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EXP-3 : Linear Regression: Parameter Estimation using OLS, MLE, and Gradient Descent.

OLS

```
In [19]: import numpy as np
from sklearn.linear_model import LinearRegression
from sklearn.metrics import mean_squared_error, r2_score
```

```
In [20]: # x = np.array([1,2,3]).reshape(-1,1)
# y = np.array([2,3,5])
```

```
In [21]: x = np.array([10,20,30,50]).reshape(-1,1)
y = np.array([12,21,29,48])
```

```
In [22]: model = LinearRegression()
model.fit(x, y)
```

```
Out[22]: ▾ LinearRegression ⓘ ⓘ
```

```
▶ Parameters
```

```
In [23]: w = model.coef_[0]
b = model.intercept_
```

```
In [24]: print(f"w (slope) = {w}")
print(f"b (intercept) = {b}")
```

```
w (slope) = 0.8971428571428572
b (intercept) = 2.8285714285714256
```

```
In [25]: y_pred = model.predict(x)
print("\nPredictions for training data:")
for xi,yi,ypi in zip(x.flatten(),y,y_pred):
    print(f"x={xi}, Actual Sales={yi}, Predicted Sales={ypi:.2f}")
```

Predictions for training data:
x=10, Actual Sales=12, Predicted Sales=11.80
x=20, Actual Sales=21, Predicted Sales=20.77
x=30, Actual Sales=29, Predicted Sales=29.74
x=50, Actual Sales=48, Predicted Sales=47.69

```
In [28]: mse = mean_squared_error(y, y_pred)
r2 = r2_score(y, y_pred)
```

```
In [29]: print(f"\nMean Squared Error (MSE) = {mse:.4f}")
print(f"R^2 Score = {r2:.4f}")
```

Mean Squared Error (MSE) = 0.1857
R² Score = 0.9989

MLE

```
In [30]: from scipy.optimize import minimize
```

```
In [37]: x = np.array([1,2,3])
y = np.array([2,3,5])
```

```
In [38]: def neg_log_likelihood(params):
    w,b = params
    sigma2 = 1
    y_pred = w*x + b
    nll = 0.5*np.sum((y - y_pred)**2/sigma2)
    return nll
```

```
In [39]: initial_guess = [0, 0]
```

```
In [40]: result = minimize(neg_log_likelihood, initial_guess)
w_mle, b_mle = result.x
```

```
In [41]: print(f"MLE w = {w_mle}")
print(f"MLE b = {b_mle}")
```

MLE w = 1.500000042671844
MLE b = 0.3333333912814873

```
In [43]: y_pred = w_mle * x + b_mle
print("\nPredictions for training data:")
for xi,yi,ypi in zip(x.flatten(),y,y_pred):
    print(f"x={xi}, Actual Sales={yi}, Predicted Sales={ypi:.2f}")
```

```
Predictions for training data:  
x=1, Actual Sales=2, Predicted Sales=1.83  
x=2, Actual Sales=3, Predicted Sales=3.33  
x=3, Actual Sales=5, Predicted Sales=4.83
```

```
In [44]: mse = mean_squared_error(y, y_pred)  
r2 = r2_score(y, y_pred)
```

```
In [45]: print(f"\nMean Squared Error (MSE) = {mse:.4f}")  
print(f"R^2 Score = {r2:.4f}")
```

```
Mean Squared Error (MSE) = 0.0556  
R^2 Score = 0.9643
```

Gradient Descent

```
In [78]: import numpy as np  
import matplotlib.pyplot as plt
```

```
In [79]: w, b = 0, 0  
alpha = 0.0001  
n_iter = 1000  
n = len(x)
```

```
In [80]: for i in range(n_iter):  
    y_pred = w*x.flatten() + b  
    dw = (-2/n)*np.sum(x.flatten()*(y - y_pred))  
    db = (-2/n)*np.sum(y - y_pred)  
    w -= alpha*dw  
    b -= alpha*db
```

```
In [81]: print("Slope (w):", w)  
print("Intercept(b):", b)
```

```
Slope (w): 0.9277932204091286  
Intercept(b): 0.4003820339618283
```

```
In [82]: y_pred = w * x + b  
print("\nPredictions for training data:")  
for xi,yi,ypi in zip(x.flatten(),y,y_pred):  
    print(f"x={xi}, Actual Sales={yi}, Predicted Sales={ypi:.2f}")
```

```
Predictions for training data:  
x=1, Actual Sales=2, Predicted Sales=1.33  
x=2, Actual Sales=3, Predicted Sales=2.26  
x=3, Actual Sales=5, Predicted Sales=3.18
```

```
In [83]: mse = mean_squared_error(y, y_pred)  
r2 = r2_score(y, y_pred)
```

```
In [84]: print(f"\nMean Squared Error (MSE) = {mse:.4f}")  
print(f"R^2 Score = {r2:.4f}")
```

Mean Squared Error (MSE) = 1.4346

R^2 Score = 0.0778

```
In [85]: x = np.array([1,2,3])
y = np.array([2,3,5])
n = len(x)
```

```
In [86]: def loss(w1):
    w0 = np.mean(y) - w1 * np.mean(x)
    y_pred = w1 * x + w0
    return np.sum((y - y_pred) ** 2)
```

```
In [87]: def gradient(w1):
    w0 = np.mean(y) - w1 * np.mean(x)
    y_pred = w1 * x + w0
    return - 2 * np.sum(x*(y - y_pred))
```

```
In [88]: lr = 0.1
w1 = 4
iterations = 15
```

```
In [89]: w1_values = []
loss_values = []
```

```
In [90]: for i in range(iterations):
    w1_values.append(w1)
    loss_values.append(loss(w1))

    grad = gradient(w1)
    w1 = w1 - lr * grad
```

```
In [91]: w_space = np.linspace(-2,4,200)
loss_space = [loss(w) for w in w_space]
```

```
In [93]: plt.figure(figsize=(8,5))
plt.plot(w_space, loss_space, label="J(w1)")
plt.scatter(w1_values, loss_values, color = "red", label="GD steps")
plt.xlabel("w1(slope)")
plt.ylabel("Sum of Squared Errors(Loss)")
plt.title("Gradient Descent on Slope Only(w1)")
plt.legend()
plt.grid(True)
plt.show()
```

