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PART 1: LINEAR REGRESSION (Mobile Phone Price Prediction)

Step 1. Import Libraries and Define Helper Functions

```
import numpy as np
import pandas as pd
from sklearn.model_selection import train_test_split
from sklearn.preprocessing import StandardScaler
from sklearn.metrics import mean_squared_error, r2_score
import matplotlib.pyplot as plt

# Reproducibility
RANDOM_STATE = 42

# Function to add intercept term
def add_intercept(X):
    return np.concatenate([np.ones((X.shape[0], 1)), X], axis=1)

# Closed-form (normal equation)
def normal_eq(X, y, l2=0.0):
    n_features = X.shape[1]
    I = np.eye(n_features)
    I[0, 0] = 0 # do not regularize intercept
    return np.linalg.pinv(X.T @ X + l2 * I) @ (X.T @ y)

# Prediction function
def predict(X, theta):
    return X @ theta

# Gradient Descent Implementation
def gradient_descent(X, y, lr=1e-3, n_iters=10000, l2=0.0, tol=1e-8):
    m, n = X.shape
    theta = np.zeros(n)
    prev_loss = np.inf

    for i in range(n_iters):
        preds = X @ theta
        error = preds - y
        grad = (1/m) * (X.T @ error) + (l2/m) * np.r_[0, theta[1:]]
        theta -= lr * grad

        loss = (1/(2*m)) * np.sum(error**2)
        if abs(prev_loss - loss) < tol:
            break
        prev_loss = loss
    return theta
```

Step 2. Load Dataset and Prepare Train/Test Sets

```
# Load your dataset
mobile = pd.read_csv("/content/Mobile-Price-Prediction-cleaned_data.csv")

# Check columns
print(mobile.head())

# Detect target column automatically
target_candidates = [c for c in mobile.columns if 'price' in c.lower()]
target_col = target_candidates[0] if target_candidates else mobile.columns[-1]
print("Using target column:", target_col)

# Features and target
X = mobile.drop(columns=[target_col]).select_dtypes(include=[np.number]).values
y = mobile[target_col].values

# Split dataset
```

```
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_state=RANDOM_STATE)
```

	Ratings	RAM	ROM	Mobile_Size	Primary_Cam	Selfi_Cam	Battery_Power	\
0	4.3	4.0	128.0	6.00	48	13.0	4000	
1	3.4	6.0	64.0	4.50	48	12.0	4000	
2	4.3	4.0	4.0	4.50	64	16.0	4000	
3	4.4	6.0	64.0	6.40	48	15.0	3800	
4	4.5	6.0	128.0	6.18	35	15.0	3800	

```
Price
0 24999
1 15999
2 15000
3 18999
4 18999
Using target column: Price
```

Step 3. Closed-Form Solution

```
X_train_int = add_intercept(X_train)
X_test_int = add_intercept(X_test)

theta_closed = normal_eq(X_train_int, y_train)
y_pred_closed = predict(X_test_int, theta_closed)

print("Closed-form MSE:", mean_squared_error(y_test, y_pred_closed))
print("Closed-form R²:", r2_score(y_test, y_pred_closed))
```

```
Closed-form MSE: 239357657.42978132
Closed-form R²: 0.4332281397249509
```

Step 4. Gradient Descent Solution

```
from sklearn.preprocessing import StandardScaler

# Scale the features for Gradient Descent
scaler_gd = StandardScaler()
X_train_scaled = scaler_gd.fit_transform(X_train_int)
X_test_scaled = scaler_gd.transform(X_test_int)

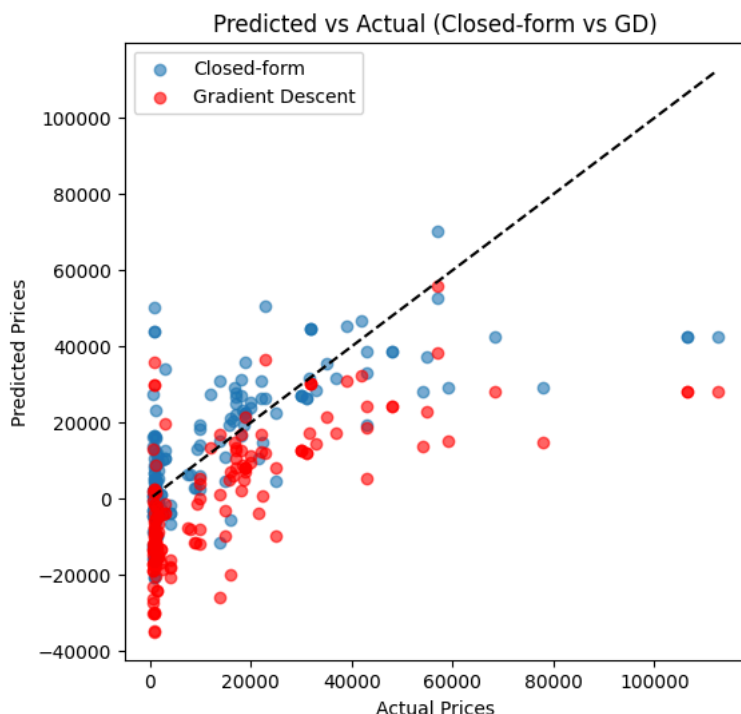
theta_gd = gradient_descent(X_train_scaled, y_train, lr=0.001, n_iters=20000)
y_pred_gd = predict(X_test_scaled, theta_gd)

print("Gradient Descent MSE:", mean_squared_error(y_test, y_pred_gd))
print("Gradient Descent R²:", r2_score(y_test, y_pred_gd))
```

```
Gradient Descent MSE: 453014018.7566579
Gradient Descent R²: -0.07268595832038338
```

Step 5. Plot Predicted vs Actual (Comparison)

```
plt.figure(figsize=(6,6))
plt.scatter(y_test, y_pred_closed, alpha=0.6, label="Closed-form")
plt.scatter(y_test, y_pred_gd, alpha=0.6, label="Gradient Descent", color="red")
plt.plot([y_test.min(), y_test.max()], [y_test.min(), y_test.max()], 'k--')
plt.xlabel("Actual Prices")
plt.ylabel("Predicted Prices")
plt.legend()
plt.title("Predicted vs Actual (Closed-form vs GD)")
plt.show()
```



Step 6. Ridge Regression (L2 Regularization)

```
l2 = 1.0
theta_ridge = normal_eq(X_train_int, y_train, l2=l2)
y_pred_ridge = predict(X_test_int, theta_ridge)

print(f"Ridge Regression ( $\lambda=\{l2\}$ ) MSE:", mean_squared_error(y_test, y_pred_ridge))
```

Ridge Regression ($\lambda=1.0$) MSE: 238951584.5159223

Step 7. With and Without Standardization

```
scaler = StandardScaler()
X_train_s = scaler.fit_transform(X_train)
X_test_s = scaler.transform(X_test)

X_train_s_int = add_intercept(X_train_s)
X_test_s_int = add_intercept(X_test_s)

theta_ridge_std = normal_eq(X_train_s_int, y_train, l2=l2)
y_pred_ridge_std = predict(X_test_s_int, theta_ridge_std)

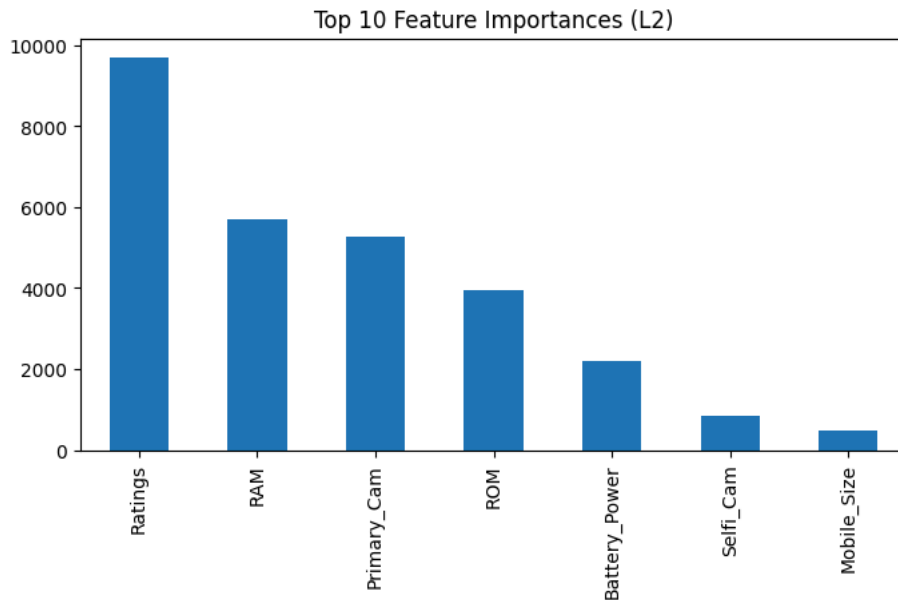
print("Without Standardization MSE:", mean_squared_error(y_test, y_pred_ridge))
print("With Standardization MSE:", mean_squared_error(y_test, y_pred_ridge_std))
```

Without Standardization MSE: 238951584.5159223
With Standardization MSE: 239200533.96478516

Step 8. Feature Importance from Ridge Weights

```
feature_names = mobile.drop(columns=[target_col]).select_dtypes(include=[np.number]).columns
weights = theta_ridge_std[1:]
importance = pd.Series(np.abs(weights), index=feature_names).sort_values(ascending=False)

importance.head(10).plot(kind="bar", figsize=(8,4), title="Top 10 Feature Importances (L2)")
plt.show()
```



PART 2: LINEAR CLASSIFICATION (Bank Note Authentication)

Step 1. Load and Split Dataset

```
from sklearn.linear_model import LogisticRegression
from sklearn.metrics import accuracy_score

bank = pd.read_csv("/content/BankNote_Authentication.csv")
print(bank.head())

Xb = bank.iloc[:, :-1].values
yb = bank.iloc[:, -1].values

Xb_train, Xb_test, yb_train, yb_test = train_test_split(Xb, yb, test_size=0.2, random_state=RANDOM_STATE)
```

	variance	skewness	curtosis	entropy	class
0	3.62160	8.6661	-2.8073	-0.44699	0
1	4.54590	8.1674	-2.4586	-1.46210	0
2	3.86600	-2.6383	1.9242	0.10645	0
3	3.45660	9.5228	-4.0112	-3.59440	0
4	0.32924	-4.4552	4.5718	-0.98880	0

Step 2. Logistic Regression with/without Regularization

```
# Without L2 (penalty='none')
clf_none = LogisticRegression(penalty=None, solver='saga', max_iter=5000)
clf_none.fit(Xb_train, yb_train)

# With L2
clf_l2 = LogisticRegression(penalty='l2', C=1.0, solver='saga', max_iter=5000)
clf_l2.fit(Xb_train, yb_train)

print("No Regularization -> Train acc:", accuracy_score(yb_train, clf_none.predict(Xb_train)),
      "| Test acc:", accuracy_score(yb_test, clf_none.predict(Xb_test)))

print("With L2 -> Train acc:", accuracy_score(yb_train, clf_l2.predict(Xb_train)),
      "| Test acc:", accuracy_score(yb_test, clf_l2.predict(Xb_test)))

No Regularization -> Train acc: 0.9927073837739289 | Test acc: 0.9854545454545455
With L2 -> Train acc: 0.99179580674567 | Test acc: 0.9854545454545455
```

Step 3. Accuracy vs λ Plot

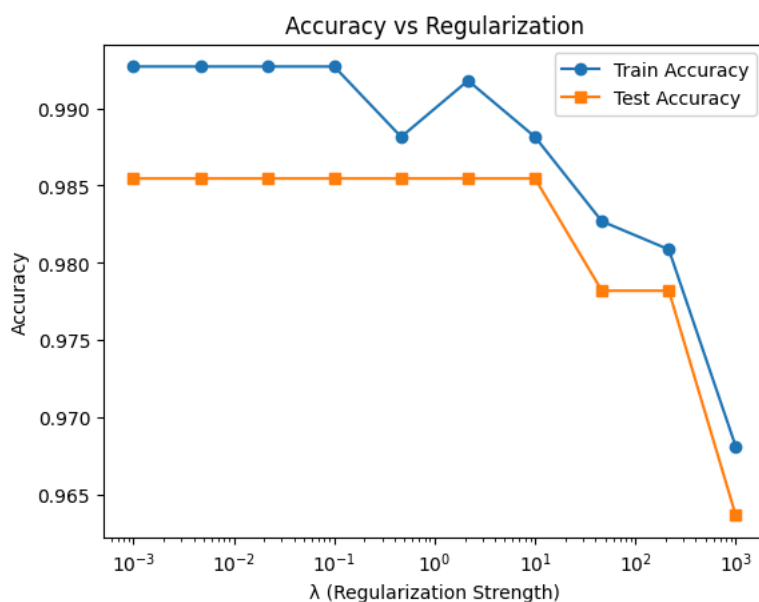
```
lambdas = np.logspace(-3, 3, 10)
train_acc, test_acc = [], []
```

```

for lam in lambdas:
    C = 1.0 / lam
    clf = LogisticRegression(penalty='l2', C=C, solver='saga', max_iter=5000)
    clf.fit(Xb_train, yb_train)
    train_acc.append(accuracy_score(yb_train, clf.predict(Xb_train)))
    test_acc.append(accuracy_score(yb_test, clf.predict(Xb_test)))

plt.semilogx(lambdas, train_acc, 'o-', label='Train Accuracy')
plt.semilogx(lambdas, test_acc, 's-', label='Test Accuracy')
plt.xlabel('λ (Regularization Strength)')
plt.ylabel('Accuracy')
plt.title('Accuracy vs Regularization')
plt.legend()
plt.show()

```



Step 4. Visualize Data in 3D

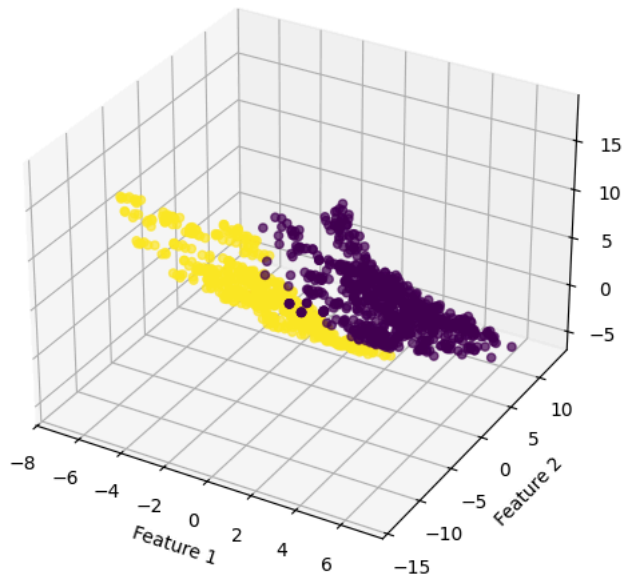
```

from mpl_toolkits.mplot3d import Axes3D

fig = plt.figure(figsize=(8,6))
ax = fig.add_subplot(111, projection='3d')
ax.scatter(Xb[:,0], Xb[:,1], Xb[:,2], c=yb, cmap='viridis', alpha=0.7)
ax.set_xlabel('Feature 1')
ax.set_ylabel('Feature 2')
ax.set_zlabel('Feature 3')
plt.title('3D Visualization of Banknote Features')
plt.show()

```

3D Visualization of Banknote Features



Step 5. Add Outliers and Refit