3.Linear Regression

March 30, 2025

0.1 Linear Regression

[4]:
```
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns
from sklearn.datasets import fetch_california_housing, load_diabetes
from sklearn.model_selection import train_test_split, cross_val_score,␣
↪learning_curve
from sklearn.linear_model import LinearRegression, Ridge, Lasso, ElasticNet
from sklearn.preprocessing import StandardScaler, PolynomialFeatures
from sklearn.pipeline import Pipeline
from sklearn.metrics import mean_squared_error, r2_score, mean_absolute_error
from sklearn.feature_selection import SelectKBest, f_regression
from sklearn.model_selection import GridSearchCV
```

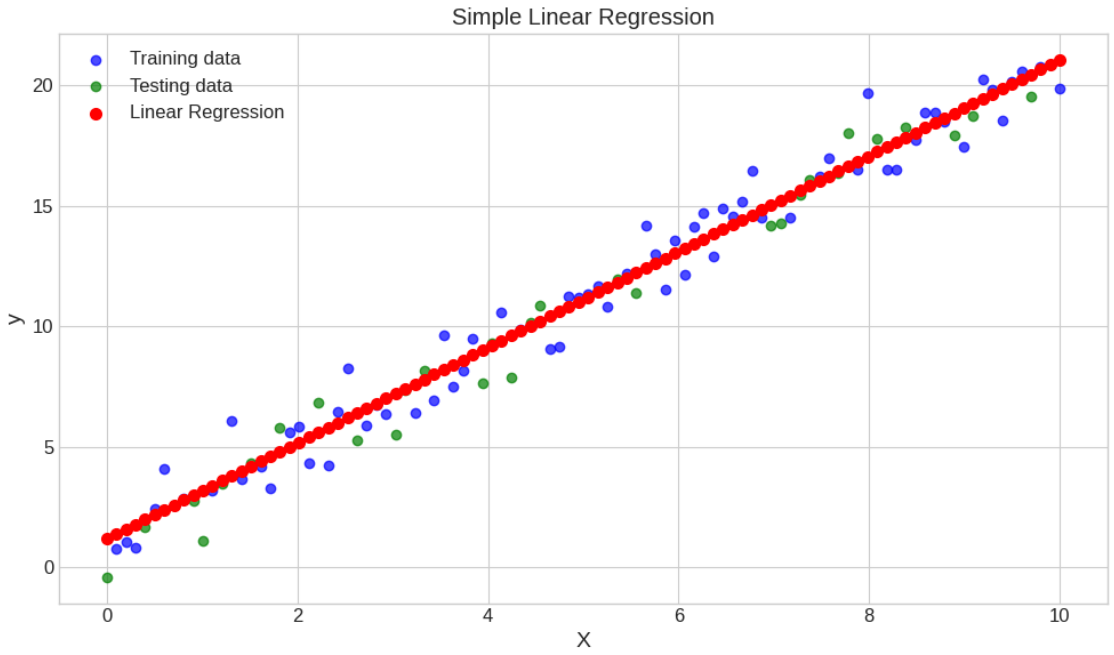
[7]:
```
# Set random seed for reproducibility
np.random.seed(42)
```

[6]:
```
# Configure matplotlib for better plots
plt.style.use('seaborn-v0_8-whitegrid')
plt.rcParams['figure.figsize'] = [10, 6]
plt.rcParams['font.size'] = 12
```

[9]:
```
print("Part 1: Simple Linear Regression")
print("--------------------------------")

# Create a simple syntnetic dataset
X_simple = np.linspace(0,10,100).reshape(-1,1)
y_simple = 2* X_simple.ravel() + 1 + np.random.normal(0,1,100)

# Split the data
X_train_simple, X_test_simple, y_train_simple, y_test_simple = train_test_split(
    X_simple, y_simple, test_size=0.3, random_state=42)

# Train a linear regression model
lr_simple = LinearRegression()
lr_simple.fit(X_train_simple, y_train_simple)
```

```python
# Make Prediction
y_pred_simple = lr_simple.predict(X_test_simple)

# Print model parameters
print(f"Model parameters:")
print(f"Coefficient (slope): {lr_simple.coef_[0]:.4f}")
print(f"Intercept: {lr_simple.intercept_:.4f}")

# Evaluate the model
mse_simple = mean_squared_error(y_test_simple, y_pred_simple)
r2_simple = r2_score(y_test_simple, y_pred_simple)
print(f"Mean Squared Error: {mse_simple:.4f}")
print(f"R-squared score: {r2_simple:.4f}")

# Visualize the results
plt.figure(figsize=(10,6))
plt.scatter(X_train_simple,
            y_train_simple,
            color = 'blue', alpha=0.7,
            label='Training data')
plt.scatter(X_test_simple,
            y_test_simple,
            color = 'green', alpha=0.7,
            label='Testing data')
plt.scatter(X_simple,
            lr_simple.predict(X_simple),
            color = 'red', linewidth=2,
            label='Linear Regression')
plt.title('Simple Linear Regression')
plt.xlabel('X', fontsize=14)
plt.ylabel('y', fontsize=14)
plt.legend(fontsize=12)
plt.grid(True)
plt.tight_layout()
plt.show()
```

```
Part 1: Simple Linear Regression
--------------------------------
Model parameters:
Coefficient (slope): 1.9869
Intercept: 1.1804
Mean Squared Error: 0.8669
R-squared score: 0.9751
```



Multiple Linear Regression with California Housing Dataset

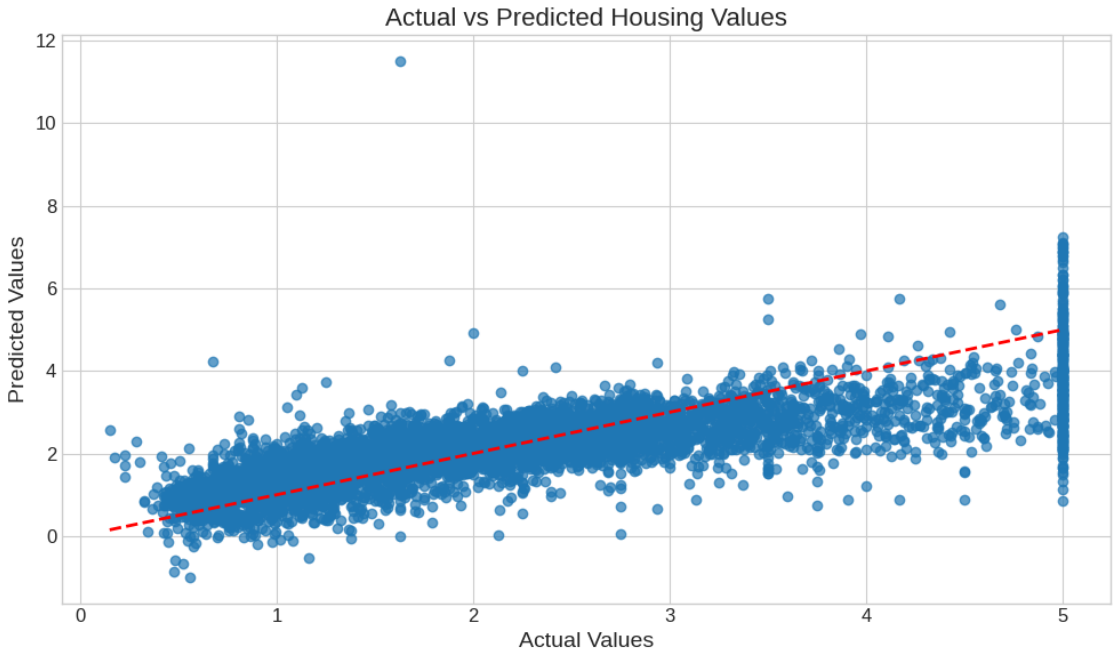
[12]:
```
print("\nPart 2: Multiple Linear Regression with California Housing Dataset")
print("-----------------------------------------------------------------")

# Load the california Housing dataset
california = fetch_california_housing()
X = california.data
y = california.target
feature_names = california.feature_names

# Print basic dataset information
print(f"Dataset shape: {X.shape}")
print(f"Feature names: {feature_names}")
print(f"Target: {california.DESCR.split('Attribute Information')[0].split('.
  ↪')[-2]}")

# Basic statistics
print("\nBasic statistics fo features:")
california_df = pd.DataFrame(X, columns=feature_names)
print(california_df.describe().round(2))

# Basic statistics for target
print("\nBasic statistics for target (housing price):")
print(pd.Series(y).describe().round(2))
```

```python
#Split the data
X_train, X_test, y_train, y_test = train_test_split(X,y, test_size=0.3,␣
 ↪random_state=42)

# Train a multiple linear regression models
lr = LinearRegression()
lr.fit(X_train, y_train)

# Make Predictions
y_pred =lr.predict(X_test)

# Evaluate the models
mse = mean_squared_error(y_test, y_pred)
rmse = np.sqrt(mse)
r2 = r2_score(y_test, y_pred)
mae = mean_absolute_error(y_test, y_pred)

print(f"\nModel evaluation:")
print(f"Mean Squared Error: {mse:.4f}")
print(f"Root Mean Squared Error: {rmse:.4f}")
print(f"Mean Absolute Error: {mae:.4f}")
print(f"R² Score: {r2:.4f}")

# Print Coefficients
print("\nModel Coefficients:")
for feature, coef in zip(feature_names, lr.coef_):
  print(f"{feature}:{coef:.6f}")
print(f"Intercept: {lr.intercept_:.6f}")
```

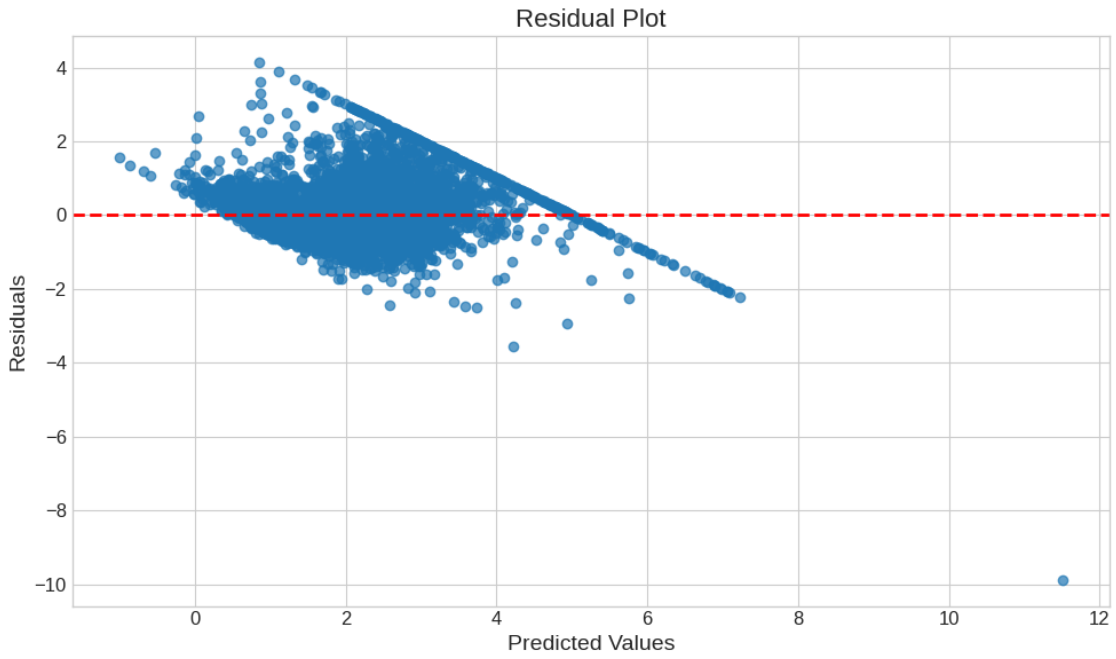
```
Part 2: Multiple Linear Regression with California Housing Dataset
--------------------------------------------------------------------
Dataset shape: (20640, 8)
Feature names: ['MedInc', 'HouseAge', 'AveRooms', 'AveBedrms', 'Population',
'AveOccup', 'Latitude', 'Longitude']
Target:

Basic statistics fo features:
         MedInc  HouseAge  AveRooms  AveBedrms  Population  AveOccup  Latitude
Longitude
count  20640.00  20640.00  20640.00   20640.00    20640.00  20640.00  20640.00
20640.00
mean       3.87     28.64      5.43       1.10     1425.48      3.07     35.63
-119.57
std        1.90     12.59      2.47       0.47     1132.46     10.39      2.14
2.00
min        0.50      1.00      0.85       0.33        3.00      0.69     32.54
```

```
-124.35
25%        2.56     18.00      4.44       1.01      787.00       2.43     33.93
-121.80
50%        3.53     29.00      5.23       1.05     1166.00       2.82     34.26
-118.49
75%        4.74     37.00      6.05       1.10     1725.00       3.28     37.71
-118.01
max       15.00     52.00    141.91      34.07    35682.00    1243.33     41.95
-114.31

Basic statistics for target (housing price):
count    20640.00
mean         2.07
std          1.15
min          0.15
25%          1.20
50%          1.80
75%          2.65
max          5.00
dtype: float64

Model evaluation:
Mean Squared Error: 0.5306
Root Mean Squared Error: 0.7284
Mean Absolute Error: 0.5272
R² Score: 0.5958

Model Coefficients:
MedInc:0.445823
HouseAge:0.009682
AveRooms:-0.122095
AveBedrms:0.778600
Population:-0.000001
AveOccup:-0.003370
Latitude:-0.418537
Longitude:-0.433688
Intercept: -37.056241
```

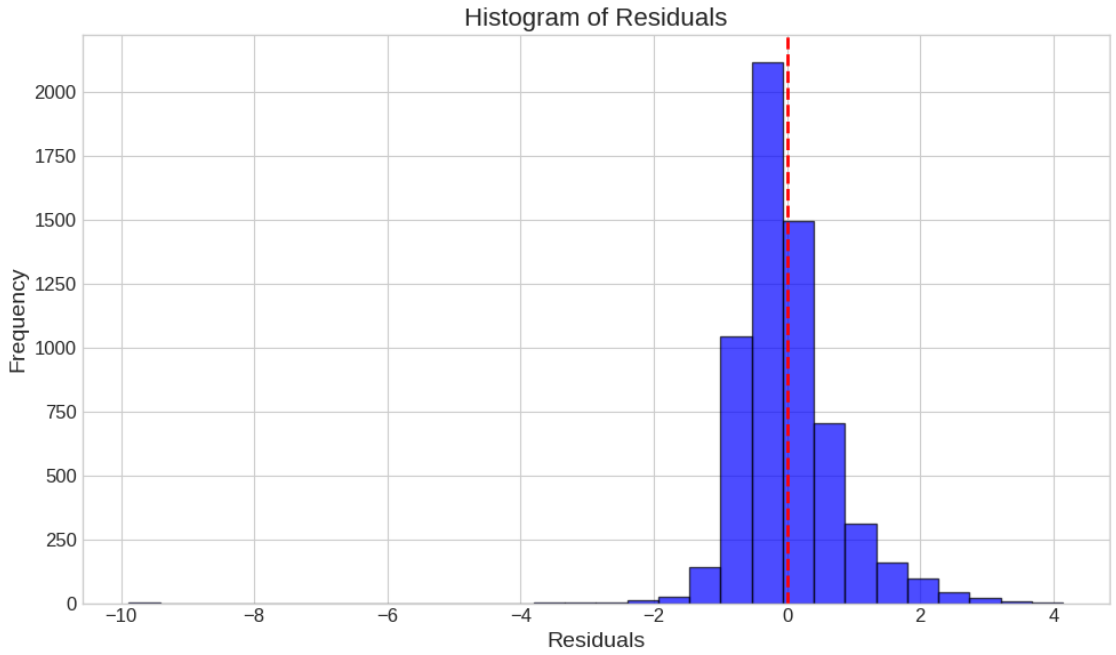
[13]:
```python
# Visualize actual vs predicted values
plt.figure(figsize=(10,6))
plt.scatter(y_test, y_pred, alpha=0.7)
plt.plot([y.min(),y.max()],[y.min(),y.max()], 'r--', lw=2)
plt.xlabel('Actual Values', fontsize=14)
plt.ylabel('Predicted Values', fontsize=14)
plt.title('Actual vs Predicted Housing Values', fontsize=16)
plt.tight_layout()
plt.show()
```



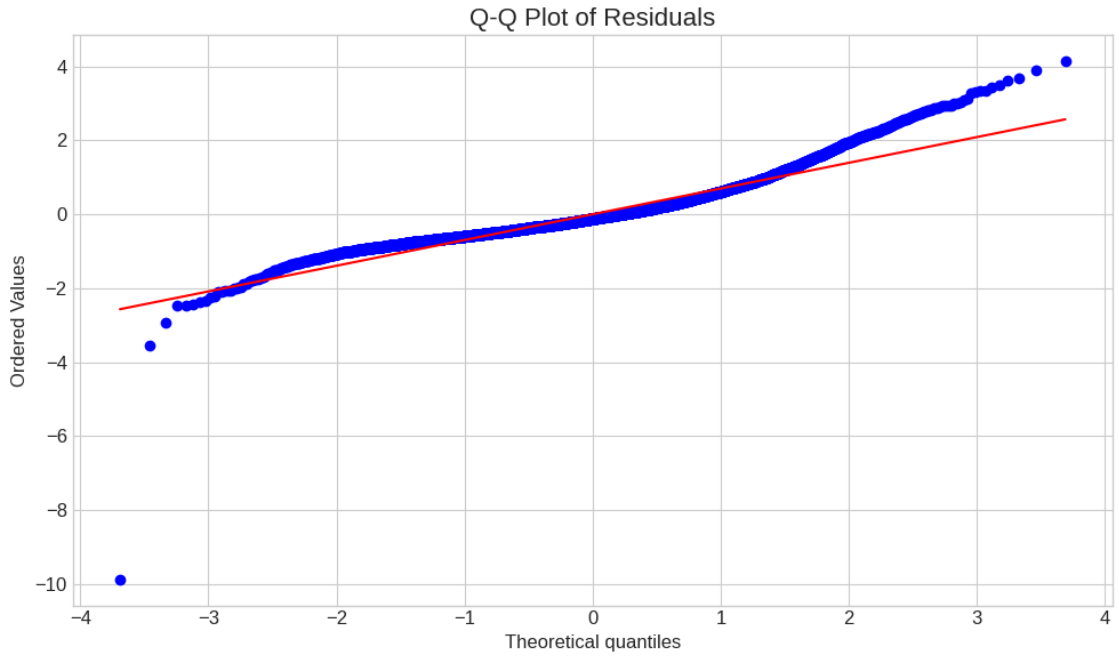
[14]:
```
# Visualize residuals
residuals = y_test - y_pred
plt.figure(figsize=(10, 6))
plt.scatter(y_pred, residuals, alpha=0.7)
plt.axhline(y=0, color='r', linestyle='--', lw=2)
plt.xlabel('Predicted Values', fontsize=14)
plt.ylabel('Residuals', fontsize=14)
plt.title('Residual Plot', fontsize=16)
plt.tight_layout()
plt.show()
```



[15]:
```
# Histogram of residuals
plt.figure(figsize=(10, 6))
plt.hist(residuals, bins=30, alpha=0.7, color='blue', edgecolor='black')
plt.axvline(x=0, color='r', linestyle='--', lw=2)
plt.xlabel('Residuals', fontsize=14)
plt.ylabel('Frequency', fontsize=14)
plt.title('Histogram of Residuals', fontsize=16)
plt.tight_layout()
plt.show()
```



[16]:
```
# QQ plot for checking normality of residuals
from scipy import stats
plt.figure(figsize=(10, 6))
stats.probplot(residuals, plot=plt)
plt.title('Q-Q Plot of Residuals', fontsize=16)
plt.tight_layout()
plt.show()
```

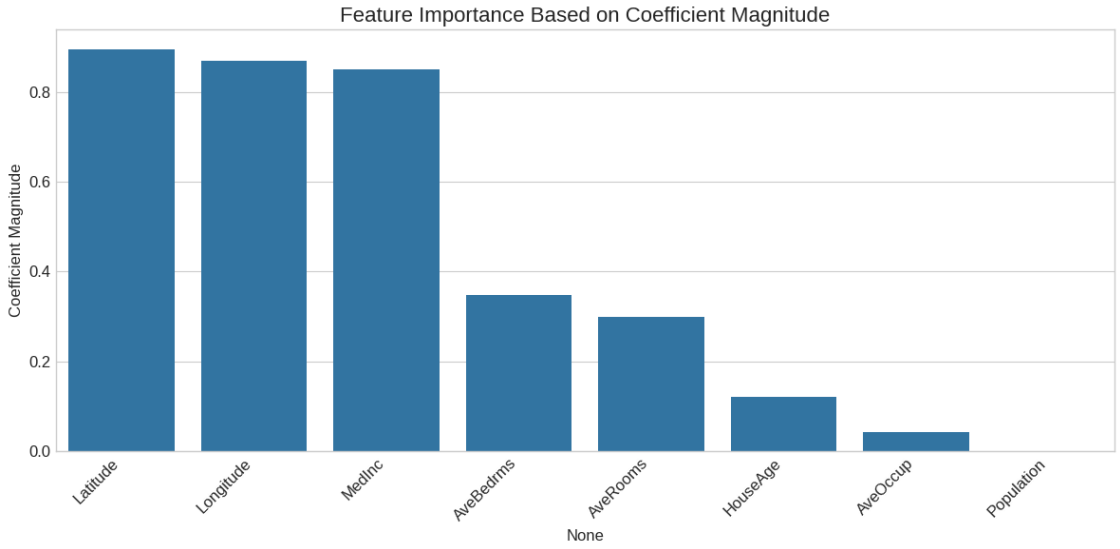


Feature Scaling and Preprocessing

[17]:
```
print("\nPart 3: Feature Scaling and Preprocessing")
print("----------------------------------------")

# Create a pipeline with preprocessing
pipeline = Pipeline([
    ('scaler', StandardScaler()),
    ('regression', LinearRegression())
])

# Train the pipeline
pipeline.fit(X_train, y_train)

# Make predictions
y_pred_scaled = pipeline.predict(X_test)

# Evaluate the model
mse_scaled = mean_squared_error(y_test, y_pred_scaled)
r2_scaled = r2_score(y_test, y_pred_scaled)

print(f"Model evaluation with feature scaling:")
print(f"Mean Squared Error: {mse_scaled:.4f}")
print(f"R² Score: {r2_scaled:.4f}")
print(f"Improvement in MSE: {mse - mse_scaled:.4f}")
```

```python
# Coefficients after scaling
lr_scaled = pipeline.named_steps['regression']
scaler = pipeline.named_steps['scaler']
print("\nModel coefficients after scaling:")
for feature, coef in zip(feature_names, lr_scaled.coef_):
    print(f"{feature}: {coef:.6f}")

# Feature importance (absolute coefficient values)
coefs = pd.DataFrame(
    np.abs(lr_scaled.coef_),
    index=feature_names,
    columns=['Coefficient Magnitude']
)
coefs = coefs.sort_values('Coefficient Magnitude', ascending=False)

plt.figure(figsize=(12, 6))
sns.barplot(x=coefs.index, y='Coefficient Magnitude', data=coefs)
plt.xticks(rotation=45, ha='right')
plt.title('Feature Importance Based on Coefficient Magnitude', fontsize=16)
plt.tight_layout()
plt.show()
```

```
Part 3: Feature Scaling and Preprocessing
----------------------------------------
Model evaluation with feature scaling:
Mean Squared Error: 0.5306
R² Score: 0.5958
Improvement in MSE: 0.0000

Model coefficients after scaling:
MedInc: 0.849222
HouseAge: 0.122119
AveRooms: -0.299558
AveBedrms: 0.348410
Population: -0.000884
AveOccup: -0.041698
Latitude: -0.893856
Longitude: -0.868617
```



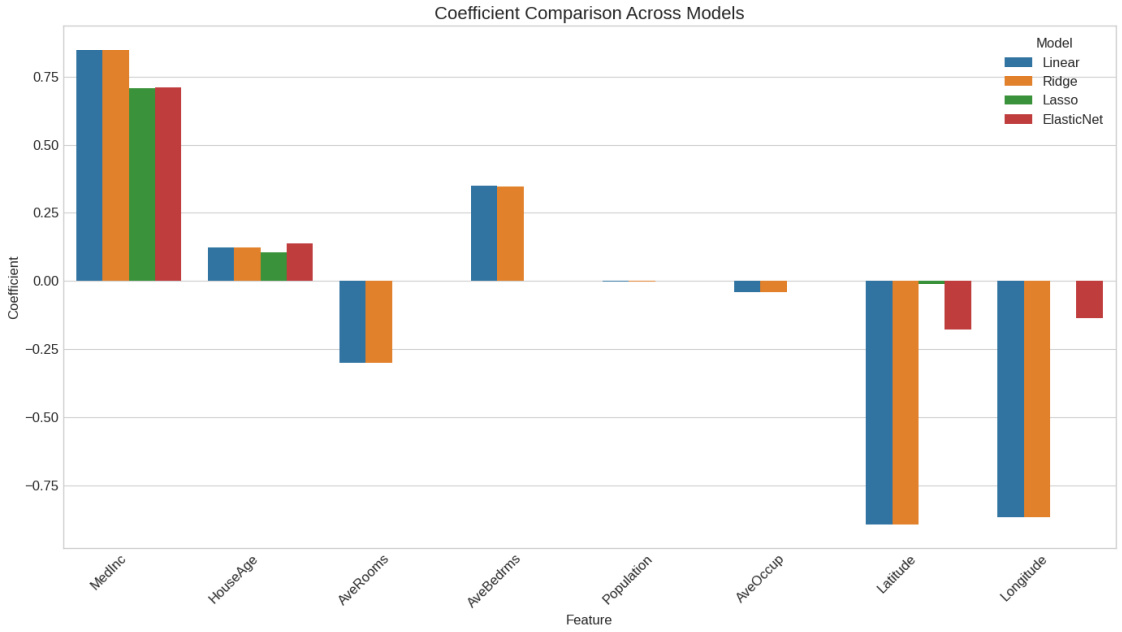
Regularization Techniques

[18]:
```
print("\nPart 4: Regularization Techniques")
print("--------------------------------")

# Create a pipeline with different regularization techniques
# Ridge Regression
ridge_pipeline = Pipeline([
    ('scaler', StandardScaler()),
    ('ridge', Ridge(alpha=1.0))
])

# Lasso Regression
lasso_pipeline = Pipeline([
    ('scaler', StandardScaler()),
    ('lasso', Lasso(alpha=0.1))
])

# ElasticNet Regression
elastic_pipeline = Pipeline([
    ('scaler', StandardScaler()),
    ('elastic', ElasticNet(alpha=0.1, l1_ratio=0.5))
])

# Train models
ridge_pipeline.fit(X_train, y_train)
lasso_pipeline.fit(X_train, y_train)
elastic_pipeline.fit(X_train, y_train)
```

```python
# Make predictions
y_pred_ridge = ridge_pipeline.predict(X_test)
y_pred_lasso = lasso_pipeline.predict(X_test)
y_pred_elastic = elastic_pipeline.predict(X_test)

# Evaluate models
print("\nModel comparison:")
print(f"Linear Regression R²: {r2_scaled:.4f}")
print(f"Ridge Regression R²: {r2_score(y_test, y_pred_ridge):.4f}")
print(f"Lasso Regression R²: {r2_score(y_test, y_pred_lasso):.4f}")
print(f"ElasticNet Regression R²: {r2_score(y_test, y_pred_elastic):.4f}")

# Get coefficients
ridge_coef = ridge_pipeline.named_steps['ridge'].coef_
lasso_coef = lasso_pipeline.named_steps['lasso'].coef_
elastic_coef = elastic_pipeline.named_steps['elastic'].coef_

# Visualize coefficients from different models
coefs_df = pd.DataFrame({
    'Feature': feature_names,
    'Linear': lr_scaled.coef_,
    'Ridge': ridge_coef,
    'Lasso': lasso_coef,
    'ElasticNet': elastic_coef
})

coefs_melted = pd.melt(
    coefs_df,
    id_vars='Feature',
    value_vars=['Linear', 'Ridge', 'Lasso', 'ElasticNet'],
    var_name='Model',
    value_name='Coefficient'
)

plt.figure(figsize=(14, 8))
sns.barplot(x='Feature', y='Coefficient', hue='Model', data=coefs_melted)
plt.xticks(rotation=45, ha='right')
plt.title('Coefficient Comparison Across Models', fontsize=16)
plt.legend(title='Model')
plt.tight_layout()
plt.show()
```

```
Part 4: Regularization Techniques
------------------------------

Model comparison:
```

```
Linear Regression R²: 0.5958
Ridge Regression R²: 0.5958
Lasso Regression R²: 0.4935
ElasticNet Regression R²: 0.5276
```



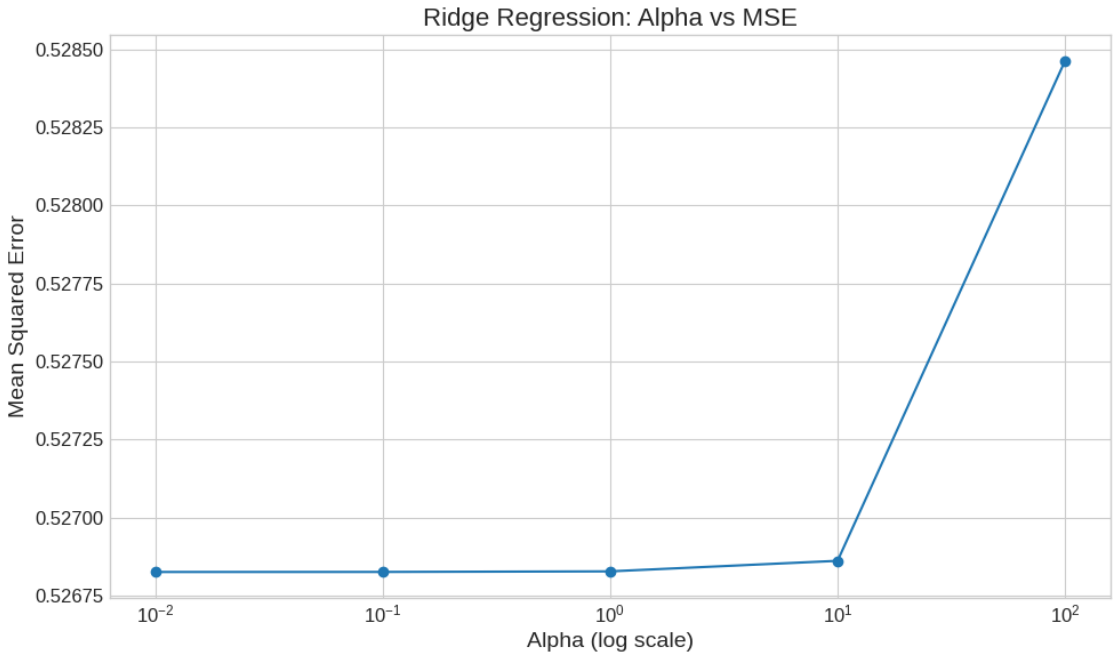
Hyperparameter Tuning

[20]:
```
print("\nPart 5: Hyperparameter Tuning")
print("----------------------------")

# Define parameter grids
ridge_param_grid = {
    'ridge__alpha': [0.01, 0.1, 1.0, 10.0, 100.0]
}

lasso_param_grid = {
    'lasso__alpha': [0.001, 0.01, 0.1, 1.0, 10.0]
}

elastic_param_grid = {
    'elastic__alpha': [0.001, 0.01, 0.1, 1.0],
    'elastic__l1_ratio': [0.1, 0.3, 0.5, 0.7, 0.9]
}

# Perform grid search
ridge_gs = GridSearchCV(ridge_pipeline, ridge_param_grid, cv=5,␣
 ↪scoring='neg_mean_squared_error')
```

```
lasso_gs = GridSearchCV(lasso_pipeline, lasso_param_grid, cv=5,␣
 ↪scoring='neg_mean_squared_error')
elastic_gs = GridSearchCV(elastic_pipeline, elastic_param_grid, cv=5,␣
 ↪scoring='neg_mean_squared_error')

# Train models
ridge_gs.fit(X_train, y_train)
lasso_gs.fit(X_train, y_train)
elastic_gs.fit(X_train, y_train)

# Print best parameters
print("\nBest hyperparameters:")
print(f"Ridge: {ridge_gs.best_params_}, MSE: {-ridge_gs.best_score_:.4f}")
print(f"Lasso: {lasso_gs.best_params_}, MSE: {-lasso_gs.best_score_:.4f}")
print(f"ElasticNet: {elastic_gs.best_params_}, MSE: {-elastic_gs.best_score_:.
 ↪4f}")

# Evaluate on test set
best_ridge = ridge_gs.best_estimator_
best_lasso = lasso_gs.best_estimator_
best_elastic = elastic_gs.best_estimator_

y_pred_best_ridge = best_ridge.predict(X_test)
y_pred_best_lasso = best_lasso.predict(X_test)
y_pred_best_elastic = best_elastic.predict(X_test)

# Calculate R² scores
r2_best_ridge = r2_score(y_test, y_pred_best_ridge)
r2_best_lasso = r2_score(y_test, y_pred_best_lasso)
r2_best_elastic = r2_score(y_test, y_pred_best_elastic)

print("\nTest set performance (R²):")
print(f"Ridge: {r2_best_ridge:.4f}")
print(f"Lasso: {r2_best_lasso:.4f}")
print(f"ElasticNet: {r2_best_elastic:.4f}")

# Visualize alpha vs performance for Ridge
alphas = ridge_param_grid['ridge__alpha']
ridge_scores = []

for alpha in alphas:
    ridge = Pipeline([
        ('scaler', StandardScaler()),
        ('ridge', Ridge(alpha=alpha))
    ])

    # Use cross-validation to get reliable score
```

```
    scores = cross_val_score(ridge, X_train, y_train,
                             cv=5, scoring='neg_mean_squared_error')
    ridge_scores.append(-np.mean(scores))

plt.figure(figsize=(10, 6))
plt.plot(alphas, ridge_scores, 'o-')
plt.xscale('log')
plt.xlabel('Alpha (log scale)', fontsize=14)
plt.ylabel('Mean Squared Error', fontsize=14)
plt.title('Ridge Regression: Alpha vs MSE', fontsize=16)
plt.grid(True)
plt.tight_layout()
plt.show()
```

```
Part 5: Hyperparameter Tuning
----------------------------

Best hyperparameters:
Ridge: {'ridge__alpha': 0.01}, MSE: 0.5268
Lasso: {'lasso__alpha': 0.001}, MSE: 0.5267
ElasticNet: {'elastic__alpha': 0.001, 'elastic__l1_ratio': 0.9}, MSE: 0.5267

Test set performance (R²):
Ridge: 0.5958
Lasso: 0.5964
ElasticNet: 0.5964
```

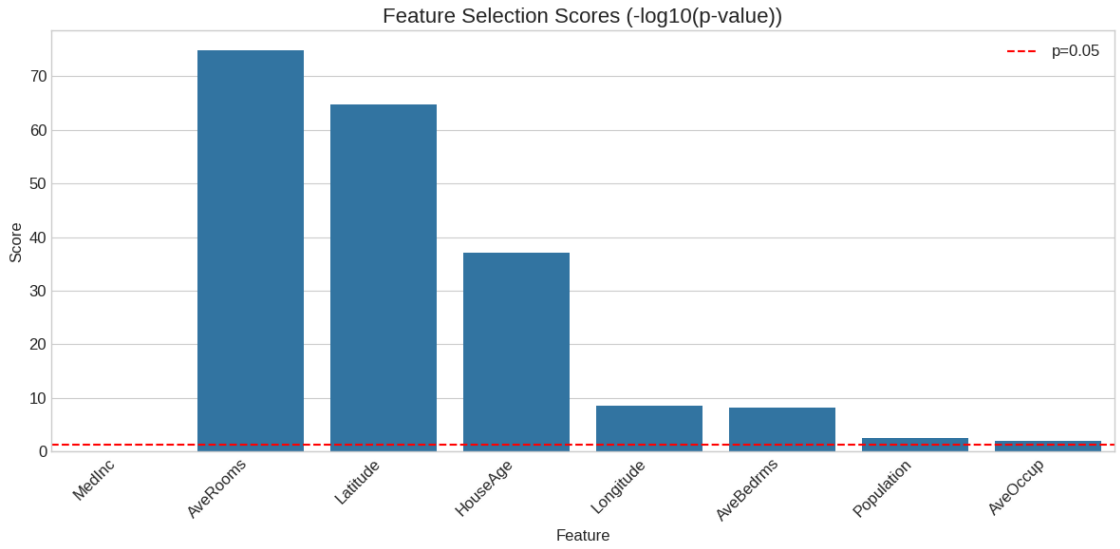


Feature Selection

[21]:
```
print("\nPart 6: Feature Selection")
print("-----------------------")

# Use SelectKBest for feature selection
selector = SelectKBest(f_regression, k=5)
X_train_selected = selector.fit_transform(X_train, y_train)
X_test_selected = selector.transform(X_test)

# Get selected feature indices
selected_indices = selector.get_support(indices=True)
selected_features = [feature_names[i] for i in selected_indices]

print(f"Selected features: {selected_features}")

# Train model on selected features
lr_selected = LinearRegression()
lr_selected.fit(X_train_selected, y_train)
y_pred_selected = lr_selected.predict(X_test_selected)
r2_selected = r2_score(y_test, y_pred_selected)

print(f"R² with all features: {r2:.4f}")
print(f"R² with selected features: {r2_selected:.4f}")

# Plot feature scores
scores = -np.log10(selector.pvalues_)
scores_df = pd.DataFrame({'Feature': feature_names, 'Score': scores})
scores_df = scores_df.sort_values('Score', ascending=False)

plt.figure(figsize=(12, 6))
sns.barplot(x='Feature', y='Score', data=scores_df)
plt.xticks(rotation=45, ha='right')
plt.axhline(y=-np.log10(0.05), color='r', linestyle='--', label='p=0.05')
plt.title('Feature Selection Scores (-log10(p-value))', fontsize=16)
plt.legend()
plt.tight_layout()
plt.show()
```

```
Part 6: Feature Selection
-----------------------
Selected features: ['MedInc', 'HouseAge', 'AveRooms', 'Latitude', 'Longitude']
R² with all features: 0.5958
R² with selected features: 0.5949
```

```
<ipython-input-21-de9d6fe86cea>:25: RuntimeWarning: divide by zero encountered
in log10
  scores = -np.log10(selector.pvalues_)
```

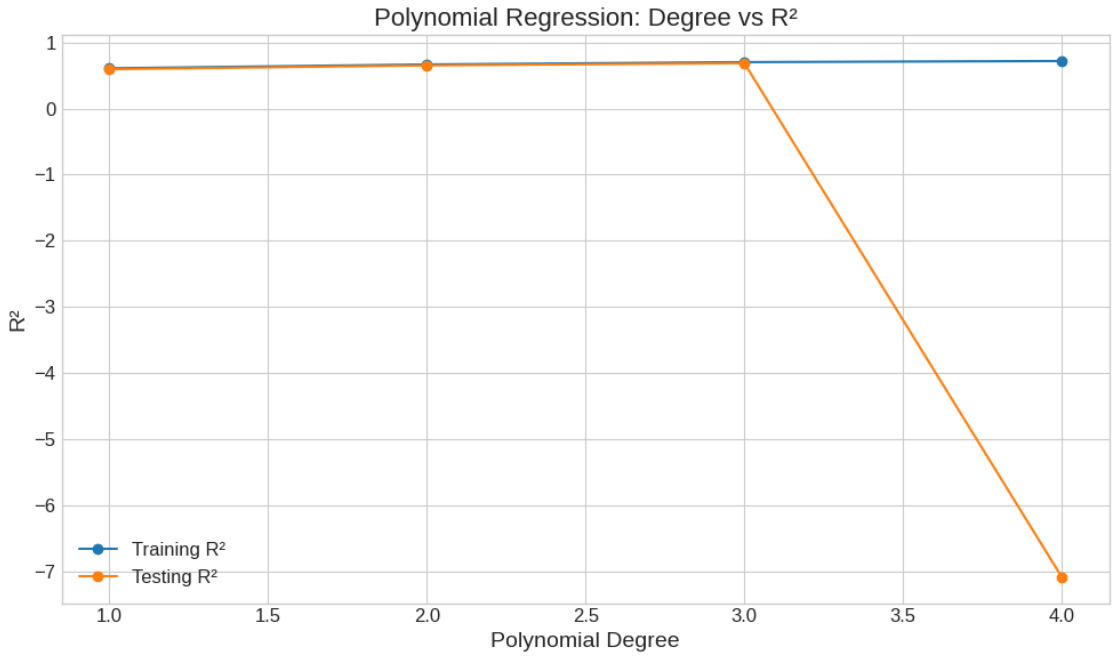


Polynomial Regression

[22]:
```
print("\nPart 7: Polynomial Regression")
print("----------------------------")

# Create a polynomial pipeline
poly_pipeline = Pipeline([
    ('poly', PolynomialFeatures(degree=2, include_bias=False)),
    ('scaler', StandardScaler()),
    ('regression', LinearRegression())
])

# Train model
poly_pipeline.fit(X_train, y_train)
y_pred_poly = poly_pipeline.predict(X_test)
r2_poly = r2_score(y_test, y_pred_poly)

print(f"Linear Regression R²: {r2:.4f}")
print(f"Polynomial Regression R²: {r2_poly:.4f}")

# Try different polynomial degrees
degrees = [1, 2, 3, 4]
train_scores = []
test_scores = []
```

```python
for degree in degrees:
    poly_pipeline = Pipeline([
        ('poly', PolynomialFeatures(degree=degree, include_bias=False)),
        ('scaler', StandardScaler()),
        ('regression', Ridge(alpha=1.0))  # Using Ridge to prevent overfitting
    ])

    poly_pipeline.fit(X_train, y_train)

    # Score on training data
    train_score = poly_pipeline.score(X_train, y_train)
    train_scores.append(train_score)

    # Score on test data
    test_score = poly_pipeline.score(X_test, y_test)
    test_scores.append(test_score)

# Plot results
plt.figure(figsize=(10, 6))
plt.plot(degrees, train_scores, 'o-', label='Training R²')
plt.plot(degrees, test_scores, 'o-', label='Testing R²')
plt.xlabel('Polynomial Degree', fontsize=14)
plt.ylabel('R²', fontsize=14)
plt.title('Polynomial Regression: Degree vs R²', fontsize=16)
plt.grid(True)
plt.legend()
plt.tight_layout()
plt.show()
```

```
Part 7: Polynomial Regression
----------------------------
Linear Regression R²: 0.5958
Polynomial Regression R²: 0.6534
```

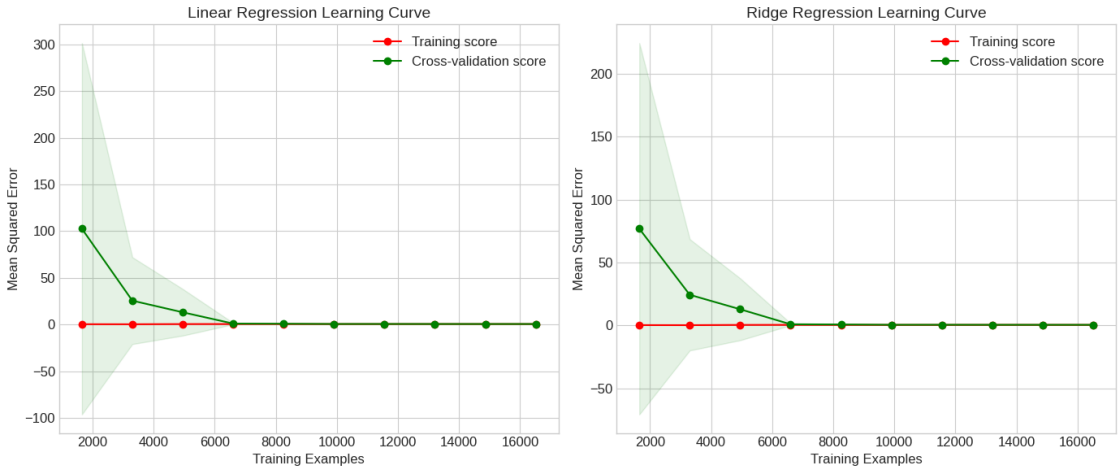


Learning Curves

[23]:
```
print("\nPart 8: Learning Curves")
print("--------------------")

# Generate learning curves
train_sizes = np.linspace(0.1, 1.0, 10)

# Linear Regression learning curve
lr_train_sizes, lr_train_scores, lr_test_scores = learning_curve(
    LinearRegression(), X, y, train_sizes=train_sizes,
    scoring='neg_mean_squared_error', cv=5, n_jobs=-1
)

# Ridge Regression learning curve
ridge_train_sizes, ridge_train_scores, ridge_test_scores = learning_curve(
    Ridge(alpha=1.0), X, y, train_sizes=train_sizes,
    scoring='neg_mean_squared_error', cv=5, n_jobs=-1
)

# Convert MSE to positive for better visualization
lr_train_scores_mean = -np.mean(lr_train_scores, axis=1)
lr_train_scores_std = np.std(lr_train_scores, axis=1)
lr_test_scores_mean = -np.mean(lr_test_scores, axis=1)
lr_test_scores_std = np.std(lr_test_scores, axis=1)
```

```
ridge_train_scores_mean = -np.mean(ridge_train_scores, axis=1)
ridge_train_scores_std = np.std(ridge_train_scores, axis=1)
ridge_test_scores_mean = -np.mean(ridge_test_scores, axis=1)
ridge_test_scores_std = np.std(ridge_test_scores, axis=1)

# Plot learning curves
plt.figure(figsize=(14, 6))

plt.subplot(1, 2, 1)
plt.fill_between(lr_train_sizes, lr_train_scores_mean - lr_train_scores_std,
                 lr_train_scores_mean + lr_train_scores_std, alpha=0.1,␣
 ↪color="r")
plt.fill_between(lr_train_sizes, lr_test_scores_mean - lr_test_scores_std,
                 lr_test_scores_mean + lr_test_scores_std, alpha=0.1, color="g")
plt.plot(lr_train_sizes, lr_train_scores_mean, 'o-', color="r", label="Training␣
 ↪score")
plt.plot(lr_train_sizes, lr_test_scores_mean, 'o-', color="g",␣
 ↪label="Cross-validation score")
plt.title("Linear Regression Learning Curve", fontsize=14)
plt.xlabel("Training Examples", fontsize=12)
plt.ylabel("Mean Squared Error", fontsize=12)
plt.legend(loc="best")
plt.grid(True)

plt.subplot(1, 2, 2)
plt.fill_between(ridge_train_sizes, ridge_train_scores_mean -␣
 ↪ridge_train_scores_std,
                 ridge_train_scores_mean + ridge_train_scores_std, alpha=0.1,␣
 ↪color="r")
plt.fill_between(ridge_train_sizes, ridge_test_scores_mean -␣
 ↪ridge_test_scores_std,
                 ridge_test_scores_mean + ridge_test_scores_std, alpha=0.1,␣
 ↪color="g")
plt.plot(ridge_train_sizes, ridge_train_scores_mean, 'o-', color="r",␣
 ↪label="Training score")
plt.plot(ridge_train_sizes, ridge_test_scores_mean, 'o-', color="g",␣
 ↪label="Cross-validation score")
plt.title("Ridge Regression Learning Curve", fontsize=14)
plt.xlabel("Training Examples", fontsize=12)
plt.ylabel("Mean Squared Error", fontsize=12)
plt.legend(loc="best")
plt.grid(True)

plt.tight_layout()
plt.show()
```

```
Part 8: Learning Curves
--------------------
```



Cross Validation

[24]:
```
print("\nPart 9: Cross-Validation")
print("----------------------")

# Perform k-fold cross-validation
from sklearn.model_selection import KFold

models = {
    'Linear Regression': LinearRegression(),
    'Ridge': Ridge(alpha=1.0),
    'Lasso': Lasso(alpha=0.1),
    'ElasticNet': ElasticNet(alpha=0.1, l1_ratio=0.5)
}

cv = KFold(n_splits=5, shuffle=True, random_state=42)

# Prepare data
scaler = StandardScaler()
X_scaled = scaler.fit_transform(X)

for name, model in models.items():
    scores = cross_val_score(model, X_scaled, y, cv=cv,␣
 ↪scoring='neg_mean_squared_error')
    rmse_scores = np.sqrt(-scores)
    print(f"{name} CV RMSE: {rmse_scores.mean():.4f} ± {rmse_scores.std():.4f}")
```

```
Part 9: Cross-Validation
```

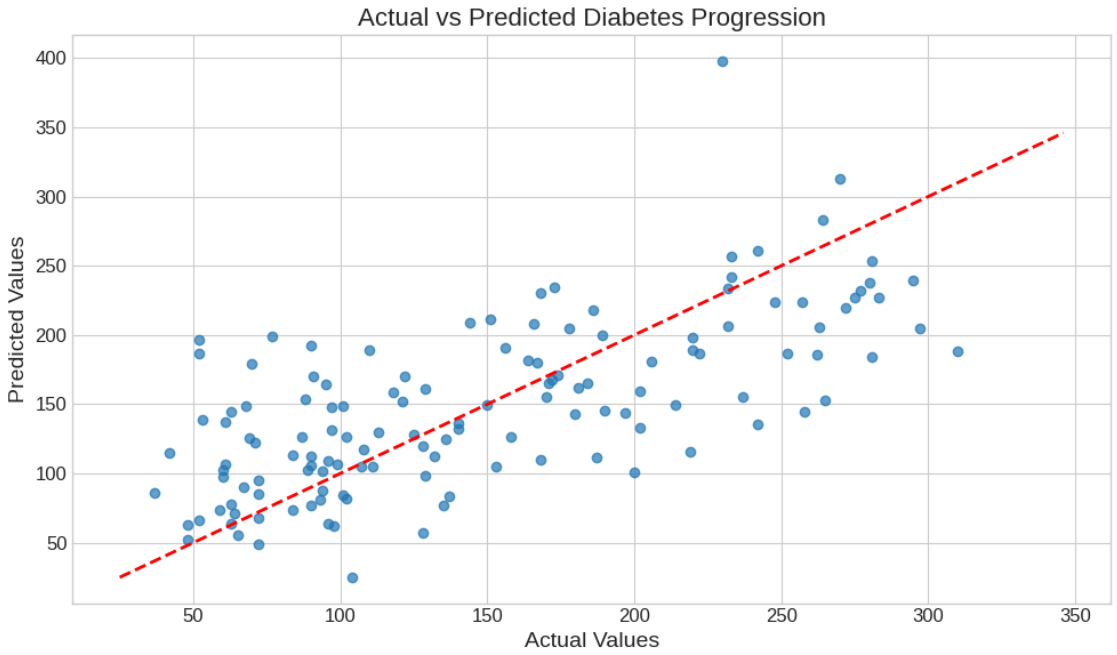
```
--------------------
Linear Regression CV RMSE: 0.7283 ± 0.0149
Ridge CV RMSE: 0.7282 ± 0.0149
Lasso CV RMSE: 0.8211 ± 0.0084
ElasticNet CV RMSE: 0.7935 ± 0.0094
```

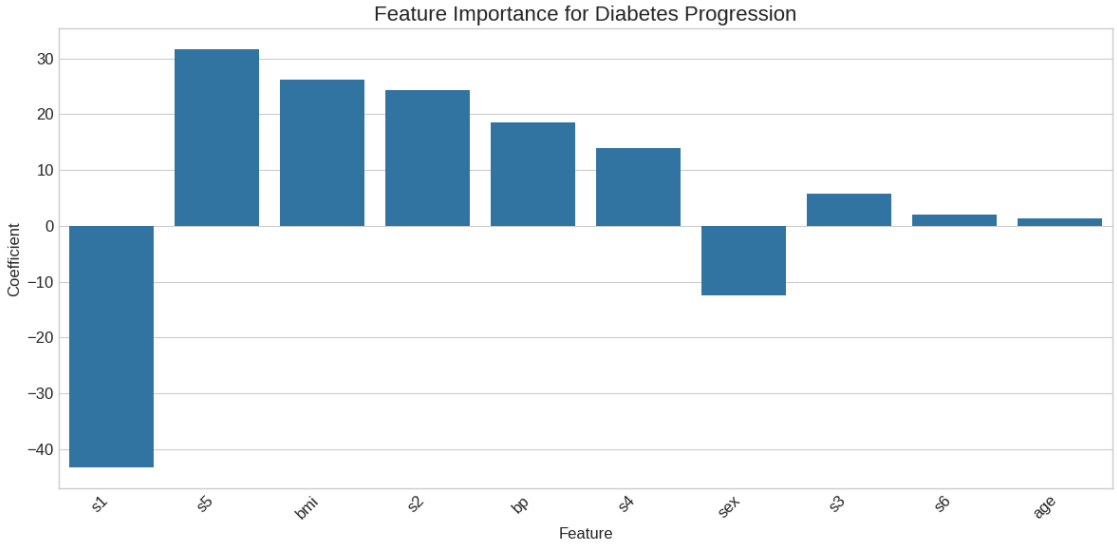
0.2 Case Study: Diabetes Dataset

[25]:
```python
print("\nPart 10: Case Study - Diabetes Dataset")
print("-----------------------------------")

# Load the diabetes dataset
diabetes = load_diabetes()
X_diabetes = diabetes.data
y_diabetes = diabetes.target
feature_names_diabetes = diabetes.feature_names

print(f"Dataset shape: {X_diabetes.shape}")
print(f"Feature names: {feature_names_diabetes}")

# Split the data
X_train_diabetes, X_test_diabetes, y_train_diabetes, y_test_diabetes =␣
 ↪train_test_split(
    X_diabetes, y_diabetes, test_size=0.3, random_state=42
)

# Create a pipeline with preprocessing and regularization
pipeline_diabetes = Pipeline([
    ('scaler', StandardScaler()),
    ('poly', PolynomialFeatures(degree=2, include_bias=False)),
    ('regression', Ridge(alpha=1.0))
])

# Train the model
pipeline_diabetes.fit(X_train_diabetes, y_train_diabetes)

# Make predictions
y_pred_diabetes = pipeline_diabetes.predict(X_test_diabetes)

# Evaluate the model
mse_diabetes = mean_squared_error(y_test_diabetes, y_pred_diabetes)
r2_diabetes = r2_score(y_test_diabetes, y_pred_diabetes)

print(f"Mean Squared Error: {mse_diabetes:.4f}")
print(f"R² Score: {r2_diabetes:.4f}")

# Visualize actual vs predicted values
```

```
plt.figure(figsize=(10, 6))
plt.scatter(y_test_diabetes, y_pred_diabetes, alpha=0.7)
plt.plot([y_diabetes.min(), y_diabetes.max()], [y_diabetes.min(), y_diabetes.
  ↪max()], 'r--', lw=2)
plt.xlabel('Actual Values', fontsize=14)
plt.ylabel('Predicted Values', fontsize=14)
plt.title('Actual vs Predicted Diabetes Progression', fontsize=16)
plt.tight_layout()
plt.show()

# Feature importance analysis
# Train a simpler model to get coefficients
lr_diabetes = Pipeline([
    ('scaler', StandardScaler()),
    ('regression', LinearRegression())
])
lr_diabetes.fit(X_train_diabetes, y_train_diabetes)

# Get coefficients
coefs_diabetes = lr_diabetes.named_steps['regression'].coef_
coefs_df_diabetes = pd.DataFrame({
    'Feature': feature_names_diabetes,
    'Coefficient': coefs_diabetes
})
coefs_df_diabetes = coefs_df_diabetes.reindex(
    coefs_df_diabetes['Coefficient'].abs().sort_values(ascending=False).index
)

plt.figure(figsize=(12, 6))
sns.barplot(x='Feature', y='Coefficient', data=coefs_df_diabetes)
plt.xticks(rotation=45, ha='right')
plt.title('Feature Importance for Diabetes Progression', fontsize=16)
plt.tight_layout()
plt.show()
```

```
Part 10: Case Study - Diabetes Dataset
----------------------------------
Dataset shape: (442, 10)
Feature names: ['age', 'sex', 'bmi', 'bp', 's1', 's2', 's3', 's4', 's5', 's6']
Mean Squared Error: 2995.2155
R² Score: 0.4452
```





[27]:
```
!sudo apt-get update
!sudo apt-get install texlive-xetex pandoc
```

```
Get:1 http://security.ubuntu.com/ubuntu jammy-security InRelease [129 kB]
Hit:2 http://archive.ubuntu.com/ubuntu jammy InRelease
Get:3 http://archive.ubuntu.com/ubuntu jammy-updates InRelease [128 kB]
Get:4 http://archive.ubuntu.com/ubuntu jammy-backports InRelease [127 kB]
```

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Get:5 https://cloud.r-project.org/bin/linux/ubuntu jammy-cran40/ InRelease
[3,632 B]
Get:6 https://developer.download.nvidia.com/compute/cuda/repos/ubuntu2204/x86_64
InRelease [1,581 B]
Get:7 https://r2u.stat.illinois.edu/ubuntu jammy InRelease [6,555 B]
Hit:8 https://ppa.launchpadcontent.net/deadsnakes/ppa/ubuntu jammy InRelease
Hit:9 https://ppa.launchpadcontent.net/graphics-drivers/ppa/ubuntu jammy
InRelease
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Packages [47.7 kB]
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[1,239 kB]
Get:14 http://security.ubuntu.com/ubuntu jammy-security/restricted amd64
Packages [3,892 kB]
Get:15 http://archive.ubuntu.com/ubuntu jammy-updates/universe amd64 Packages
[1,538 kB]
Get:16 http://archive.ubuntu.com/ubuntu jammy-updates/multiverse amd64 Packages
[55.7 kB]
Get:17 http://archive.ubuntu.com/ubuntu jammy-updates/restricted amd64 Packages
[4,049 kB]
Get:18 http://archive.ubuntu.com/ubuntu jammy-updates/main amd64 Packages [3,045
kB]
Get:19 http://archive.ubuntu.com/ubuntu jammy-backports/universe amd64 Packages
[35.2 kB]
Get:20
https://developer.download.nvidia.com/compute/cuda/repos/ubuntu2204/x86_64
Packages [1,381 kB]
Get:21 https://r2u.stat.illinois.edu/ubuntu jammy/main all Packages [8,788 kB]
Get:22 https://r2u.stat.illinois.edu/ubuntu jammy/main amd64 Packages [2,684 kB]
Fetched 29.9 MB in 4s (8,515 kB/s)
Reading package lists… Done
W: Skipping acquire of configured file 'main/source/Sources' as repository
'https://r2u.stat.illinois.edu/ubuntu jammy InRelease' does not seem to provide
it (sources.list entry misspelt?)
Reading package lists… Done
Building dependency tree… Done
Reading state information… Done
The following additional packages will be installed:
  dvisvgm fonts-droid-fallback fonts-lato fonts-lmodern fonts-noto-mono
  fonts-texgyre fonts-urw-base35 libapache-pom-java
  libcmark-gfm-extensions0.29.0.gfm.3 libcmark-gfm0.29.0.gfm.3
  libcommons-logging-java libcommons-parent-java libfontbox-java libfontenc1
  libgs9 libgs9-common libidn12 libijs-0.35 libjbig2dec0 libkpathsea6
  libpdfbox-java libptexenc1 libruby3.0 libsynctex2 libteckit0 libtexlua53
  libtexluajit2 libwoff1 libzzip-0-13 lmodern pandoc-data poppler-data
```

```
  preview-latex-style rake ruby ruby-net-telnet ruby-rubygems ruby-webrick
  ruby-xmlrpc ruby3.0 rubygems-integration t1utils teckit tex-common tex-gyre
  texlive-base texlive-binaries texlive-fonts-recommended texlive-latex-base
  texlive-latex-extra texlive-latex-recommended texlive-pictures
  texlive-plain-generic tipa xfonts-encodings xfonts-utils
Suggested packages:
  fonts-noto fonts-freefont-otf | fonts-freefont-ttf libavalon-framework-java
  libcommons-logging-java-doc libexcalibur-logkit-java liblog4j1.2-java
  texlive-luatex pandoc-citeproc context wkhtmltopdf librsvg2-bin groff ghc
  nodejs php python libjs-mathjax libjs-katex citation-style-language-styles
  poppler-utils ghostscript fonts-japanese-mincho | fonts-ipafont-mincho
  fonts-japanese-gothic | fonts-ipafont-gothic fonts-arphic-ukai
  fonts-arphic-uming fonts-nanum ri ruby-dev bundler debhelper gv
  | postscript-viewer perl-tk xpdf | pdf-viewer xzdec
  texlive-fonts-recommended-doc texlive-latex-base-doc python3-pygments
  icc-profiles libfile-which-perl libspreadsheet-parseexcel-perl
  texlive-latex-extra-doc texlive-latex-recommended-doc texlive-pstricks
  dot2tex prerex texlive-pictures-doc vprerex default-jre-headless tipa-doc
The following NEW packages will be installed:
  dvisvgm fonts-droid-fallback fonts-lato fonts-lmodern fonts-noto-mono
  fonts-texgyre fonts-urw-base35 libapache-pom-java
  libcmark-gfm-extensions0.29.0.gfm.3 libcmark-gfm0.29.0.gfm.3
  libcommons-logging-java libcommons-parent-java libfontbox-java libfontenc1
  libgs9 libgs9-common libidn12 libijs-0.35 libjbig2dec0 libkpathsea6
  libpdfbox-java libptexenc1 libruby3.0 libsynctex2 libteckit0 libtexlua53
  libtexluajit2 libwoff1 libzzip-0-13 lmodern pandoc pandoc-data poppler-data
  preview-latex-style rake ruby ruby-net-telnet ruby-rubygems ruby-webrick
  ruby-xmlrpc ruby3.0 rubygems-integration t1utils teckit tex-common tex-gyre
  texlive-base texlive-binaries texlive-fonts-recommended texlive-latex-base
  texlive-latex-extra texlive-latex-recommended texlive-pictures
  texlive-plain-generic texlive-xetex tipa xfonts-encodings xfonts-utils
0 upgraded, 58 newly installed, 0 to remove and 41 not upgraded.
Need to get 202 MB of archives.
After this operation, 728 MB of additional disk space will be used.
Get:1 http://archive.ubuntu.com/ubuntu jammy/main amd64 fonts-droid-fallback all
1:6.0.1r16-1.1build1 [1,805 kB]
Get:2 http://archive.ubuntu.com/ubuntu jammy/main amd64 fonts-lato all 2.0-2.1
[2,696 kB]
Get:3 http://archive.ubuntu.com/ubuntu jammy/main amd64 poppler-data all
0.4.11-1 [2,171 kB]
Get:4 http://archive.ubuntu.com/ubuntu jammy/universe amd64 tex-common all 6.17
[33.7 kB]
Get:5 http://archive.ubuntu.com/ubuntu jammy/main amd64 fonts-urw-base35 all
20200910-1 [6,367 kB]
Get:6 http://archive.ubuntu.com/ubuntu jammy-updates/main amd64 libgs9-common
all 9.55.0~dfsg1-0ubuntu5.11 [753 kB]
Get:7 http://archive.ubuntu.com/ubuntu jammy-updates/main amd64 libidn12 amd64
1.38-4ubuntu1 [60.0 kB]
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0.35-15build2 [16.5 kB]
Get:9 http://archive.ubuntu.com/ubuntu jammy/main amd64 libjbig2dec0 amd64
0.19-3build2 [64.7 kB]
Get:10 http://archive.ubuntu.com/ubuntu jammy-updates/main amd64 libgs9 amd64
9.55.0~dfsg1-0ubuntu5.11 [5,031 kB]
Get:11 http://archive.ubuntu.com/ubuntu jammy-updates/main amd64 libkpathsea6
amd64 2021.20210626.59705-1ubuntu0.2 [60.4 kB]
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1.0.2-1build4 [45.2 kB]
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2.13.1-1 [1,221 kB]
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2.004.5-6.1 [4,532 kB]
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20201225-1build1 [397 kB]
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20180621-3.1 [10.2 MB]
Get:17 http://archive.ubuntu.com/ubuntu jammy/universe amd64 libapache-pom-java
all 18-1 [4,720 B]
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gfm0.29.0.gfm.3 amd64 0.29.0.gfm.3-3 [115 kB]
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extensions0.29.0.gfm.3 amd64 0.29.0.gfm.3-3 [25.1 kB]
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java all 43-1 [10.8 kB]
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java all 1.2-2 [60.3 kB]
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1:1.1.4-1build3 [14.7 kB]
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amd64 2021.20210626.59705-1ubuntu0.2 [39.1 kB]
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all 1.18 [5,336 B]
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3.0.2-7ubuntu2.8 [50.1 kB]
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3.3.5-2 [228 kB]
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[5,100 B]
Get:28 http://archive.ubuntu.com/ubuntu jammy/main amd64 rake all 13.0.6-2 [61.7
kB]
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0.1.1-2 [12.6 kB]
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all 1.7.0-3ubuntu0.1 [52.1 kB]
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0.3.2-1ubuntu0.1 [24.9 kB]
```

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Get:32 http://archive.ubuntu.com/ubuntu jammy-updates/main amd64 libruby3.0
amd64 3.0.2-7ubuntu2.8 [5,113 kB]
Get:33 http://archive.ubuntu.com/ubuntu jammy-updates/main amd64 libsynctex2
amd64 2021.20210626.59705-1ubuntu0.2 [55.6 kB]
Get:34 http://archive.ubuntu.com/ubuntu jammy/universe amd64 libteckit0 amd64
2.5.11+ds1-1 [421 kB]
Get:35 http://archive.ubuntu.com/ubuntu jammy-updates/main amd64 libtexlua53
amd64 2021.20210626.59705-1ubuntu0.2 [120 kB]
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amd64 2021.20210626.59705-1ubuntu0.2 [267 kB]
Get:37 http://archive.ubuntu.com/ubuntu jammy/universe amd64 libzzip-0-13 amd64
0.13.72+dfsg.1-1.1 [27.0 kB]
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1:1.0.5-0ubuntu2 [578 kB]
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1:7.7+6build2 [94.6 kB]
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2.004.5-6.1 [9,471 kB]
Get:41 http://archive.ubuntu.com/ubuntu jammy/universe amd64 pandoc-data all
2.9.2.1-3ubuntu2 [81.8 kB]
Get:42 http://archive.ubuntu.com/ubuntu jammy/universe amd64 pandoc amd64
2.9.2.1-3ubuntu2 [20.3 MB]
Get:43 http://archive.ubuntu.com/ubuntu jammy/universe amd64 preview-latex-style
all 12.2-1ubuntu1 [185 kB]
Get:44 http://archive.ubuntu.com/ubuntu jammy/main amd64 t1utils amd64
1.41-4build2 [61.3 kB]
Get:45 http://archive.ubuntu.com/ubuntu jammy/universe amd64 teckit amd64
2.5.11+ds1-1 [699 kB]
Get:46 http://archive.ubuntu.com/ubuntu jammy/universe amd64 tex-gyre all
20180621-3.1 [6,209 kB]
Get:47 http://archive.ubuntu.com/ubuntu jammy-updates/universe amd64 texlive-
binaries amd64 2021.20210626.59705-1ubuntu0.2 [9,860 kB]
Get:48 http://archive.ubuntu.com/ubuntu jammy/universe amd64 texlive-base all
2021.20220204-1 [21.0 MB]
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recommended all 2021.20220204-1 [4,972 kB]
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all 2021.20220204-1 [1,128 kB]
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1:1.8.16-2 [207 kB]
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1:1.8.16-2 [5,199 kB]
Get:53 http://archive.ubuntu.com/ubuntu jammy/universe amd64 texlive-latex-
recommended all 2021.20220204-1 [14.4 MB]
Get:54 http://archive.ubuntu.com/ubuntu jammy/universe amd64 texlive-pictures
all 2021.20220204-1 [8,720 kB]
Get:55 http://archive.ubuntu.com/ubuntu jammy/universe amd64 texlive-latex-extra
all 2021.20220204-1 [13.9 MB]
```

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Get:56 http://archive.ubuntu.com/ubuntu jammy/universe amd64 texlive-plain-
generic all 2021.20220204-1 [27.5 MB]
Get:57 http://archive.ubuntu.com/ubuntu jammy/universe amd64 tipa all 2:1.3-21
[2,967 kB]
Get:58 http://archive.ubuntu.com/ubuntu jammy/universe amd64 texlive-xetex all
2021.20220204-1 [12.4 MB]
Fetched 202 MB in 3s (65.6 MB/s)
debconf: unable to initialize frontend: Dialog
debconf: (No usable dialog-like program is installed, so the dialog based
frontend cannot be used. at /usr/share/perl5/Debconf/FrontEnd/Dialog.pm line 78,
<> line 58.)
debconf: falling back to frontend: Readline
debconf: unable to initialize frontend: Readline
debconf: (This frontend requires a controlling tty.)
debconf: falling back to frontend: Teletype
dpkg-preconfigure: unable to re-open stdin:
Selecting previously unselected package fonts-droid-fallback.
(Reading database … 126209 files and directories currently installed.)
Preparing to unpack …/00-fonts-droid-fallback_1%3a6.0.1r16-1.1build1_all.deb
…
Unpacking fonts-droid-fallback (1:6.0.1r16-1.1build1) …
Selecting previously unselected package fonts-lato.
Preparing to unpack …/01-fonts-lato_2.0-2.1_all.deb …
Unpacking fonts-lato (2.0-2.1) …
Selecting previously unselected package poppler-data.
Preparing to unpack …/02-poppler-data_0.4.11-1_all.deb …
Unpacking poppler-data (0.4.11-1) …
Selecting previously unselected package tex-common.
Preparing to unpack …/03-tex-common_6.17_all.deb …
Unpacking tex-common (6.17) …
Selecting previously unselected package fonts-urw-base35.
Preparing to unpack …/04-fonts-urw-base35_20200910-1_all.deb …
Unpacking fonts-urw-base35 (20200910-1) …
Selecting previously unselected package libgs9-common.
Preparing to unpack …/05-libgs9-common_9.55.0~dfsg1-0ubuntu5.11_all.deb …
Unpacking libgs9-common (9.55.0~dfsg1-0ubuntu5.11) …
Selecting previously unselected package libidn12:amd64.
Preparing to unpack …/06-libidn12_1.38-4ubuntu1_amd64.deb …
Unpacking libidn12:amd64 (1.38-4ubuntu1) …
Selecting previously unselected package libijs-0.35:amd64.
Preparing to unpack …/07-libijs-0.35_0.35-15build2_amd64.deb …
Unpacking libijs-0.35:amd64 (0.35-15build2) …
Selecting previously unselected package libjbig2dec0:amd64.
Preparing to unpack …/08-libjbig2dec0_0.19-3build2_amd64.deb …
Unpacking libjbig2dec0:amd64 (0.19-3build2) …
Selecting previously unselected package libgs9:amd64.
Preparing to unpack …/09-libgs9_9.55.0~dfsg1-0ubuntu5.11_amd64.deb …
Unpacking libgs9:amd64 (9.55.0~dfsg1-0ubuntu5.11) …
```

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Selecting previously unselected package libkpathsea6:amd64.
Preparing to unpack …/10-libkpathsea6_2021.20210626.59705-1ubuntu0.2_amd64.deb
…
Unpacking libkpathsea6:amd64 (2021.20210626.59705-1ubuntu0.2) …
Selecting previously unselected package libwoff1:amd64.
Preparing to unpack …/11-libwoff1_1.0.2-1build4_amd64.deb …
Unpacking libwoff1:amd64 (1.0.2-1build4) …
Selecting previously unselected package dvisvgm.
Preparing to unpack …/12-dvisvgm_2.13.1-1_amd64.deb …
Unpacking dvisvgm (2.13.1-1) …
Selecting previously unselected package fonts-lmodern.
Preparing to unpack …/13-fonts-lmodern_2.004.5-6.1_all.deb …
Unpacking fonts-lmodern (2.004.5-6.1) …
Selecting previously unselected package fonts-noto-mono.
Preparing to unpack …/14-fonts-noto-mono_20201225-1build1_all.deb …
Unpacking fonts-noto-mono (20201225-1build1) …
Selecting previously unselected package fonts-texgyre.
Preparing to unpack …/15-fonts-texgyre_20180621-3.1_all.deb …
Unpacking fonts-texgyre (20180621-3.1) …
Selecting previously unselected package libapache-pom-java.
Preparing to unpack …/16-libapache-pom-java_18-1_all.deb …
Unpacking libapache-pom-java (18-1) …
Selecting previously unselected package libcmark-gfm0.29.0.gfm.3:amd64.
Preparing to unpack …/17-libcmark-gfm0.29.0.gfm.3_0.29.0.gfm.3-3_amd64.deb …
Unpacking libcmark-gfm0.29.0.gfm.3:amd64 (0.29.0.gfm.3-3) …
Selecting previously unselected package libcmark-gfm-
extensions0.29.0.gfm.3:amd64.
Preparing to unpack …/18-libcmark-gfm-
extensions0.29.0.gfm.3_0.29.0.gfm.3-3_amd64.deb …
Unpacking libcmark-gfm-extensions0.29.0.gfm.3:amd64 (0.29.0.gfm.3-3) …
Selecting previously unselected package libcommons-parent-java.
Preparing to unpack …/19-libcommons-parent-java_43-1_all.deb …
Unpacking libcommons-parent-java (43-1) …
Selecting previously unselected package libcommons-logging-java.
Preparing to unpack …/20-libcommons-logging-java_1.2-2_all.deb …
Unpacking libcommons-logging-java (1.2-2) …
Selecting previously unselected package libfontenc1:amd64.
Preparing to unpack …/21-libfontenc1_1%3a1.1.4-1build3_amd64.deb …
Unpacking libfontenc1:amd64 (1:1.1.4-1build3) …
Selecting previously unselected package libptexenc1:amd64.
Preparing to unpack …/22-libptexenc1_2021.20210626.59705-1ubuntu0.2_amd64.deb
…
Unpacking libptexenc1:amd64 (2021.20210626.59705-1ubuntu0.2) …
Selecting previously unselected package rubygems-integration.
Preparing to unpack …/23-rubygems-integration_1.18_all.deb …
Unpacking rubygems-integration (1.18) …
Selecting previously unselected package ruby3.0.
Preparing to unpack …/24-ruby3.0_3.0.2-7ubuntu2.8_amd64.deb …
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Unpacking ruby3.0 (3.0.2-7ubuntu2.8) …
Selecting previously unselected package ruby-rubygems.
Preparing to unpack …/25-ruby-rubygems_3.3.5-2_all.deb …
Unpacking ruby-rubygems (3.3.5-2) …
Selecting previously unselected package ruby.
Preparing to unpack …/26-ruby_1%3a3.0~exp1_amd64.deb …
Unpacking ruby (1:3.0~exp1) …
Selecting previously unselected package rake.
Preparing to unpack …/27-rake_13.0.6-2_all.deb …
Unpacking rake (13.0.6-2) …
Selecting previously unselected package ruby-net-telnet.
Preparing to unpack …/28-ruby-net-telnet_0.1.1-2_all.deb …
Unpacking ruby-net-telnet (0.1.1-2) …
Selecting previously unselected package ruby-webrick.
Preparing to unpack …/29-ruby-webrick_1.7.0-3ubuntu0.1_all.deb …
Unpacking ruby-webrick (1.7.0-3ubuntu0.1) …
Selecting previously unselected package ruby-xmlrpc.
Preparing to unpack …/30-ruby-xmlrpc_0.3.2-1ubuntu0.1_all.deb …
Unpacking ruby-xmlrpc (0.3.2-1ubuntu0.1) …
Selecting previously unselected package libruby3.0:amd64.
Preparing to unpack …/31-libruby3.0_3.0.2-7ubuntu2.8_amd64.deb …
Unpacking libruby3.0:amd64 (3.0.2-7ubuntu2.8) …
Selecting previously unselected package libsynctex2:amd64.
Preparing to unpack …/32-libsynctex2_2021.20210626.59705-1ubuntu0.2_amd64.deb
…
Unpacking libsynctex2:amd64 (2021.20210626.59705-1ubuntu0.2) …
Selecting previously unselected package libteckit0:amd64.
Preparing to unpack …/33-libteckit0_2.5.11+ds1-1_amd64.deb …
Unpacking libteckit0:amd64 (2.5.11+ds1-1) …
Selecting previously unselected package libtexlua53:amd64.
Preparing to unpack …/34-libtexlua53_2021.20210626.59705-1ubuntu0.2_amd64.deb
…
Unpacking libtexlua53:amd64 (2021.20210626.59705-1ubuntu0.2) …
Selecting previously unselected package libtexluajit2:amd64.
Preparing to unpack
…/35-libtexluajit2_2021.20210626.59705-1ubuntu0.2_amd64.deb …
Unpacking libtexluajit2:amd64 (2021.20210626.59705-1ubuntu0.2) …
Selecting previously unselected package libzzip-0-13:amd64.
Preparing to unpack …/36-libzzip-0-13_0.13.72+dfsg.1-1.1_amd64.deb …
Unpacking libzzip-0-13:amd64 (0.13.72+dfsg.1-1.1) …
Selecting previously unselected package xfonts-encodings.
Preparing to unpack …/37-xfonts-encodings_1%3a1.0.5-0ubuntu2_all.deb …
Unpacking xfonts-encodings (1:1.0.5-0ubuntu2) …
Selecting previously unselected package xfonts-utils.
Preparing to unpack …/38-xfonts-utils_1%3a7.7+6build2_amd64.deb …
Unpacking xfonts-utils (1:7.7+6build2) …
Selecting previously unselected package lmodern.
Preparing to unpack …/39-lmodern_2.004.5-6.1_all.deb …
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Unpacking lmodern (2.004.5-6.1) …
Selecting previously unselected package pandoc-data.
Preparing to unpack …/40-pandoc-data_2.9.2.1-3ubuntu2_all.deb …
Unpacking pandoc-data (2.9.2.1-3ubuntu2) …
Selecting previously unselected package pandoc.
Preparing to unpack …/41-pandoc_2.9.2.1-3ubuntu2_amd64.deb …
Unpacking pandoc (2.9.2.1-3ubuntu2) …
Selecting previously unselected package preview-latex-style.
Preparing to unpack …/42-preview-latex-style_12.2-1ubuntu1_all.deb …
Unpacking preview-latex-style (12.2-1ubuntu1) …
Selecting previously unselected package t1utils.
Preparing to unpack …/43-t1utils_1.41-4build2_amd64.deb …
Unpacking t1utils (1.41-4build2) …
Selecting previously unselected package teckit.
Preparing to unpack …/44-teckit_2.5.11+ds1-1_amd64.deb …
Unpacking teckit (2.5.11+ds1-1) …
Selecting previously unselected package tex-gyre.
Preparing to unpack …/45-tex-gyre_20180621-3.1_all.deb …
Unpacking tex-gyre (20180621-3.1) …
Selecting previously unselected package texlive-binaries.
Preparing to unpack …/46-texlive-
binaries_2021.20210626.59705-1ubuntu0.2_amd64.deb …
Unpacking texlive-binaries (2021.20210626.59705-1ubuntu0.2) …
Selecting previously unselected package texlive-base.
Preparing to unpack …/47-texlive-base_2021.20220204-1_all.deb …
Unpacking texlive-base (2021.20220204-1) …
Selecting previously unselected package texlive-fonts-recommended.
Preparing to unpack …/48-texlive-fonts-recommended_2021.20220204-1_all.deb …
Unpacking texlive-fonts-recommended (2021.20220204-1) …
Selecting previously unselected package texlive-latex-base.
Preparing to unpack …/49-texlive-latex-base_2021.20220204-1_all.deb …
Unpacking texlive-latex-base (2021.20220204-1) …
Selecting previously unselected package libfontbox-java.
Preparing to unpack …/50-libfontbox-java_1%3a1.8.16-2_all.deb …
Unpacking libfontbox-java (1:1.8.16-2) …
Selecting previously unselected package libpdfbox-java.
Preparing to unpack …/51-libpdfbox-java_1%3a1.8.16-2_all.deb …
Unpacking libpdfbox-java (1:1.8.16-2) …
Selecting previously unselected package texlive-latex-recommended.
Preparing to unpack …/52-texlive-latex-recommended_2021.20220204-1_all.deb …
Unpacking texlive-latex-recommended (2021.20220204-1) …
Selecting previously unselected package texlive-pictures.
Preparing to unpack …/53-texlive-pictures_2021.20220204-1_all.deb …
Unpacking texlive-pictures (2021.20220204-1) …
Selecting previously unselected package texlive-latex-extra.
Preparing to unpack …/54-texlive-latex-extra_2021.20220204-1_all.deb …
Unpacking texlive-latex-extra (2021.20220204-1) …
Selecting previously unselected package texlive-plain-generic.
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Preparing to unpack …/55-texlive-plain-generic_2021.20220204-1_all.deb …
Unpacking texlive-plain-generic (2021.20220204-1) …
Selecting previously unselected package tipa.
Preparing to unpack …/56-tipa_2%3a1.3-21_all.deb …
Unpacking tipa (2:1.3-21) …
Selecting previously unselected package texlive-xetex.
Preparing to unpack …/57-texlive-xetex_2021.20220204-1_all.deb …
Unpacking texlive-xetex (2021.20220204-1) …
Setting up fonts-lato (2.0-2.1) …
Setting up fonts-noto-mono (20201225-1build1) …
Setting up libwoff1:amd64 (1.0.2-1build4) …
Setting up libtexlua53:amd64 (2021.20210626.59705-1ubuntu0.2) …
Setting up libijs-0.35:amd64 (0.35-15build2) …
Setting up libtexluajit2:amd64 (2021.20210626.59705-1ubuntu0.2) …
Setting up libfontbox-java (1:1.8.16-2) …
Setting up rubygems-integration (1.18) …
Setting up libzzip-0-13:amd64 (0.13.72+dfsg.1-1.1) …
Setting up fonts-urw-base35 (20200910-1) …
Setting up poppler-data (0.4.11-1) …
Setting up tex-common (6.17) …
debconf: unable to initialize frontend: Dialog
debconf: (No usable dialog-like program is installed, so the dialog based
frontend cannot be used. at /usr/share/perl5/Debconf/FrontEnd/Dialog.pm line
78.)
debconf: falling back to frontend: Readline
update-language: texlive-base not installed and configured, doing nothing!
Setting up libfontenc1:amd64 (1:1.1.4-1build3) …
Setting up libjbig2dec0:amd64 (0.19-3build2) …
Setting up libteckit0:amd64 (2.5.11+ds1-1) …
Setting up libapache-pom-java (18-1) …
Setting up ruby-net-telnet (0.1.1-2) …
Setting up xfonts-encodings (1:1.0.5-0ubuntu2) …
Setting up t1utils (1.41-4build2) …
Setting up libidn12:amd64 (1.38-4ubuntu1) …
Setting up fonts-texgyre (20180621-3.1) …
Setting up libkpathsea6:amd64 (2021.20210626.59705-1ubuntu0.2) …
Setting up ruby-webrick (1.7.0-3ubuntu0.1) …
Setting up libcmark-gfm0.29.0.gfm.3:amd64 (0.29.0.gfm.3-3) …
Setting up fonts-lmodern (2.004.5-6.1) …
Setting up libcmark-gfm-extensions0.29.0.gfm.3:amd64 (0.29.0.gfm.3-3) …
Setting up fonts-droid-fallback (1:6.0.1r16-1.1build1) …
Setting up pandoc-data (2.9.2.1-3ubuntu2) …
Setting up ruby-xmlrpc (0.3.2-1ubuntu0.1) …
Setting up libsynctex2:amd64 (2021.20210626.59705-1ubuntu0.2) …
Setting up libgs9-common (9.55.0~dfsg1-0ubuntu5.11) …
Setting up teckit (2.5.11+ds1-1) …
Setting up libpdfbox-java (1:1.8.16-2) …
Setting up libgs9:amd64 (9.55.0~dfsg1-0ubuntu5.11) …
```

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Setting up preview-latex-style (12.2-1ubuntu1) …
Setting up libcommons-parent-java (43-1) …
Setting up dvisvgm (2.13.1-1) …
Setting up libcommons-logging-java (1.2-2) …
Setting up xfonts-utils (1:7.7+6build2) …
Setting up libptexenc1:amd64 (2021.20210626.59705-1ubuntu0.2) …
Setting up pandoc (2.9.2.1-3ubuntu2) …
Setting up texlive-binaries (2021.20210626.59705-1ubuntu0.2) …
update-alternatives: using /usr/bin/xdvi-xaw to provide /usr/bin/xdvi.bin
(xdvi.bin) in auto mode
update-alternatives: using /usr/bin/bibtex.original to provide /usr/bin/bibtex
(bibtex) in auto mode
Setting up lmodern (2.004.5-6.1) …
Setting up texlive-base (2021.20220204-1) …
/usr/bin/ucfr
/usr/bin/ucfr
/usr/bin/ucfr
/usr/bin/ucfr
mktexlsr: Updating /var/lib/texmf/ls-R-TEXLIVEDIST…
mktexlsr: Updating /var/lib/texmf/ls-R-TEXMFMAIN…
mktexlsr: Updating /var/lib/texmf/ls-R…
mktexlsr: Done.
tl-paper: setting paper size for dvips to a4:
/var/lib/texmf/dvips/config/config-paper.ps
tl-paper: setting paper size for dvipdfmx to a4:
/var/lib/texmf/dvipdfmx/dvipdfmx-paper.cfg
tl-paper: setting paper size for xdvi to a4: /var/lib/texmf/xdvi/XDvi-paper
tl-paper: setting paper size for pdftex to a4: /var/lib/texmf/tex/generic/tex-
ini-files/pdftexconfig.tex
debconf: unable to initialize frontend: Dialog
debconf: (No usable dialog-like program is installed, so the dialog based
frontend cannot be used. at /usr/share/perl5/Debconf/FrontEnd/Dialog.pm line
78.)
debconf: falling back to frontend: Readline
Setting up tex-gyre (20180621-3.1) …
Setting up texlive-plain-generic (2021.20220204-1) …
Setting up texlive-latex-base (2021.20220204-1) …
Setting up texlive-latex-recommended (2021.20220204-1) …
Setting up texlive-pictures (2021.20220204-1) …
Setting up texlive-fonts-recommended (2021.20220204-1) …
Setting up tipa (2:1.3-21) …
Setting up texlive-latex-extra (2021.20220204-1) …
Setting up texlive-xetex (2021.20220204-1) …
Setting up rake (13.0.6-2) …
Setting up libruby3.0:amd64 (3.0.2-7ubuntu2.8) …
Setting up ruby3.0 (3.0.2-7ubuntu2.8) …
Setting up ruby (1:3.0~exp1) …
Setting up ruby-rubygems (3.3.5-2) …
```

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Processing triggers for man-db (2.10.2-1) …
Processing triggers for mailcap (3.70+nmu1ubuntu1) …
Processing triggers for fontconfig (2.13.1-4.2ubuntu5) …
Processing triggers for libc-bin (2.35-0ubuntu3.8) …
/sbin/ldconfig.real: /usr/local/lib/libhwloc.so.15 is not a symbolic link

/sbin/ldconfig.real: /usr/local/lib/libtcm.so.1 is not a symbolic link

/sbin/ldconfig.real: /usr/local/lib/libtbbmalloc_proxy.so.2 is not a symbolic
link

/sbin/ldconfig.real: /usr/local/lib/libtbbbind_2_0.so.3 is not a symbolic link

/sbin/ldconfig.real: /usr/local/lib/libtbbmalloc.so.2 is not a symbolic link

/sbin/ldconfig.real: /usr/local/lib/libtbb.so.12 is not a symbolic link

/sbin/ldconfig.real: /usr/local/lib/libur_adapter_opencl.so.0 is not a symbolic
link

/sbin/ldconfig.real: /usr/local/lib/libtbbbind.so.3 is not a symbolic link

/sbin/ldconfig.real: /usr/local/lib/libtcm_debug.so.1 is not a symbolic link

/sbin/ldconfig.real: /usr/local/lib/libur_adapter_level_zero.so.0 is not a
symbolic link

/sbin/ldconfig.real: /usr/local/lib/libur_loader.so.0 is not a symbolic link

/sbin/ldconfig.real: /usr/local/lib/libumf.so.0 is not a symbolic link

/sbin/ldconfig.real: /usr/local/lib/libtbbbind_2_5.so.3 is not a symbolic link

Processing triggers for tex-common (6.17) …
debconf: unable to initialize frontend: Dialog
debconf: (No usable dialog-like program is installed, so the dialog based
frontend cannot be used. at /usr/share/perl5/Debconf/FrontEnd/Dialog.pm line
78.)
debconf: falling back to frontend: Readline
Running updmap-sys. This may take some time… done.
Running mktexlsr /var/lib/texmf … done.
Building format(s) --all.
        This may take some time… done.
```

[ ]:
```
!jupyter nbconvert --to pdf "/content/drive/MyDrive/Colab_Notebooks/
↪Machine_Learning/2.Logistic_Regression_Scikit-Learn.ipynb"
```