

Lab - 2 Assignment: Linear Regression

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Objective

The main objective of this assignment is to understand the complete Machine Learning (ML) pipeline by applying it step-by-step to a Linear Regression problem.

We perform two tasks:

1. Simple Linear Regression (Single Feature)
2. Multiple Linear Regression (All Features)

Related Theory

Linear Regression

Linear Regression is a supervised learning algorithm used to predict a continuous target variable based on one or more input features. It finds a **linear relationship** between the features and the target.

- **Simple Linear Regression (SLR):** Uses one input feature to predict the target.

Equation: $y = b_0 + b_1x$

- b_0 : intercept
- b_1 : slope
- The model minimizes the difference between predicted and actual values using **Mean Squared Error (MSE)**.

- **Multiple Linear Regression (MLR):** Uses two or more features to predict the target.

Equation: $y = b_0 + b_1x_1 + b_2x_2 + \dots + b_nx_n$

Each coefficient shows the effect of that feature on the target while keeping other features constant.

Key Idea: Linear regression provides a simple and interpretable model to predict continuous outcomes and understand the influence of features.

Task 1: Simple Linear Regression (Single Feature)

1. Data Retrieval and Collection

In this step, the dataset `housing.csv` is loaded for analysis. This dataset contains various housing related features. After loading the data, its shape, column names and sample records are examined to understand the structure and available variables. This step ensures that the dataset is correctly imported and ready for processing.

```
In [1]: #import dependencies
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
```

```
In [2]: #Load Dataset
df = pd.read_csv('housing.csv')
```

```
In [3]: #Display no. of rows and columns
print('Shape:', df.shape)
```

Shape: (20640, 10)

```
In [4]: #Display column names
print('Columns:', df.columns)
```

```
Columns: Index(['longitude', 'latitude', 'housing_median_age', 'total_rooms',
       'total_bedrooms', 'population', 'households', 'median_income',
       'median_house_value', 'ocean_proximity'],
      dtype='str')
```

```
In [5]: #Display top 5 rows  
df.head()
```

```
Out[5]:
```

	longitude	latitude	housing_median_age	total_rooms	total_bedrooms	population	households	median_income	median_house_value
0	-122.23	37.88	41.0	880.0	129.0	322.0	126.0	8.3252	452600.0
1	-122.22	37.86	21.0	7099.0	1106.0	2401.0	1138.0	8.3014	358500.0
2	-122.24	37.85	52.0	1467.0	190.0	496.0	177.0	7.2574	352100.0
3	-122.25	37.85	52.0	1274.0	235.0	558.0	219.0	5.6431	341300.0
4	-122.25	37.85	52.0	1627.0	280.0	565.0	259.0	3.8462	342200.0

2. Data Cleaning

The dataset is checked for missing values and correct data types which ensures that it is suitable for model training. Clean data helps avoid errors during training and improves reliability of the model.

```
In [6]: # Check for missing values  
print(df.isnull().sum())  
  
# Drop rows with missing values  
df = df.dropna()
```

```
longitude          0  
latitude          0  
housing_median_age 0  
total_rooms        0  
total_bedrooms    207  
population         0  
households         0  
median_income      0  
median_house_value 0  
ocean_proximity    0  
dtype: int64
```

```
In [7]: # Verify data types  
df.dtypes
```

```
Out[7]: longitude      float64  
latitude        float64  
housing_median_age  float64  
total_rooms      float64  
total_bedrooms    float64  
population       float64  
households        float64  
median_income     float64  
median_house_value float64  
ocean_proximity   str  
dtype: object
```

3. Feature Design

Only one of the input variable, `housing_median_age` is selected as the independent variable, while `median_house_value` is taken as the target variable.

```
In [8]: X_simple = df[['housing_median_age']]  
y = df['median_house_value']  
  
X_simple.head(), y.head()
```

```
Out[8]: (    housing_median_age  
0              41.0  
1              21.0  
2              52.0  
3              52.0  
4              52.0,  
0    452600.0  
1    358500.0  
2    352100.0  
3    341300.0  
4    342200.0  
Name: median_house_value, dtype: float64)
```

4. Algorithm Selection

We select **Linear Regression**, as the goal is to predict a continuous numerical value, namely the median house value. Linear regression is suitable because it models the relationship between input features and the target variable between input features and the target variable using a linear equation.

```
In [9]: from sklearn.linear_model import LinearRegression  
  
# Initialize Linear Regression model  
model = LinearRegression()
```

5. Loss Function Selection

Mean Squared Error(MSE) is chosen as the loss function to evaluate model performance which measures the average of the squared differences between the predicted and actual values.

6. Model Learning (Training)

The data is split into a training set and a testing set. The linear regression model is fit to the training data, where the model learns the best fit straight line, that is, the slope and intercept values that minimize the loss function.

```
In [10]: from sklearn.model_selection import train_test_split  
  
X_train, X_test, y_train, y_test = train_test_split(  
    X_simple, y, test_size=0.2, random_state=42)  
  
#Train the model  
model.fit(X_train, y_train)
```

Out[10]:

```
▼ LinearRegression ⓘ ⓘ  
► Parameters
```

7. Model Evaluation

Evaluation of the trained model is carried out using the test data. Metrics such as Mean Squared Error (MSE) and R² score are used to measure the accuracy of the predictions made by the model.

```
In [11]: from sklearn.metrics import mean_squared_error, r2_score

y_pred = model.predict(X_test)
print('MSE:', mean_squared_error(y_test, y_pred))
print('R2:', r2_score(y_test, y_pred))

MSE: 13495246619.234802
R2: 0.013157717592842233
```

Model Interpretation

The coefficient represents the change in median house value for a one-unit increase in housing median age. The intercept represents the predicted house value when the housing median age is zero.

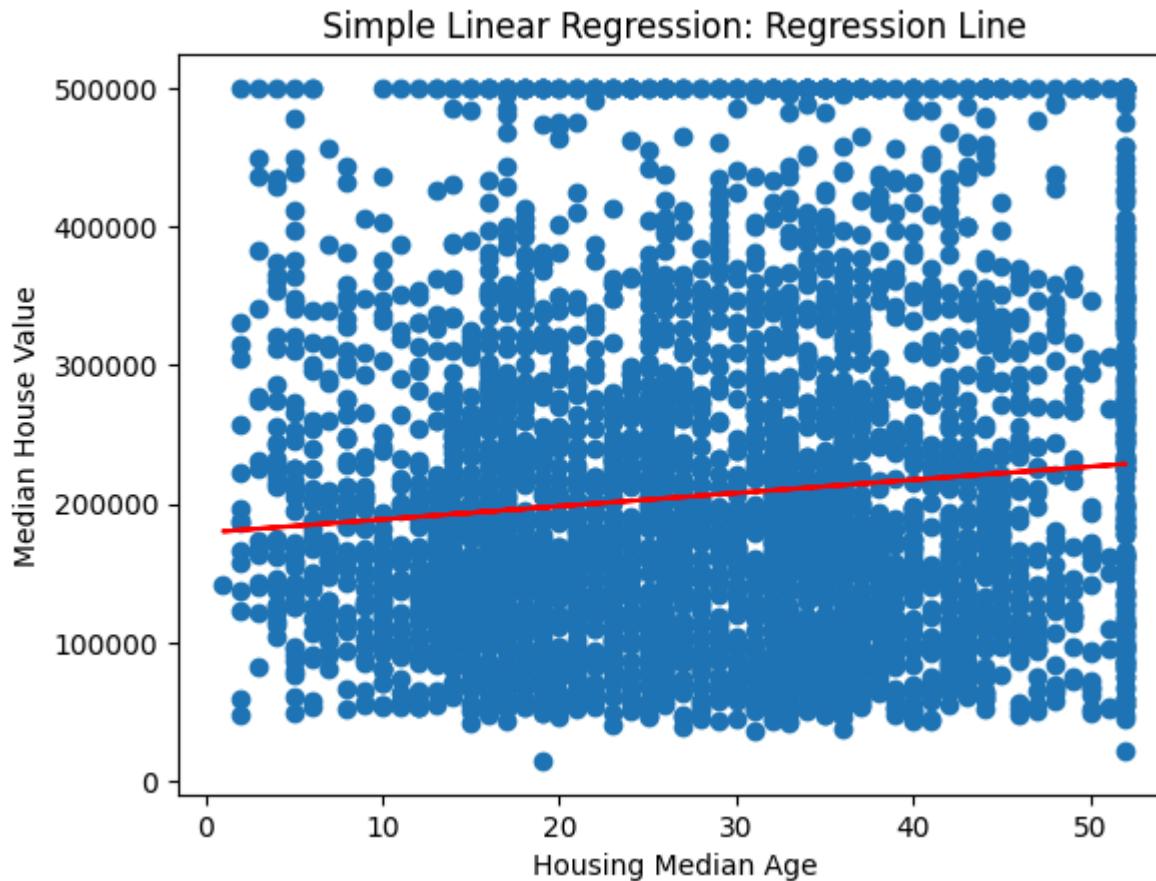
```
In [12]: print('Coefficient:', model.coef_[0])
print('Intercept:', model.intercept_)

Coefficient: 951.7605822368147
Intercept: 179409.75880973757
```

Visualization of Regression Line

This plot shows the relationship between housing median age and median house value along with the fitted regression line.

```
In [13]: plt.scatter(X_test, y_test)
plt.plot(X_test, y_pred, color='red')
plt.xlabel('Housing Median Age')
plt.ylabel('Median House Value')
plt.title("Simple Linear Regression: Regression Line")
plt.show()
```

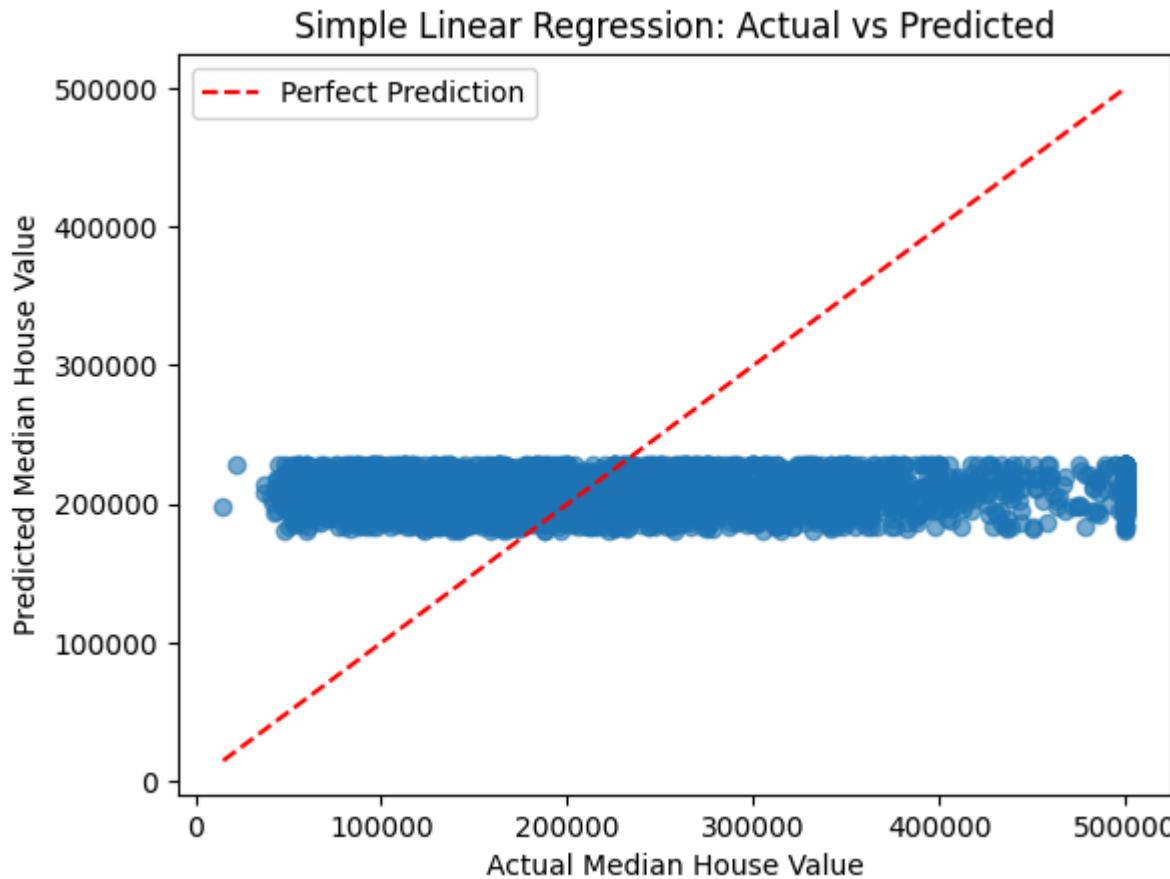


Visualization of Actual vs Predicted Values

This plot compares the actual median house values (`y_test`) against the predicted values (`y_pred`). The red diagonal line represents perfect prediction, where actual = predicted. Points close to the line indicate accurate predictions.

```
In [14]: plt.scatter(y_test, y_pred, alpha=0.6)
plt.plot([y_test.min(), y_test.max()],
         [y_test.min(), y_test.max()], color='red', linestyle='--', label="Perfect Prediction")
plt.xlabel("Actual Median House Value")
plt.ylabel("Predicted Median House Value")
plt.title("Simple Linear Regression: Actual vs Predicted")
```

```
plt.legend()  
plt.show()
```



Task 2: Multiple Linear Regression (All Features)

1. Data Retrieval and Collection

```
In [15]: import pandas as pd
```

```
# Load dataset
df = pd.read_csv("housing.csv")

# Display basic information
df.shape, df.columns, df.head()
```

```
Out[15]: ((20640, 10),
Index(['longitude', 'latitude', 'housing_median_age', 'total_rooms',
       'total_bedrooms', 'population', 'households', 'median_income',
       'median_house_value', 'ocean_proximity'],
      dtype='str'),
   longitude  latitude  housing_median_age  total_rooms  total_bedrooms \
0     -122.23    37.88           41.0        880.0         129.0
1     -122.22    37.86           21.0       7099.0        1106.0
2     -122.24    37.85           52.0       1467.0         190.0
3     -122.25    37.85           52.0       1274.0        235.0
4     -122.25    37.85           52.0       1627.0        280.0

   population  households  median_income  median_house_value ocean_proximity
0        322.0       126.0       8.3252        452600.0    NEAR BAY
1      2401.0      1138.0       8.3014        358500.0    NEAR BAY
2        496.0       177.0       7.2574        352100.0    NEAR BAY
3        558.0       219.0       5.6431        341300.0    NEAR BAY
4        565.0       259.0       3.8462        342200.0    NEAR BAY )
```

2. Data Cleaning

```
In [16]: # Check for missing values
print(df.isnull().sum())
```

```
longitude          0
latitude          0
housing_median_age 0
total_rooms        0
total_bedrooms     207
population         0
households         0
median_income      0
median_house_value 0
ocean_proximity    0
dtype: int64
```

```
In [17]: # Drop rows with missing values
df = df.dropna()
```

```
In [18]: # Verify data types
df.dtypes
```

```
Out[18]: longitude      float64
latitude        float64
housing_median_age float64
total_rooms      float64
total_bedrooms   float64
population       float64
households       float64
median_income    float64
median_house_value float64
ocean_proximity  str
dtype: object
```

3. Feature Design

All features except `median_house_value` are selected as input variables, while `median_house_value` remains the target variable.

```
In [19]: X_multi = df.drop('median_house_value', axis=1)
y=df['median_house_value']
```

3.1 Feature Scaling

the main goal of feature scaling is to normalize features so they are on a similar scale. Feature scaling improves numerical stability and ensures no feature dominates due to scale differences.

```
In [20]: from sklearn.compose import ColumnTransformer
from sklearn.preprocessing import StandardScaler, OneHotEncoder

# Identify numeric and categorical columns
numeric_cols = X_multi.select_dtypes(include='number').columns.tolist()
categorical_cols = X_multi.select_dtypes(include='object').columns.tolist()

# Create preprocessor
preprocessor = ColumnTransformer([
    ('num', StandardScaler(), numeric_cols),
    ('cat', OneHotEncoder(drop='first'), categorical_cols)
])

X_scaled = preprocessor.fit_transform(X_multi)
```

```
C:\Users\DELL\AppData\Local\Temp\ipykernel_7280\1791977775.py:6: PandasWarning: For backward compatibility, 'str' dtypes are included by select_dtypes when 'object' dtype is specified. This behavior is deprecated and will be removed in a future version. Explicitly pass 'str' to `include` to select them, or to `exclude` to remove them and silence this warning.
See https://pandas.pydata.org/docs/user_guide/migration-3-strings.html#string-migration-select-dtypes for details on how to write code that works with pandas 2 and 3.
categorical_cols = X_multi.select_dtypes(include='object').columns.tolist()
```

4. Algorithm Selection

Multiple Linear Regression is selected because the goal is to predict a continuous numerical value. The algorithm models the relationship between multiple independent variables and the target using a linear equation.

```
In [21]: from sklearn.linear_model import LinearRegression

# Initialize Linear Regression model
lr_multi = LinearRegression()
```

5. Loss Function Selection

Mean Squared Error (MSE) is used as the loss function.

```
In [22]: from sklearn.metrics import mean_squared_error, r2_score
```

6. Model Training

The data set is split into training set and testing set. The model learns optimal coefficients for all the input features as well as an intercept by adjusting the loss function during training.

```
In [23]: from sklearn.model_selection import train_test_split

# Split dataset into training and testing sets
X_train_m, X_test_m, y_train_m, y_test_m = train_test_split(
    X_scaled, y, test_size=0.2, random_state=42)

#Train the model
lr_multi.fit(X_train_m, y_train_m)
```

```
Out[23]: ▾ LinearRegression ⓘ ⓘ
▶ Parameters
```

7. Model Evaluation

The trained model is evaluated using the test data. MSE and R² score are calculated to assess the performance of the model.

```
In [24]: # Predict on test set
y_pred_m = lr_multi.predict(X_test_m)

#Evaluation metrics
print('MSE:', mean_squared_error(y_test_m, y_pred_m))
print('R2:', r2_score(y_test_m, y_pred_m))
```

```
MSE: 4802173538.60416
R2: 0.6488402154431994
```

In [25]:

```
#Model Interpretation
print('Intercept:', lr_multi.intercept_)

# Get feature names from the preprocessor
feature_names = preprocessor.get_feature_names_out()

# Create a dataframe for better visualization
coefficients_df = pd.DataFrame({
    'Feature': feature_names,
    'Coefficient': lr_multi.coef_
})

print('\nCoefficients with Feature Names:')
# Display as HTML table in Jupyter
from IPython.display import display, HTML
display(coefficients_df.style.set_caption("Model Coefficients").hide(axis="index"))
```

Intercept: 219277.54116831796

Coefficients with Feature Names:

Model Coefficients

Feature	Coefficient
num_longitude	-54313.155671
num_latitude	-54812.655941
num_housing_median_age	13615.994239
num_total_rooms	-13815.254127
num_total_bedrooms	43403.303232
num_population	-41258.829711
num_households	16493.026736
num_median_income	74596.794611
cat_ocean_proximity_INLAND	-39240.217778
cat_ocean_proximity_ISLAND	213653.374463
cat_ocean_proximity_NEAR BAY	-6232.416876
cat_ocean_proximity_NEAR OCEAN	3166.477128

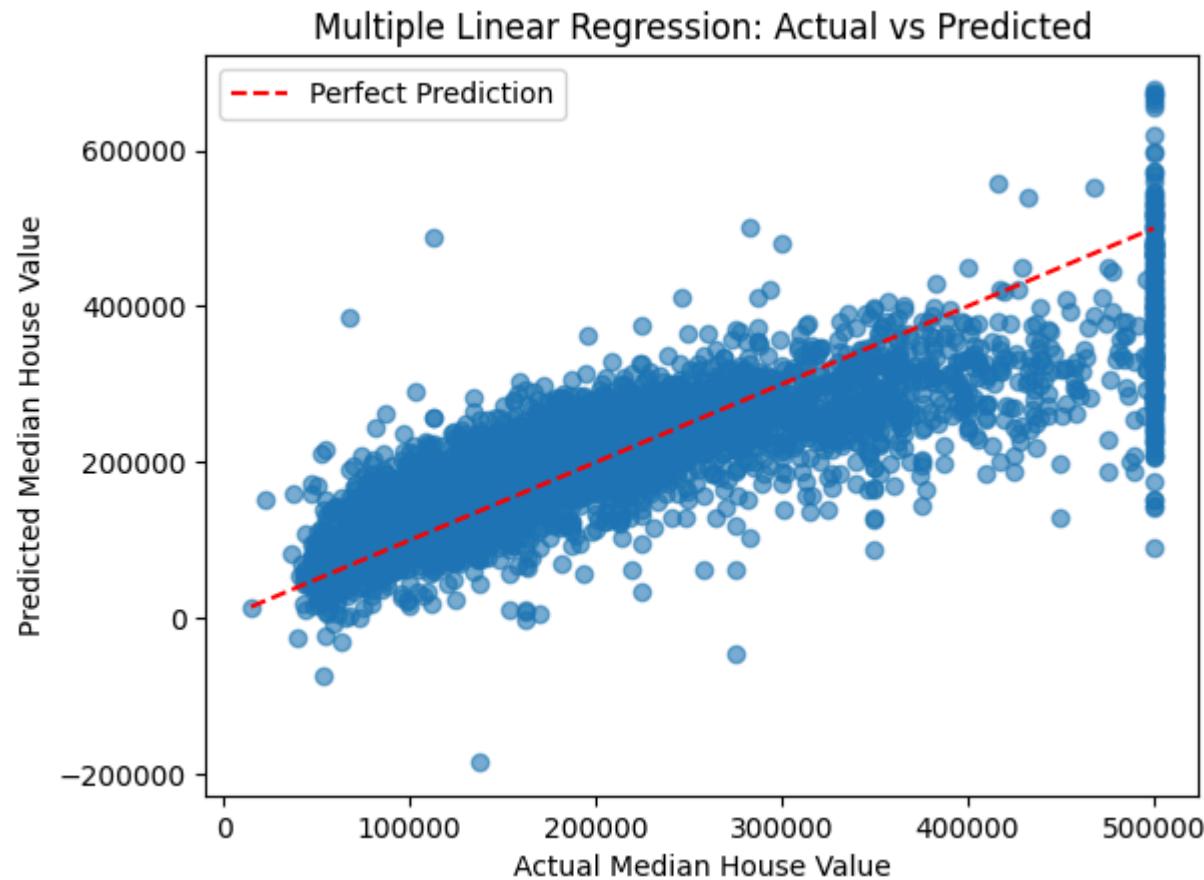
Visualization: Actual vs Predicted Values

This plot compares actual median house values against predicted values. The red diagonal line represents perfect prediction ($y_{actual} = y_{predicted}$). Points close to the line indicate better model performance.

```
In [26]: import matplotlib.pyplot as plt

plt.scatter(y_test_m, y_pred_m, alpha=0.6)
plt.plot([y_test_m.min(), y_test_m.max()],
         [y_test_m.min(), y_test_m.max()], color='red', linestyle='--', label="Perfect Prediction")
plt.xlabel("Actual Median House Value")
plt.ylabel("Predicted Median House Value")
plt.title("Multiple Linear Regression: Actual vs Predicted")
```

```
plt.legend()  
plt.show()
```



Model Comparison

It has been found that multiple linear regression outperforms the simple one by a greater extent. Adding relevant features dramatically improves model performance. Going from 1 to 12 features improved R^2 by approximately 50 times. Simple Linear Regression (Task 1) achieved an R^2 score of only 0.013, meaning it explains just 1.3% of the variation in house prices whereas Multiple Linear Regression (Task 2) demonstrates dramatically superior results with an R^2 score of 0.649, explaining nearly 65% of the price variation.

Multiple Linear Regression provides better prediction because it incorporates more information about what actually affects house prices by incorporating 12 different features. Though Single-feature models offer exceptional clarity and simplicity, they inevitably oversimplify reality. They are fundamentally inaccurate and unrealistic for real-world applications.

Discussion and Conclusion

This lab compared between Simple Linear Regression using only housing median ages and Multiple Linear Regression using 12 features, thereby highlighting the importance of Feature Engineering in machine learning models. Simple Linear Regression achieved minimal predictive power with an R^2 of 0.013 (explaining only 1.3% of variance) and an average prediction error of \$116,636, rendering it impractical for real-world applications. In contrast, Multiple Linear Regression dramatically outperformed it with an R^2 of 0.649 (explaining 64.9% of variance) and a reduced error of \$69,299 — a 50-fold improvement achieved by incorporating relevant features like location, income levels, and property characteristics.

From the visualizations, it has been found that Task 1's actual vs predicted plot showed predictions frozen at a constant value, while Task 2's plot displayed predictions distributed around the diagonal line, reflecting genuine price relationships. Thus, the lab effectively demonstrates that comprehensive feature selection directly determines model reliability and business applicability—a fundamental principle showing that relevant features matter far more than model simplicity.