predict(X_new, theta):
  return X_new @ theta

X_new = np.array([
  [1, 1, 1, 1],
  [1, 2, 0, 4],
  [1, 3, 2, 1]
])
predictions = predict(X_new, theta)
for i, x in enumerate(X_new):
  print(f"Predicted y for (X1,X2,X3)=({x[1]},{x[2]},{x[3]}): {predictions[i]:.4f}")
```

```
Model (learning rate=0.1):
y = 5.3139 + -2.0037*X1 + 0.5326*X2 + -0.2656*X3
Final loss: 0.7385
```




```
Predicted y for (X1,X2,X3)=(1,1,1): 3.5773
Predicted y for (X1,X2,X3)=(2,0,4): 0.2443
Predicted y for (X1,X2,X3)=(3,2,1): 0.1025
```