

Experiment 2: Loan Amount Prediction using Linear Regression

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1 Aim

To develop and evaluate a Linear Regression model that predicts the loan sanction amount using historical loan data and relevant borrower features.

2 Libraries Used

- Pandas: Data manipulation
- NumPy: Numerical operations
- Scikit-learn: Model building, preprocessing, and evaluation
- Matplotlib and Seaborn: Data visualization

3 Objective

- Preprocess and clean the dataset
- Perform exploratory data analysis (EDA)
- Engineer features to improve model accuracy
- Train and validate a Linear Regression model

- Evaluate model performance using MAE, MSE, RMSE, and R^2 metrics
- Visualize results and interpret model behavior

4 Mathematical Description

In this experiment, **Linear Regression** is used to predict the loan sanction amount based on several input features.

The mathematical model for Linear Regression is:

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_n x_n + \epsilon \quad (1)$$

Where:

- y is the dependent variable (Loan Sanction Amount).
- x_1, x_2, \dots, x_n are the independent variables (features such as Age, Income, Credit Score, etc.).
- β_0 is the intercept term.
- $\beta_1, \beta_2, \dots, \beta_n$ are the coefficients (weights) representing the impact of each feature on the target.
- ϵ is the error term representing noise or unexplained variance.

The model parameters β are estimated by minimizing the **Residual Sum of Squares (RSS)**:

$$RSS = \sum_{i=1}^m (y_i - \hat{y}_i)^2 = \sum_{i=1}^m [y_i - \beta_0 + \sum_{j=1}^n \beta_j x_{ij}]^2 \quad (2)$$

Where m is the number of observations. Model evaluation uses metrics such as:

- **Mean Absolute Error (MAE)**: average absolute

difference between actual and predicted values.

- **Mean Squared Error (MSE):** average squared difference between actual and predicted values.
- **Root Mean Squared Error (RMSE):** square root of MSE, interpretable in the same units as the target.
- **R-squared (R^2):** proportion of variance explained by the model.
- **Adjusted R-squared:** adjusted for the number of predictors to avoid overfitting.

5 Python Code

Listing 1: Iris Dataset Classification

```
import pandas as pd
import numpy as np
from sklearn.model_selection import train_test_split,
    cross_validate, KFold
from sklearn.compose import Column
Transformer from sklearn.preprocessing
import StandardScaler,
    OneHotEncoder
from sklearn.pipeline import Pipeline
from sklearn.linear_model import
LinearRegression from sklearn.metrics import
mean_absolute_error,
    mean_squared_error, r2
_score import matplotlib .
pyplot as plt import seaborn
as sns

sns.set(style="whitegrid")
# Load only train.csv dataset
train_df = pd.read_csv("/content/drive/MyDrive/train.csv")

# Target variable
target = 'Loan_Sanction_Amount_(USD)'

# Drop unnecessary columns
drop_cols = ['Customer_ID', 'Name', 'Property_ID',
    'Location', 'Property_Location']
train_df.drop(columns=drop_cols, inplace=True)

# Handle missing values by dropping (or you
    can use imputation if preferred)
train_df.dropna(inplace=True)
# Target Distribution
plt.figure(figsize=(8, 5))
sns.histplot(train_df[target], kde=True, color='
skyblue') plt.title('Distribution of Loan
Sanction_Amount')
plt.xlabel(target)
plt.ylabel(
Frequency') plt.
```

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

```
# Numerical Features Distribution and Boxplots  
to detect outliers
```

```
num_features = ['Age', 'Income _ (USD)', 'Credit _  
Score', 'Dependents',  
                'Current _ Loan _ Expenses _ (USD)', '  
                'Property _ Price', 'Property _ Age  
                ']
```

```
for col in num_features:
```

```

plt.figure(figsize=(8, 4))
sns.histplot(train_df[col], kde=True, bins
=30) plt.title(f'Distribution _ of _ {
col}')
plt.xlabel(col)
plt.tight_layout
() plt.show()

plt.figure(figsize=(8,
4)) sns.boxplot(x=train_df[
col])
plt.title(f'Boxplot _ of _
{col}') plt.tight_layout()
plt.show()

# Correlation Heatmap
plt.figure(figsize=(10, 8))
corr_matrix = train_df[num_features + [target]].corr(),
sns.heatmap(corr_matrix, annot=True, cmap='coolwarm', fmt="
.2f")
plt.title('Correlation _
Heatmap') plt.tight_layout()
plt.show()

# Scatter Plots of Key Numerical Features vs Target
for col in ['Income _ (USD)', 'Credit _ Score', 'Property _ Price',
'Current _ Loan _ Expenses _ (USD)']:
plt.figure(figsize=(8, 5))
sns.scatterplot(data=train_df, x=col, y=target, alpha
=0.6)
plt.title(f'{col} _ vs _ {
target}') plt.tight_layout
()
plt.show()

# Categorical Features Boxplots vs Target
cat_features = ['Gender', 'Income _ Stability', '
Profession', 'Type _ of _ Employment',
', 'Has _ Active _ Credit _
Card',
'Co-Applicant', 'Property _ Type']

for col in cat_features:
plt.figure(figsize=(10, 5))
sns.boxplot(data=train_df, x=col, y=
target) plt.title(f'{target} _ by _ {

```

```

col}')
plt.xticks (rotation =45)
plt.tight_layout()
plt.show()
# Create total income (Income + Current Loan Expenses)
train_df['Total_Income'] = train_df['Income_(USD)']
+ train_df['Current_Loan_Expenses_(USD)']

# Optional log transformations (for skewed features)

```



```

train_df['Log_Loan_Amount'] = np.log1p(train_df[
target]) train_df['Log_Income'] = np.log1p(train_df[
Income_(USD)])

# Bin Age (optional)
train_df['Age_Bin'] = pd.cut(train_df['Age'], bins=[18
, 30, 40, 50, 60, 100], labels=False)

# Define features for model
numerical_features = [
'Age', 'Income_(USD)', 'Credit_Score', '
Dependents', 'Current_Loan_Expenses_(
USD)', 'Property_Price', '
Property_Age', 'Total_Income'
]

categorical_features = [
'Gender', 'Income_Stability', '
Profession', 'Type_of_Employment', '
Has_Active_Credit_Card', 'Co-
Applicant', 'Property_Type'
]
X = train_df[numerical_features +
categorical_features] y = train_df[target]

# Split into Train + Temp (80%) and Test (20%)
X_train_val, X_test, y_train_val, y_test =
train_test_split(X, y, test_size=0.2,
random_state=42
)

# Further split Train + Validation (75% train
, 25% val of 80%)
X_train, X_val, y_train, y_val = train_test_split(
X_train_val, y_train_val, test_size=0.25,
random_state
=42
)

# Result: Train = 60%, Val = 20%, Test = 20%
print(f"Train_size: {X_train.shape[0]},
Validation_size: {X_val.shape[0]}, Test_
size: {X_test.shape[0]}")
# Preprocessing pipeline

```

```

preprocessor = ColumnTransformer([
    ('num', StandardScaler(), numerical_features),
    ('cat', OneHotEncoder(drop='first', handle_unknown
        ='ignore'), categorical_features)
])

# Complete pipeline with Linear Regression
pipeline = Pipeline ( steps
    =[ ('preprocessor',
        preprocessor), ('regressor',
        LinearRegression())
    ])

```

```

# Fit the model on training data
pipeline.fit(X_train, y_train)
# Predict on validation data
y_val_pred = pipeline.predict(X_val)
# Calculate metrics
mae_val = mean_absolute_error(y_val,
y_val_pred) mse_val = mean_squared_error(
y_val, y_val_pred) rmse_val = np.sqrt(
mse_val)
r2_val = r2_score(y_val, y_val_pred)
adj_r2_val = 1 - (1 - r2_val) * (len(y_val) - 1) / (
len(y_val) - X_val.shape[1] - 1)

print(f"Validation MAE: {mae_val
:.2f}") print(f"Validation MSE: {
mse_val:.2f}") print(f"Validation
RMSE: {rmse_val:.2f}") print(f"
Validation R2 Score: {r2_val:.4
f}")
print(f"Validation Adjusted R2 Score: {adj_r2_val:.4f}")

# Predict on test data
y_test_pred = pipeline.predict(X_test)
# Calculate test metrics
mae_test = mean_absolute_error(y_test,
y_test_pred) mse_test = mean_squared_error(y_test
, y_test_pred) rmse_test = np.sqrt(mse_test)
r2_test = r2_score(y_test, y_test_pred)
adj_r2_test = 1 - (1 - r2_test) * (len(y_test) - 1) / (
len(y_test) - X_test.shape[1] - 1)

print(f"Test MAE: {mae_test
:.2f}") print(f"Test MSE: {
mse_test:.2f}") print(f"Test
RMSE: {rmse_test:.2f}") print(f"
Test R2 Score: {r2_test:.4
f}")
print(f"Test Adjusted R2 Score: {adj_r2_test:.4f}")

# Actual vs Predicted on Test Set
plt.figure(figsize=(8, 5))
plt.scatter(y_test, y_test_pred, alpha=0.6, color='
royalblue')
plt.plot([y_test.min(), y_test.max()], [y_test.min(), y_test

```

```

        .max()], 'r--')
plt.xlabel('Actual _ Loan _ Sanction
 _ Amount') plt.ylabel(' Predicted _
Loan _ Amount')
plt.title(' Actual _ vs _ Predicted _ Loan _
Amount _ ( Test _ Set)') plt.tight_layout()
plt.show()

# Residual Plot on Test Set
residuals_test = y_test - y_test_pred

```

```

plt.figure(figsize=(8, 5))
plt.scatter(y_test_pred, residuals_test, alpha=0.6,
            color='orange')
plt.axhline(0, linestyle='--', color='red')
plt.xlabel('Predicted _ Loan _
Amount')
plt.ylabel('Residuals')
plt.title('Residuals _ vs _ Predicted _
(Test _ Set)')
plt.tight_layout()
plt.show()

```

Cross - Validation Results (K=5)

```

from sklearn.metrics import make_scorer

scoring = {
    'MAE': 'neg_mean_absolute_error',
    'MSE': 'neg_mean_squared_error',
    'R2': 'r2'
}

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

cv_results = cross_validate(
    pipeline,
    X,
    y,
    cv=kf,
    scoring=scoring,
    return_train_score=False
)

# Convert to positive values
mae_scores = -cv_results['test_MAE']
mse_scores = -cv_results['test_MSE']
rmse_scores = np.sqrt(mse_scores)
r2_scores = cv_results['test_R2']

cv_table = pd.DataFrame({
    'Fold': [f'Fold_{i+1}' for i in range(5)],
    'MAE': mae_scores,

```

```

    'MSE':
    mse_scores , '
    RMSE':
    rmse_scores , 'R2
    _Score': r2
    _scores
}))

cv_table.loc['Average'] = cv_table.drop('Fold', axis
=1).mean ()
print(cv_table)

```

6 Output Screenshots

```
Validation MAE: 21904.22  
Validation MSE: 971926456.02  
Validation RMSE: 31175.74  
Validation R2 Score: 0.5764  
Validation Adjusted R2 Score: 0.5743  
Test MAE: 22145.56  
Test MSE: 998067220.05  
Test RMSE: 31592.20  
Test R2 Score: 0.5472  
Test Adjusted R2 Score: 0.5450
```

Figure 1: Performance Metrics

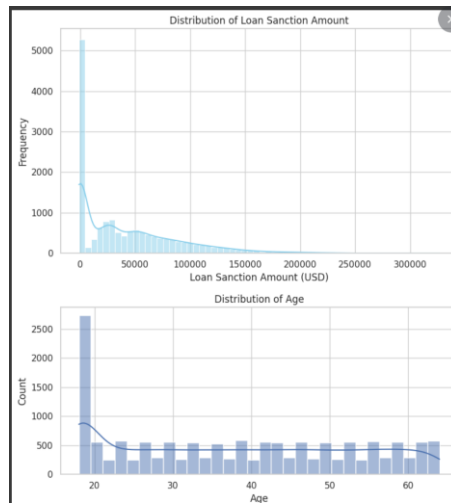


Figure 2: Distribution of Dataset

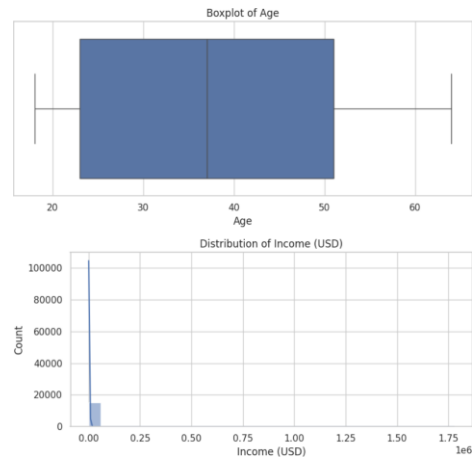


Figure 3: Boxplot of Features

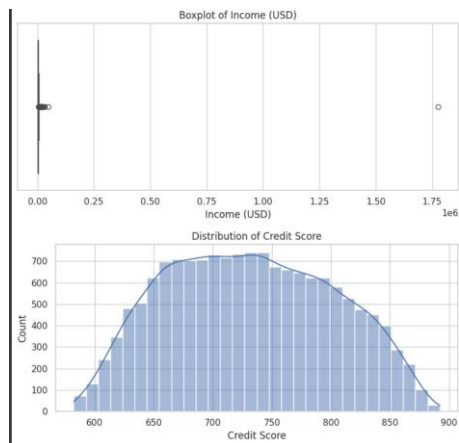


Figure 4: Distribution of Credit Score

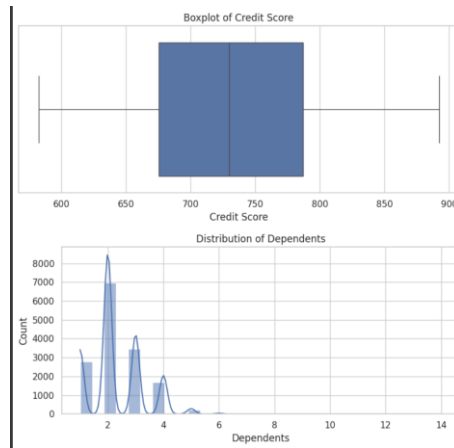


Figure 5: Distribution of Dependents

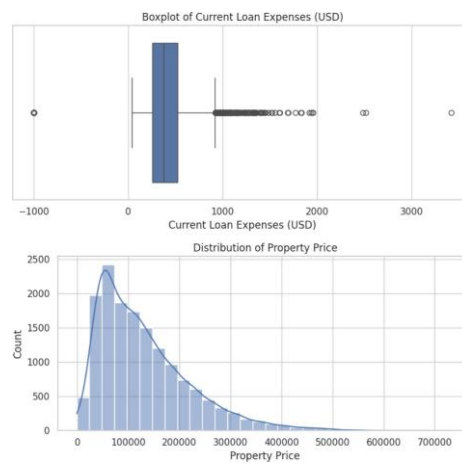


Figure 6: Current Loan Expenses Distribution

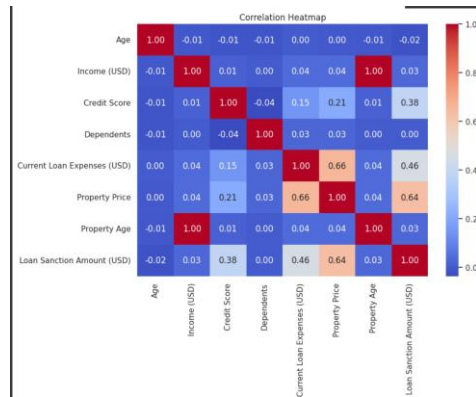


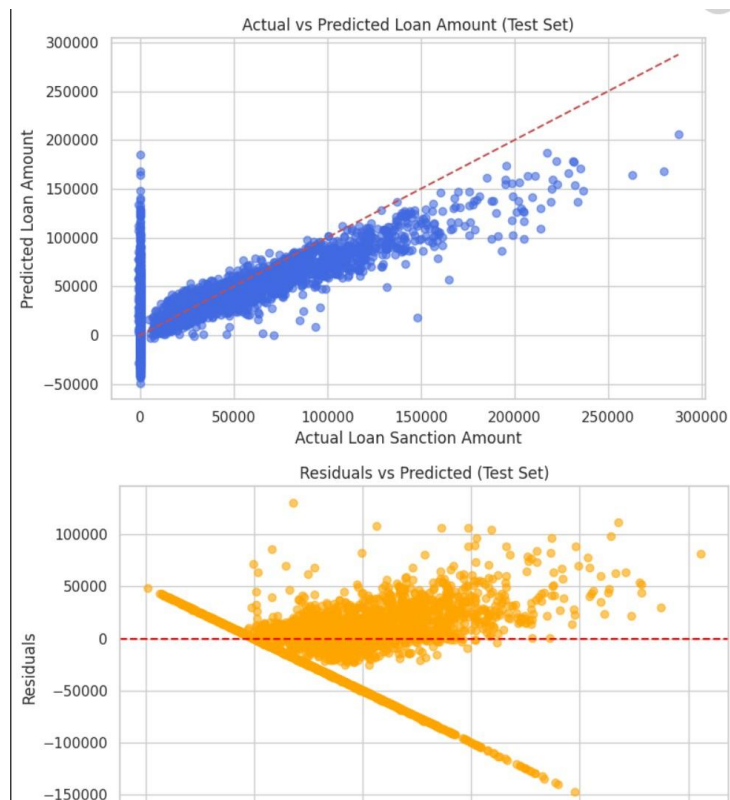
Figure 7: Correlation Heatmap



Figure 8: Credit Score vs Loan Amount



Figure 9: Property Price vs Loan Amount



1 Inference Table

Table 1: Cross-Validation Results (5-Fold)

Fold	MAE	MSE	RMSE	R ² Score
Fold 1	22090.85	9.96×10^8	31556.51	0.5483
Fold 2	21386.32	9.40×10^8	30655.92	0.5652
Fold 3	22128.77	1.08×10^9	32933.10	0.5183
Fold 4	21838.68	9.65×10^8	31069.29	0.5727
Fold 5	21917.13	9.55×10^8	30896.81	0.5817
Average	21872.35	9.88×10^8	31422.33	0.5572

Table 2: Results Summary

Description	Result
Dataset Size (after preprocessing)	15,183
Train/Test Split Ratio	60/20/20 (Train/Validation/Test)
Features Used	['Age', 'Income (USD)', 'Credit Score', 'Dependents', 'Current Loan Expenses (USD)', 'Property Price', 'Property Age', 'Total Income', 'Gender', 'Income Stability', 'Profession', 'Type of Employment', 'Has Active Credit Card', 'Co-Applicant', 'Property Type']
Model Used	Linear Regression
Cross-Validation Used?	Yes
Number of Folds (K)	5
Reference to CV Results Table	Table 1
MAE on Test Set	22145.56
MSE on Test Set	998067220.05
RMSE on Test Set	31592.20
R ² Score on Test Set	0.5472
Adjusted R ² Score on Test Set	0.5450
Most Influential Feature(s)	['Co-Applicant 0', 'Property Price', 'Credit Score']
Observations from Residual Plot	The residual plot shows a clear pattern with residuals decreasing as predicted values increase, indicating model bias and heteroscedasticity. This suggests the linear model may not fully capture the relationship.

Interpretation of Predicted vs Actual Plot	The plot shows that most predicted values align closely with actual loan amounts along the diagonal line, indicating decent model accuracy. However, there is some spread and underestimation for higher loan amounts, suggesting room for improvement in capturing extreme values.
Any Overfitting or Underfitting Observed?	No significant overfitting or underfitting observed. The training and validation errors are comparable, and residuals do not show extreme patterns, indicating the model generalizes reasonably well. However, some bias at higher values suggests slight underfitting in that range.

2 Best Practices

- **Data Preprocessing:** Handle missing values carefully (drop or impute), and remove irrelevant columns such as IDs and names that do not contribute to prediction.
- **Feature Engineering:** Create new meaningful features (e.g., total income) and apply transformations (e.g., log transformation for skewed data) to improve model performance.
- **Scaling and Encoding:** Use scaling (e.g., StandardScaler) for numerical features and one-hot encoding for categorical features to prepare data for linear regression.
- **Train-Test Split:** Use proper splits (e.g., 80/20) and consider cross-validation to ensure the model generalizes well and to prevent overfitting.
- **Model Evaluation:** Use multiple metrics (MAE, MSE, RMSE, R^2) to assess different aspects of

model performance.

- **Residual Analysis:** Analyze residual plots to detect model bias or heteroscedasticity and decide if further feature engineering or alternative models are needed.

3 Learning Outcomes

Through this experiment, I have:

- Understood the full ML pipeline from data cleaning to model evaluation.
- Learned the importance of feature engineering and proper data preprocessing.
- Learned how to visualize data and model results for better insights.

- Recognized signs of overfitting or underfitting via residual and prediction plots.
- Used cross-validation for robust model performance assessment.