main

April 19, 2024

[53]:
```
# Importing the libraries
import pandas as pd
import torch
import torch.nn as nn
import torch.optim as optim
import time
from sklearn.model_selection import train_test_split
from sklearn.preprocessing import StandardScaler, LabelEncoder
from sklearn.impute import SimpleImputer
import numpy as np
import matplotlib.pyplot as plt
import warnings
warnings.filterwarnings('ignore')
```

[54]:
```
bank_data = pd.read_csv('bank_data.csv')
bank_data.head()
```

[54]:

	Unnamed: 0	id	dependents	education	self_employed	income_annual	loan_amount	loan_term	cibil_score	residential_assets_value	commercial_assets_value	luxury_assets_value	bank_asset_value	loan_status
0	0	1	2	Graduate	No	9600000.0	29900000	12	778	2400000	17600000	22700000	NaN	Approved
1	1	2	0	Not Graduate	Yes	4100000.0	12200000	8	417	2700000	2200000	8800000	3300000.0	Rejected
2	2	3	3	Graduate	No	9100000.0	29700000	20	506	7100000	4500000	33300000	12800000.0	Rejected
3	3	4	3	Graduate	No	8200000.0	30700000	8	467	18200000	3300000	23300000	7900000.0	Rejected
4	4	5	5	Not Graduate	Yes	9800000.0	24200000	20	382	12400000	8200000	29400000	5000000.0	Rejected

[55]:
```
#check for NaN values
bank_data.isnull().sum()
```

[55]:
```
Unnamed: 0                  0
id                          0
dependents                  0
education                   0
self_employed               0
income_annual             213
loan_amount                 0
loan_term                   0
cibil_score                 0
residential_assets_value    0
commercial_assets_value     0
luxury_assets_value         0
bank_asset_value          341
loan_status                 0
dtype: int64
```

[56]:
```
# Calculate descriptive statistics for numerical columns
numerical_col_descriptive_stats = bank_data.describe()
numerical_col_descriptive_stats
```

[56]:

	Unnamed: 0	id	dependents	income_annual	loan_amount	\
count	4268.000000	4268.000000	4268.000000	4.055000e+03	4.268000e+03	
mean	2133.500000	2134.500000	2.499063	5.049420e+06	1.513004e+07	
std	1232.209804	1232.209804	1.695954	2.799091e+06	9.041673e+06	
min	0.000000	1.000000	0.000000	2.000000e+05	3.000000e+05	
25%	1066.750000	1067.750000	1.000000	2.700000e+06	7.700000e+06	
50%	2133.500000	2134.500000	3.000000	5.100000e+06	1.450000e+07	
75%	3200.250000	3201.250000	4.000000	7.500000e+06	2.150000e+07	
max	4267.000000	4268.000000	5.000000	9.900000e+06	3.950000e+07	

	loan_term	cibil_score	residential_assets_value	\
count	4268.000000	4268.000000	4.268000e+03	
mean	10.900656	599.934396	7.470197e+06	
std	5.709840	172.450571	6.502476e+06	
min	2.000000	300.000000	-1.000000e+05	
25%	6.000000	453.000000	2.200000e+06	
50%	10.000000	600.000000	5.600000e+06	
75%	16.000000	748.000000	1.130000e+07	
max	20.000000	900.000000	2.910000e+07	

	commercial_assets_value	luxury_assets_value	bank_asset_value
count	4.268000e+03	4.268000e+03	3.927000e+03
mean	4.971556e+06	1.512149e+07	4.958365e+06
std	4.388236e+06	9.099370e+06	3.262255e+06

```
min             0.000000e+00        3.000000e+05      0.000000e+00
25%             1.300000e+06        7.500000e+06      2.300000e+06
50%             3.700000e+06        1.460000e+07      4.500000e+06
75%             7.600000e+06        2.170000e+07      7.100000e+06
max             1.940000e+07        3.920000e+07      1.470000e+07
```

[57]:
```
# Summary of categorical data
categorical_col_descriptive_stats = bank_data.describe(include=['O'])
categorical_col_descriptive_stats
```

[57]:
```
        education self_employed loan_status
count        4268          4268        4268
unique          2             2           2
top      Graduate           Yes    Approved
freq         2143          2150        2655
```

[58]:
```
# Grouping by education and self_employed to compare loan status counts
education_loan_status = bank_data.groupby(['education', 'loan_status']).size().
 ↪unstack()
self_employed_loan_status = bank_data.groupby(['self_employed', 'loan_status']).
 ↪size().unstack()

education_loan_status, self_employed_loan_status
```

[58]:
```
(loan_status     Approved   Rejected
 education
  Graduate           1338        805
  Not Graduate       1317        808,
 loan_status     Approved   Rejected
 self_employed
  No                 1317        801
  Yes                1338        812)
```

[59]:
```
# Dropping unnecessary columns
bank_data = bank_data.drop(columns=['Unnamed: 0', 'id'])

# Handling missing values
imputer = SimpleImputer(strategy='median')
bank_data[['income_annual', 'bank_asset_value']] = imputer.
 ↪fit_transform(bank_data[['income_annual', 'bank_asset_value']])

# Encoding categorical variables
bank_data['education'] = bank_data['education'].map({' Graduate': 1, ' Not␣
 ↪Graduate': 0})
bank_data['self_employed'] = bank_data['self_employed'].map({' Yes': 1, ' No':␣
 ↪0})
```

```
bank_data['loan_status'] = bank_data['loan_status'].map({' Approved': 1, '␣
↪Rejected': 0})
```

[60]:
```
# Filling Negative Values with mean
mean_non_negative = bank_data[bank_data['residential_assets_value'] >=␣
↪0]['residential_assets_value'].mean()
bank_data.loc[bank_data['residential_assets_value'] < 0,␣
↪'residential_assets_value'] = mean_non_negative
```

[61]:
```
bank_data.iloc[:, :-1].describe()
```

[61]:

	dependents	education	self_employed	income_annual	loan_amount	\
count	4268.000000	4268.000000	4268.000000	4.268000e+03	4.268000e+03	
mean	2.499063	0.502109	0.503749	5.051945e+06	1.513004e+07	
std	1.695954	0.500054	0.500045	2.728357e+06	9.041673e+06	
min	0.000000	0.000000	0.000000	2.000000e+05	3.000000e+05	
25%	1.000000	0.000000	0.000000	2.800000e+06	7.700000e+06	
50%	3.000000	1.000000	1.000000	5.100000e+06	1.450000e+07	
75%	4.000000	1.000000	1.000000	7.300000e+06	2.150000e+07	
max	5.000000	1.000000	1.000000	9.900000e+06	3.950000e+07	

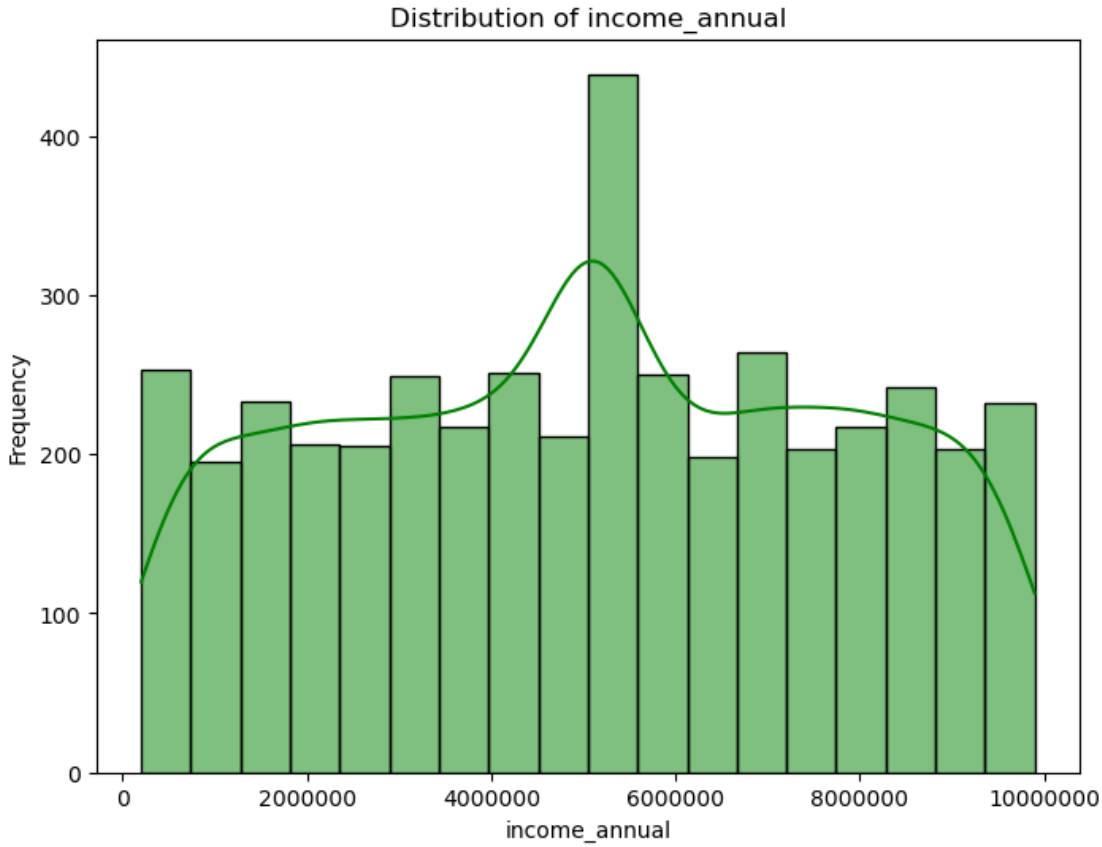
	loan_term	cibil_score	residential_assets_value	\
count	4268.000000	4268.000000	4.268000e+03	
mean	10.900656	599.934396	7.520189e+06	
std	5.709840	172.450571	6.473304e+06	
min	2.000000	300.000000	0.000000e+00	
25%	6.000000	453.000000	2.200000e+06	
50%	10.000000	600.000000	5.800000e+06	
75%	16.000000	748.000000	1.130000e+07	
max	20.000000	900.000000	2.910000e+07	

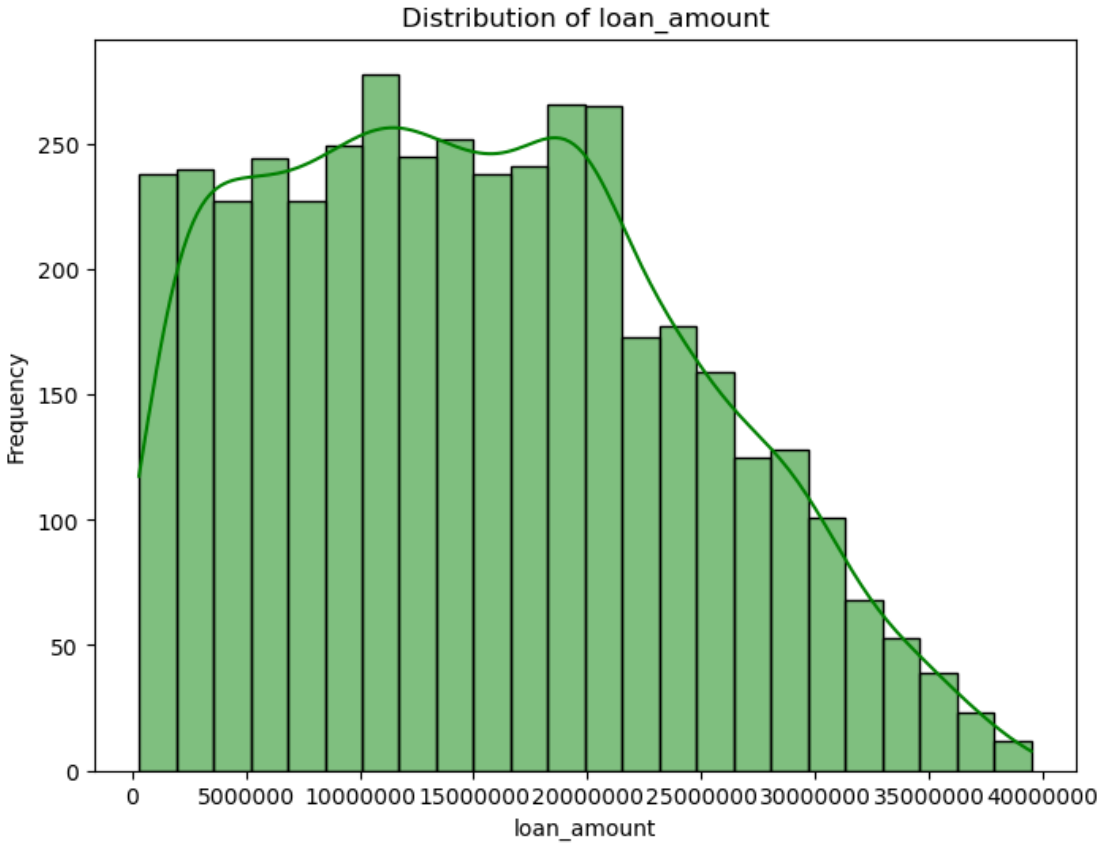
	commercial_assets_value	luxury_assets_value	bank_asset_value
count	4.268000e+03	4.268000e+03	4.268000e+03
mean	4.971556e+06	1.512149e+07	4.921743e+06
std	4.388236e+06	9.099370e+06	3.131656e+06
min	0.000000e+00	3.000000e+05	0.000000e+00
25%	1.300000e+06	7.500000e+06	2.500000e+06
50%	3.700000e+06	1.460000e+07	4.500000e+06
75%	7.600000e+06	2.170000e+07	6.800000e+06
max	1.940000e+07	3.920000e+07	1.470000e+07

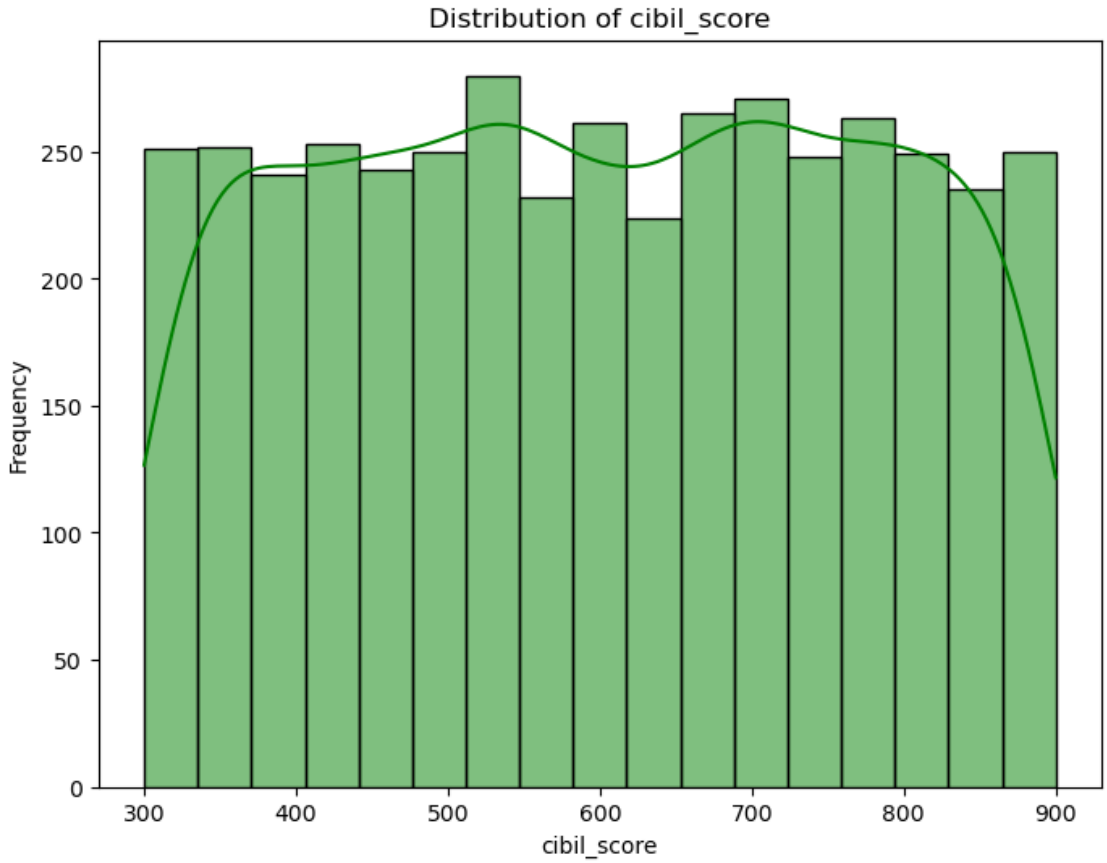
[62]:
```
import seaborn as sns
import matplotlib.pyplot as plt

# Histograms
numerical_col_vars = ['income_annual', 'loan_amount', 'cibil_score']
for var in numerical_col_vars:
```

```
    plt.figure(figsize=(8, 6))
    axis = sns.histplot(data=bank_data, x=var, kde=True, color='green')
    axis.ticklabel_format(style='plain', axis='x')  # Disable scientific␣
↪notation
    plt.title(f'Distribution of {var}')
    plt.xlabel(var)
    plt.ylabel('Frequency')
    plt.show()
```



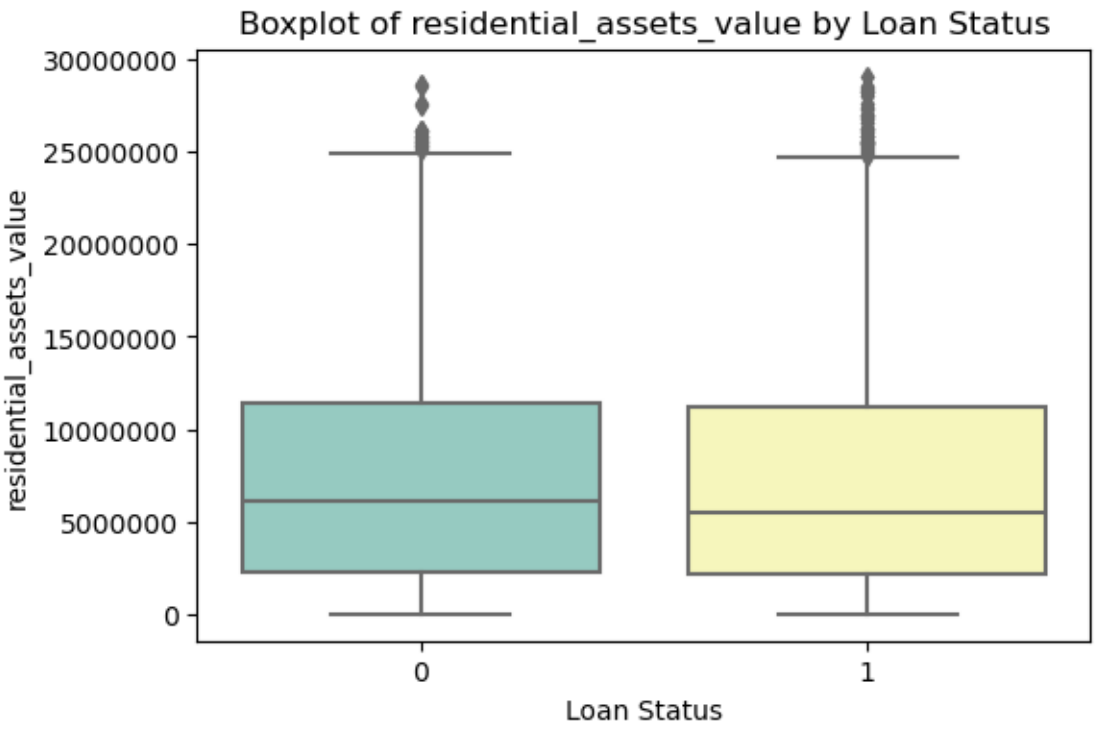

Distribution of loan_amount
Frequency
loan_amount
0
50
100
150
200
250
0
5000000
10000000
15000000
20000000
25000000
30000000
35000000
40000000

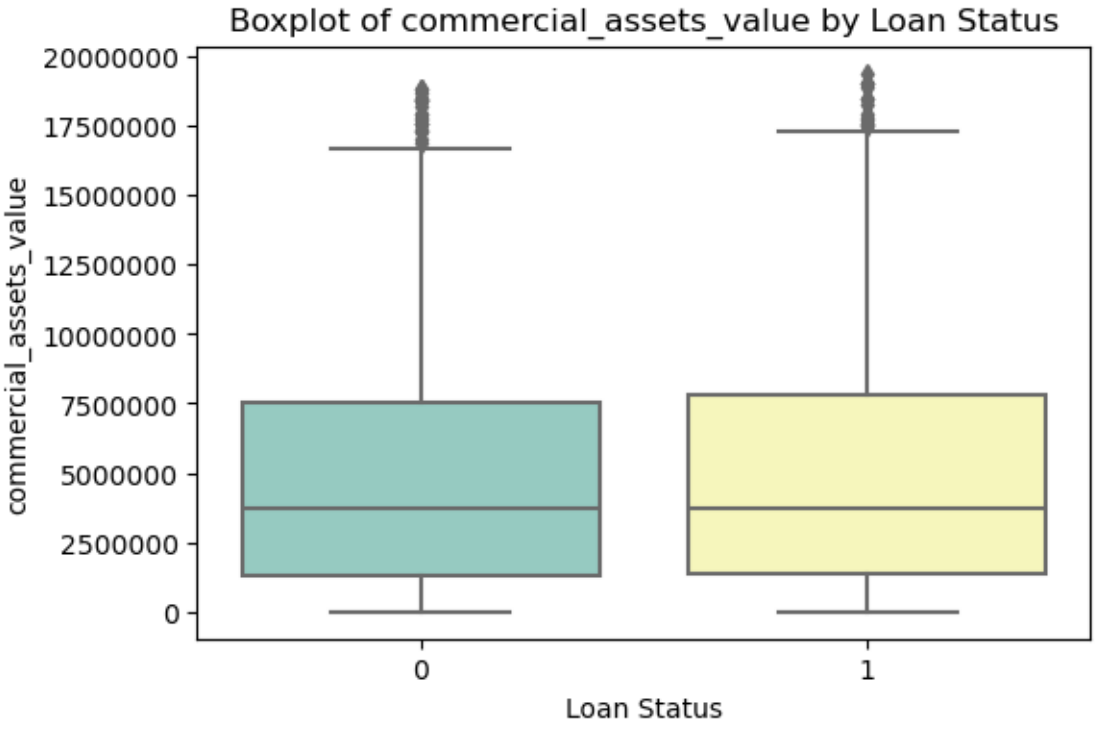


[63]:
```
import seaborn as sns
import matplotlib.pyplot as plt

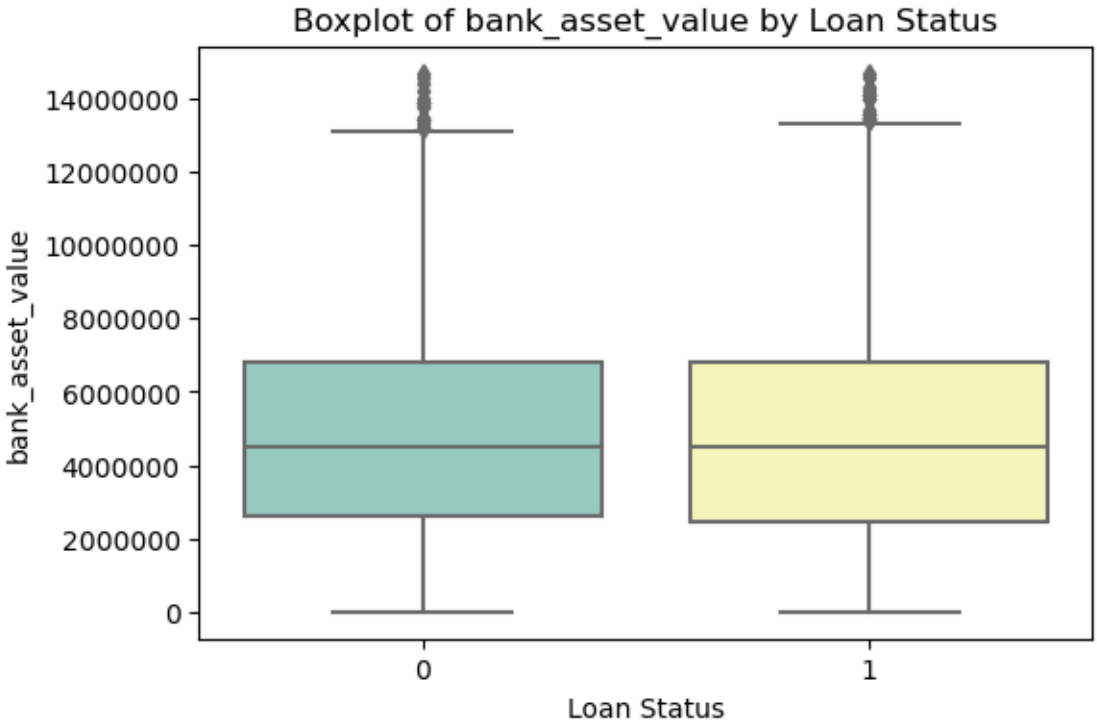
# Selecting different numerical variables for box plots
other_numerical_vars = ['residential_assets_value', 'commercial_assets_value',␣
 ↪'luxury_assets_value', 'bank_asset_value']

# Boxplots for the selected numerical variables
for var in other_numerical_vars:
    plt.figure(figsize=(6, 4))
    axis = sns.boxplot(x='loan_status', y=var, data=bank_data, palette='Set3')
    axis.ticklabel_format(style='plain', axis='y')
    plt.title(f'Boxplot of {var} by Loan Status')
    plt.xlabel('Loan Status')
    plt.ylabel(var)
    plt.show()
```


Boxplot of residential_assets_value by Loan Status
residential_assets_value
30000000
25000000
20000000
15000000
10000000
5000000
0
0
1
Loan Status

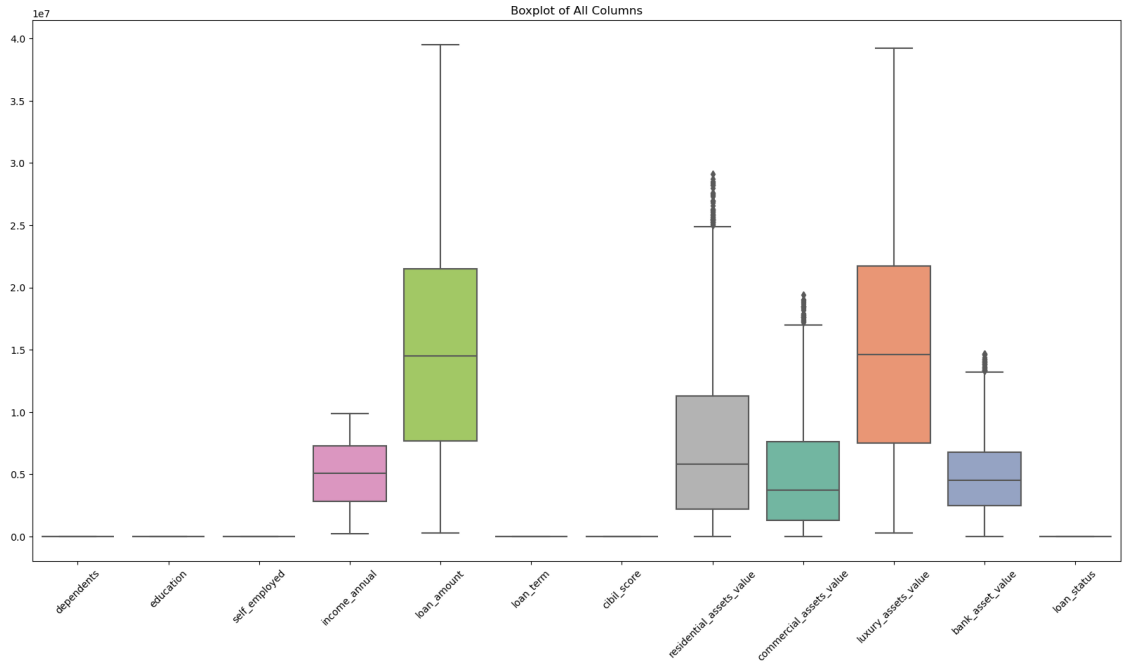

Boxplot of commercial_assets_value by Loan Status
commercial_assets_value
20000000
17500000
15000000
12500000
10000000
7500000
5000000
2500000
0
0
1
Loan Status


Boxplot of luxury_assets_value by Loan Status
luxury_assets_value
40000000
35000000
30000000
25000000
20000000
15000000
10000000
5000000
0
0
1
Loan Status


Boxplot of bank_asset_value by Loan Status
bank_asset_value
14000000
12000000
10000000
8000000
6000000
4000000
2000000
0
0
1
Loan Status

[64]:
```
import seaborn as sns
import matplotlib.pyplot as plt

# Boxplots for all columns
plt.figure(figsize=(20, 10))
sns.boxplot(data=bank_data, palette='Set2')
plt.title('Boxplot of All Columns')
plt.xticks(rotation=45)
plt.show()
```



[65]:
```
bank_data.head()
```

[65]:

	dependents	education	self_employed	income_annual	loan_amount	\
0	2	1	0	9600000.0	29900000	
1	0	0	1	4100000.0	12200000	
2	3	1	0	9100000.0	29700000	
3	3	1	0	8200000.0	30700000	
4	5	0	1	9800000.0	24200000	

	loan_term	cibil_score	residential_assets_value	commercial_assets_value	\
0	12	778	2400000.0	17600000	
1	8	417	2700000.0	2200000	
2	20	506	7100000.0	4500000	
3	8	467	18200000.0	3300000	
4	20	382	12400000.0	8200000	

```
   luxury_assets_value  bank_asset_value  loan_status
0             22700000         4500000.0            1
1              8800000         3300000.0            0
2             33300000        12800000.0            0
3             23300000         7900000.0            0
4             29400000         5000000.0            0
```

[66]:
```
# Calculate the correlation matrix for numerical columns
correlation_matrix = bank_data.corr()
correlation_matrix
```

[66]:
```
                          dependents  education  self_employed  income_annual  \
dependents                  1.000000   0.002904       0.000557       0.009312
education                   0.002904   1.000000      -0.022994       0.013018
self_employed               0.000557  -0.022994       1.000000      -0.004497
income_annual               0.009312   0.013018      -0.004497       1.000000
loan_amount                -0.003033   0.010259       0.001831       0.901647
loan_term                  -0.020145  -0.008381       0.004070       0.012515
cibil_score                -0.009991  -0.004659      -0.004856      -0.019911
residential_assets_value    0.008234   0.012234       0.007044       0.617785
commercial_assets_value    -0.001210  -0.007128      -0.017638       0.625112
luxury_assets_value         0.003287   0.011952       0.004950       0.902909
bank_asset_value            0.008374   0.008546      -0.001429       0.796866
loan_status                -0.017956   0.004737       0.000529      -0.014084

                          loan_amount  loan_term  cibil_score  \
dependents                  -0.003033  -0.020145    -0.009991
education                    0.010259  -0.008381    -0.004659
self_employed                0.001831   0.004070    -0.004856
income_annual                0.901647   0.012515    -0.019911
loan_amount                  1.000000   0.008499    -0.017055
loan_term                    0.008499   1.000000     0.007811
cibil_score                 -0.017055   0.007811     1.000000
residential_assets_value     0.591217   0.007764    -0.018359
commercial_assets_value      0.602955  -0.005422    -0.003785
luxury_assets_value          0.860838   0.012581    -0.028656
bank_asset_value             0.754248   0.012650    -0.015995
loan_status                  0.015861  -0.113015     0.770566

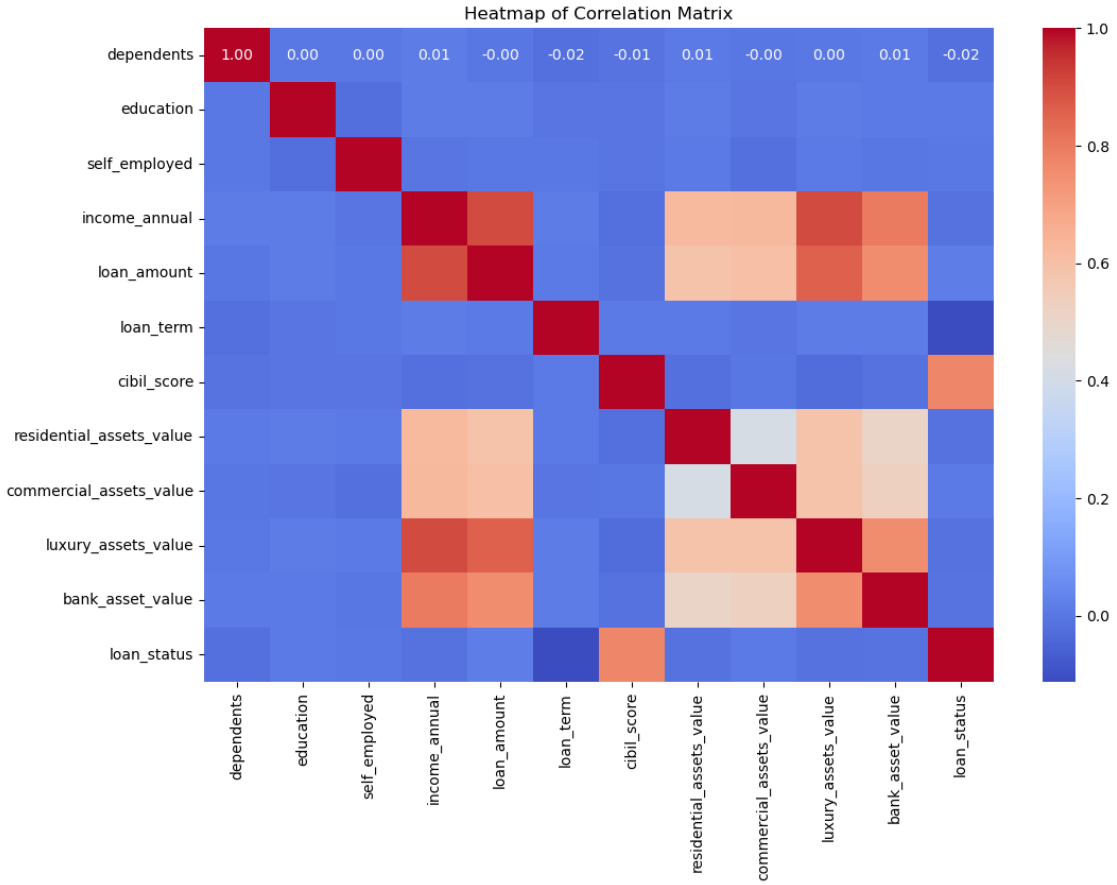
                          residential_assets_value  commercial_assets_value  \
dependents                                0.008234                -0.001210
education                                 0.012234                -0.007128
self_employed                             0.007044                -0.017638
income_annual                             0.617785                 0.625112
loan_amount                               0.591217                 0.602955
loan_term                                 0.007764                -0.005422
```

cibil_score	-0.018359	-0.003785
residential_assets_value	1.000000	0.413127
commercial_assets_value	0.413127	1.000000
luxury_assets_value	0.587511	0.590825
bank_asset_value	0.505198	0.527509
loan_status	-0.015535	0.007965

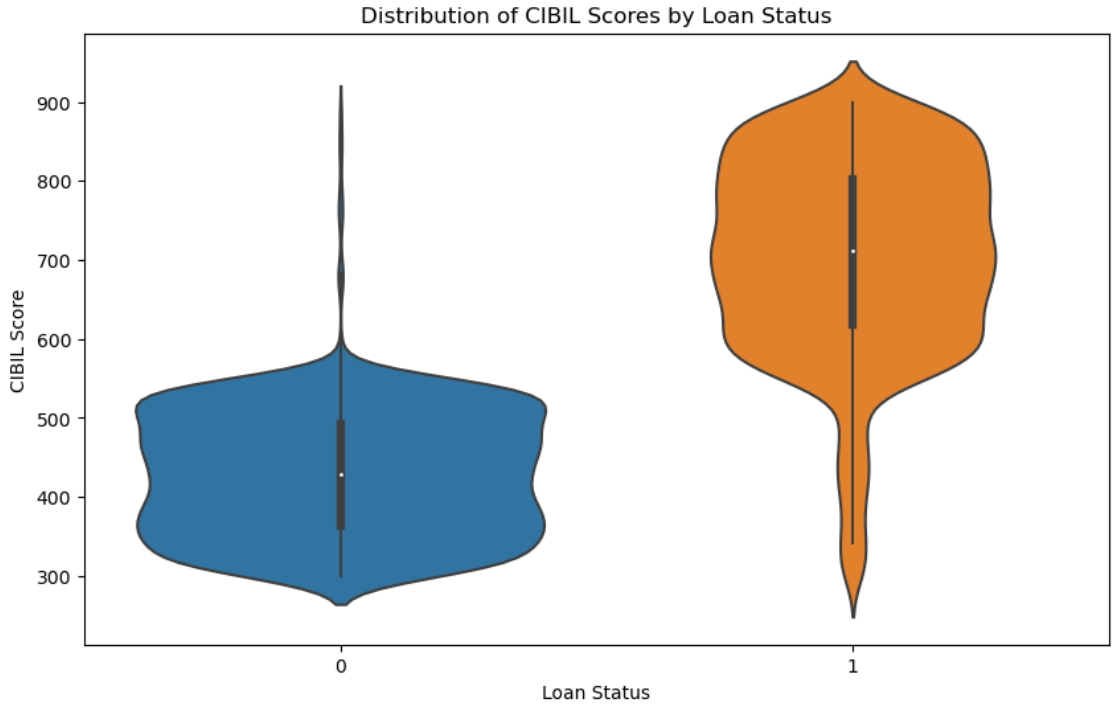
	luxury_assets_value	bank_asset_value	loan_status
dependents	0.003287	0.008374	-0.017956
education	0.011952	0.008546	0.004737
self_employed	0.004950	-0.001429	0.000529
income_annual	0.902909	0.796866	-0.014084
loan_amount	0.860838	0.754248	0.015861
loan_term	0.012581	0.012650	-0.113015
cibil_score	-0.028656	-0.015995	0.770566
residential_assets_value	0.587511	0.505198	-0.015535
commercial_assets_value	0.590825	0.527509	0.007965
luxury_assets_value	1.000000	0.756503	-0.015888
bank_asset_value	0.756503	1.000000	-0.012366
loan_status	-0.015888	-0.012366	1.000000

[67]:
```
# Calculating the correlation matrix
correlation_matrix = bank_data.corr()

# Plotting the heatmap
plt.figure(figsize=(12, 8))
sns.heatmap(correlation_matrix, annot=True, fmt=".2f", cmap='coolwarm',␣
 ↪cbar=True)
plt.title('Heatmap of Correlation Matrix')
plt.show()
```



[68]:
```
# Creating a violin plot for CIBIL scores by Loan Status
plt.figure(figsize=(10, 6))
sns.violinplot(x='loan_status', y='cibil_score', data=bank_data)
plt.title('Distribution of CIBIL Scores by Loan Status')
plt.xlabel('Loan Status')
plt.ylabel('CIBIL Score')
plt.show()
```



[69]:
```
# Splitting data into features and target variable
X = bank_data.drop(['loan_status'], axis=1)
Y = bank_data['loan_status']
```

[70]:
```
# Splitting data into training and testing sets
X_train, X_test, y_train, y_test = train_test_split(X, Y, test_size=0.2,␣
↪random_state=42)
```

0.1 SVM Model

[71]:
```
from sklearn.preprocessing import StandardScaler

# Create a scaler object
scaler = StandardScaler()

# Fit on training data and transform both training and testing sets
X_train_scaled = scaler.fit_transform(X_train)
X_test_scaled = scaler.transform(X_test)
```

[72]:
```
from sklearn.svm import SVC

# Initializing and training the SVM model
svm_model = SVC(kernel='linear', random_state=42)
svm_model.fit(X_train_scaled, y_train)
```

[72]:
```
SVC(kernel='linear', random_state=42)
```

[73]:
```
from sklearn.metrics import accuracy_score, classification_report

# Predict the labels for the test set
y_pred = svm_model.predict(X_test_scaled)

# Calculate the accuracy and classification report
accuracy = accuracy_score(y_test, y_pred)
report = classification_report(y_test, y_pred)

print("Accuracy:", accuracy)
print("Classification Report:\n", report)
```

```
Accuracy: 0.9203747072599532
Classification Report:
              precision    recall  f1-score   support

           0       0.88      0.89      0.89       303
           1       0.94      0.93      0.94       551

    accuracy                           0.92       854
   macro avg       0.91      0.91      0.91       854
weighted avg       0.92      0.92      0.92       854
```

0.1.1 Hyperparameter Tuning

[74]:
```
from sklearn.model_selection import GridSearchCV
from sklearn.svm import SVC

# Define the model to be tuned
svm_classifier = SVC(random_state=42)

# Define the hyperparameter grid
param_grid = {
    'C': [0.1, 1, 10, 100],  # Regularization parameter
    'kernel': ['linear', 'rbf', 'poly'],  # Type of SVM kernel to be used
    'gamma': ['scale', 'auto'],  # Kernel coefficient for 'rbf', 'poly'
    'degree': [2, 3, 4]  # Degree of the polynomial kernel function ('poly').
}
```

[75]:
```
# Setup the grid search with cross-validation
svm_grid_search = GridSearchCV(estimator=svm_classifier, param_grid=param_grid,␣
 ↪cv=5,scoring='accuracy', verbose=1)

# Fit the grid search to the data
```

```
svm_grid_search.fit(X_train_scaled, y_train)
```

```
Fitting 5 folds for each of 72 candidates, totalling 360 fits
```

[75]:
```
GridSearchCV(cv=5, estimator=SVC(random_state=42),
             param_grid={'C': [0.1, 1, 10, 100], 'degree': [2, 3, 4],
                         'gamma': ['scale', 'auto'],
                         'kernel': ['linear', 'rbf', 'poly']},
             scoring='accuracy', verbose=1)
```

[76]:
```
# Print the best parameters and best score
print("Best parameters:", svm_grid_search.best_params_)
print("Best cross-validation score: {:.2f}".format(svm_grid_search.best_score_))
```

```
Best parameters: {'C': 10, 'degree': 2, 'gamma': 'scale', 'kernel': 'rbf'}
Best cross-validation score: 0.94
```

[77]:
```
# Use the best estimator to make predictions on test data
y_pred_svm = svm_grid_search.best_estimator_.predict(X_test_scaled)

# Evaluate the best model on the test set
accuracy_svm = accuracy_score(y_test, y_pred_svm)
print("Test set accuracy: {:.2f}".format(accuracy_svm))
```

```
Test set accuracy: 0.94
```

[78]:
```
# Use the best estimator to make predictions on train data
y_pred_svm_train = svm_grid_search.best_estimator_.predict(X_train_scaled)

# Evaluate the best model on the train set
accuracy_svm_train = accuracy_score(y_train, y_pred_svm_train)
print("Train set accuracy: {:.2f}".format(accuracy_svm_train))
```

```
Train set accuracy: 0.98
```

[79]:
```
from sklearn.metrics import precision_score, recall_score, f1_score


# Calculate precision, recall, and F1 score
precision_svm = precision_score(y_test, y_pred_svm)
recall_svm = recall_score(y_test, y_pred_svm)
f1_svm = f1_score(y_test, y_pred_svm)

print("Precision:", precision_svm)
print("Recall:", recall_svm)
print("F1 Score:", f1_svm)
```

```
Precision: 0.9579524680073126
```

```
Recall: 0.9509981851179673
F1 Score: 0.9544626593806921
```

0.2 Multilayer Perceptron

[80]:
```
from sklearn.neural_network import MLPClassifier
from sklearn.metrics import accuracy_score, classification_report

# Initialize the MLPClassifier
mlp = MLPClassifier(hidden_layer_sizes=(100, 50),  # This is the size of the␣
 ↪hidden layer(s)
                    activation='relu',          # Activation function for the␣
 ↪hidden layer
                    solver='adam',              # The solver for weight␣
 ↪optimization
                    max_iter=300,               # Maximum number of iterations
                    random_state=42)
```

[81]:
```
# Fit the model to the scaled training data
mlp.fit(X_train_scaled, y_train)
```

[81]:
```
MLPClassifier(hidden_layer_sizes=(100, 50), max_iter=300, random_state=42)
```

[82]:
```
# Make predictions with the model
y_pred = mlp.predict(X_test_scaled)

# Calculate the accuracy and print classification report
accuracy = accuracy_score(y_test, y_pred)
report = classification_report(y_test, y_pred)

print("Accuracy:", accuracy)
print("Classification Report:\n", report)
```

```
Accuracy: 0.9601873536299765
Classification Report:
              precision    recall  f1-score   support

           0       0.94      0.95      0.94       303
           1       0.97      0.97      0.97       551

    accuracy                           0.96       854
   macro avg       0.96      0.96      0.96       854
weighted avg       0.96      0.96      0.96       854
```

0.2.1 Hyperparameter Tuning

[83]:
```
from sklearn.model_selection import GridSearchCV

# Define the MLP model
mlp = MLPClassifier(max_iter=1000, random_state=42)  # Increase max_iter for␣
↪convergence

# Define the parameter grid to search
parameter_space = {
    'hidden_layer_sizes': [(50,), (100,), (50, 50), (100, 100)],
    'activation': ['tanh', 'relu'],
    'solver': ['adam'],  # 'sgd' removed as it tends to perform worse
    'alpha': [0.0001, 0.05],
    'learning_rate_init': [0.001, 0.01],  # Added learning_rate_init for␣
↪learning rate adjustment
}
```

[84]:
```
# Set up GridSearchCV
mlp_grid_search = GridSearchCV(mlp, parameter_space, n_jobs=-1,␣
↪cv=3,scoring='accuracy', verbose=2)

# Fit GridSearchCV
mlp_grid_search.fit(X_train_scaled, y_train)
```

```
Fitting 3 folds for each of 32 candidates, totalling 96 fits
```

```
/opt/anaconda3/lib/python3.11/site-
packages/sklearn/neural_network/_multilayer_perceptron.py:686:
ConvergenceWarning: Stochastic Optimizer: Maximum iterations (1000) reached and
the optimization hasn't converged yet.
  warnings.warn(
/opt/anaconda3/lib/python3.11/site-
packages/sklearn/neural_network/_multilayer_perceptron.py:686:
ConvergenceWarning: Stochastic Optimizer: Maximum iterations (1000) reached and
the optimization hasn't converged yet.
  warnings.warn(
/opt/anaconda3/lib/python3.11/site-
packages/sklearn/neural_network/_multilayer_perceptron.py:686:
ConvergenceWarning: Stochastic Optimizer: Maximum iterations (1000) reached and
the optimization hasn't converged yet.
  warnings.warn(
```

[84]:
```
GridSearchCV(cv=3, estimator=MLPClassifier(max_iter=1000, random_state=42),
             n_jobs=-1,
             param_grid={'activation': ['tanh', 'relu'],
                         'alpha': [0.0001, 0.05],
                         'hidden_layer_sizes': [(50,), (100,), (50, 50),
```

```
                                                (100, 100)],
                                'learning_rate_init': [0.001, 0.01],
                                'solver': ['adam']},
                    scoring='accuracy', verbose=2)
```

[85]:
```
# Best parameter set
print('Best parameters found:\n', mlp_grid_search.best_params_)
```

```
Best parameters found:
 {'activation': 'tanh', 'alpha': 0.05, 'hidden_layer_sizes': (100, 100),
'learning_rate_init': 0.001, 'solver': 'adam'}
```

[86]:
```
means = mlp_grid_search.cv_results_['mean_test_score']
stds = mlp_grid_search.cv_results_['std_test_score']
for mean, std, params in zip(means, stds, mlp_grid_search.
 ↪cv_results_['params']):
    print("%0.3f (+/-%0.03f) for %r" % (mean, std * 2, params))
```

```
0.962 (+/-0.016) for {'activation': 'tanh', 'alpha': 0.0001,
'hidden_layer_sizes': (50,), 'learning_rate_init': 0.001, 'solver': 'adam'}
0.955 (+/-0.010) for {'activation': 'tanh', 'alpha': 0.0001,
'hidden_layer_sizes': (50,), 'learning_rate_init': 0.01, 'solver': 'adam'}
0.958 (+/-0.014) for {'activation': 'tanh', 'alpha': 0.0001,
'hidden_layer_sizes': (100,), 'learning_rate_init': 0.001, 'solver': 'adam'}
0.958 (+/-0.014) for {'activation': 'tanh', 'alpha': 0.0001,
'hidden_layer_sizes': (100,), 'learning_rate_init': 0.01, 'solver': 'adam'}
0.960 (+/-0.015) for {'activation': 'tanh', 'alpha': 0.0001,
'hidden_layer_sizes': (50, 50), 'learning_rate_init': 0.001, 'solver': 'adam'}
0.964 (+/-0.014) for {'activation': 'tanh', 'alpha': 0.0001,
'hidden_layer_sizes': (50, 50), 'learning_rate_init': 0.01, 'solver': 'adam'}
0.965 (+/-0.007) for {'activation': 'tanh', 'alpha': 0.0001,
'hidden_layer_sizes': (100, 100), 'learning_rate_init': 0.001, 'solver': 'adam'}
0.958 (+/-0.033) for {'activation': 'tanh', 'alpha': 0.0001,
'hidden_layer_sizes': (100, 100), 'learning_rate_init': 0.01, 'solver': 'adam'}
0.963 (+/-0.015) for {'activation': 'tanh', 'alpha': 0.05, 'hidden_layer_sizes':
(50,), 'learning_rate_init': 0.001, 'solver': 'adam'}
0.962 (+/-0.021) for {'activation': 'tanh', 'alpha': 0.05, 'hidden_layer_sizes':
(50,), 'learning_rate_init': 0.01, 'solver': 'adam'}
0.964 (+/-0.017) for {'activation': 'tanh', 'alpha': 0.05, 'hidden_layer_sizes':
(100,), 'learning_rate_init': 0.001, 'solver': 'adam'}
0.961 (+/-0.014) for {'activation': 'tanh', 'alpha': 0.05, 'hidden_layer_sizes':
(100,), 'learning_rate_init': 0.01, 'solver': 'adam'}
0.962 (+/-0.013) for {'activation': 'tanh', 'alpha': 0.05, 'hidden_layer_sizes':
(50, 50), 'learning_rate_init': 0.001, 'solver': 'adam'}
0.965 (+/-0.015) for {'activation': 'tanh', 'alpha': 0.05, 'hidden_layer_sizes':
(50, 50), 'learning_rate_init': 0.01, 'solver': 'adam'}
0.968 (+/-0.014) for {'activation': 'tanh', 'alpha': 0.05, 'hidden_layer_sizes':
```

```
(100, 100), 'learning_rate_init': 0.001, 'solver': 'adam'}
0.961 (+/-0.020) for {'activation': 'tanh', 'alpha': 0.05, 'hidden_layer_sizes':
(100, 100), 'learning_rate_init': 0.01, 'solver': 'adam'}
0.955 (+/-0.011) for {'activation': 'relu', 'alpha': 0.0001,
'hidden_layer_sizes': (50,), 'learning_rate_init': 0.001, 'solver': 'adam'}
0.951 (+/-0.006) for {'activation': 'relu', 'alpha': 0.0001,
'hidden_layer_sizes': (50,), 'learning_rate_init': 0.01, 'solver': 'adam'}
0.953 (+/-0.021) for {'activation': 'relu', 'alpha': 0.0001,
'hidden_layer_sizes': (100,), 'learning_rate_init': 0.001, 'solver': 'adam'}
0.951 (+/-0.012) for {'activation': 'relu', 'alpha': 0.0001,
'hidden_layer_sizes': (100,), 'learning_rate_init': 0.01, 'solver': 'adam'}
0.953 (+/-0.010) for {'activation': 'relu', 'alpha': 0.0001,
'hidden_layer_sizes': (50, 50), 'learning_rate_init': 0.001, 'solver': 'adam'}
0.959 (+/-0.017) for {'activation': 'relu', 'alpha': 0.0001,
'hidden_layer_sizes': (50, 50), 'learning_rate_init': 0.01, 'solver': 'adam'}
0.953 (+/-0.011) for {'activation': 'relu', 'alpha': 0.0001,
'hidden_layer_sizes': (100, 100), 'learning_rate_init': 0.001, 'solver': 'adam'}
0.951 (+/-0.017) for {'activation': 'relu', 'alpha': 0.0001,
'hidden_layer_sizes': (100, 100), 'learning_rate_init': 0.01, 'solver': 'adam'}
0.960 (+/-0.016) for {'activation': 'relu', 'alpha': 0.05, 'hidden_layer_sizes':
(50,), 'learning_rate_init': 0.001, 'solver': 'adam'}
0.958 (+/-0.018) for {'activation': 'relu', 'alpha': 0.05, 'hidden_layer_sizes':
(50,), 'learning_rate_init': 0.01, 'solver': 'adam'}
0.955 (+/-0.022) for {'activation': 'relu', 'alpha': 0.05, 'hidden_layer_sizes':
(100,), 'learning_rate_init': 0.001, 'solver': 'adam'}
0.957 (+/-0.013) for {'activation': 'relu', 'alpha': 0.05, 'hidden_layer_sizes':
(100,), 'learning_rate_init': 0.01, 'solver': 'adam'}
0.957 (+/-0.015) for {'activation': 'relu', 'alpha': 0.05, 'hidden_layer_sizes':
(50, 50), 'learning_rate_init': 0.001, 'solver': 'adam'}
0.960 (+/-0.010) for {'activation': 'relu', 'alpha': 0.05, 'hidden_layer_sizes':
(50, 50), 'learning_rate_init': 0.01, 'solver': 'adam'}
0.959 (+/-0.013) for {'activation': 'relu', 'alpha': 0.05, 'hidden_layer_sizes':
(100, 100), 'learning_rate_init': 0.001, 'solver': 'adam'}
0.957 (+/-0.018) for {'activation': 'relu', 'alpha': 0.05, 'hidden_layer_sizes':
(100, 100), 'learning_rate_init': 0.01, 'solver': 'adam'}
```

[87]:
```
# Predict on the test set using the best model
y_pred_mlp = mlp_grid_search.best_estimator_.predict(X_test_scaled)

accuracy_mlp = accuracy_score(y_test, y_pred_mlp)
accuracy_mlp
```

[87]:
```
0.9660421545667447
```

[88]:
```
# Print classification report
print(classification_report(y_test, y_pred_mlp))
```

```
              precision    recall  f1-score   support
```

```
              0       0.97      0.94      0.95       303
              1       0.97      0.98      0.97       551

       accuracy                           0.97       854
      macro avg       0.97      0.96      0.96       854
   weighted avg       0.97      0.97      0.97       854
```

[89]:
```
from sklearn.metrics import precision_score, recall_score, f1_score


# Calculate precision, recall, and F1 score
precision_mlp = precision_score(y_test, y_pred_mlp)
recall_mlp = recall_score(y_test, y_pred_mlp)
f1_mlp = f1_score(y_test, y_pred_mlp)

print("Precision:", precision_mlp)
print("Recall:", recall_mlp)
print("F1 Score:", f1_mlp)
```

```
Precision: 0.9660714285714286
Recall: 0.9818511796733213
F1 Score: 0.9738973897389739
```

[90]:
```
# Predict on the train set using the best model
y_pred_mlp_train = mlp_grid_search.best_estimator_.predict(X_train_scaled)

accuracy_mlp_train = accuracy_score(y_train, y_pred_mlp_train)
accuracy_mlp_train
```

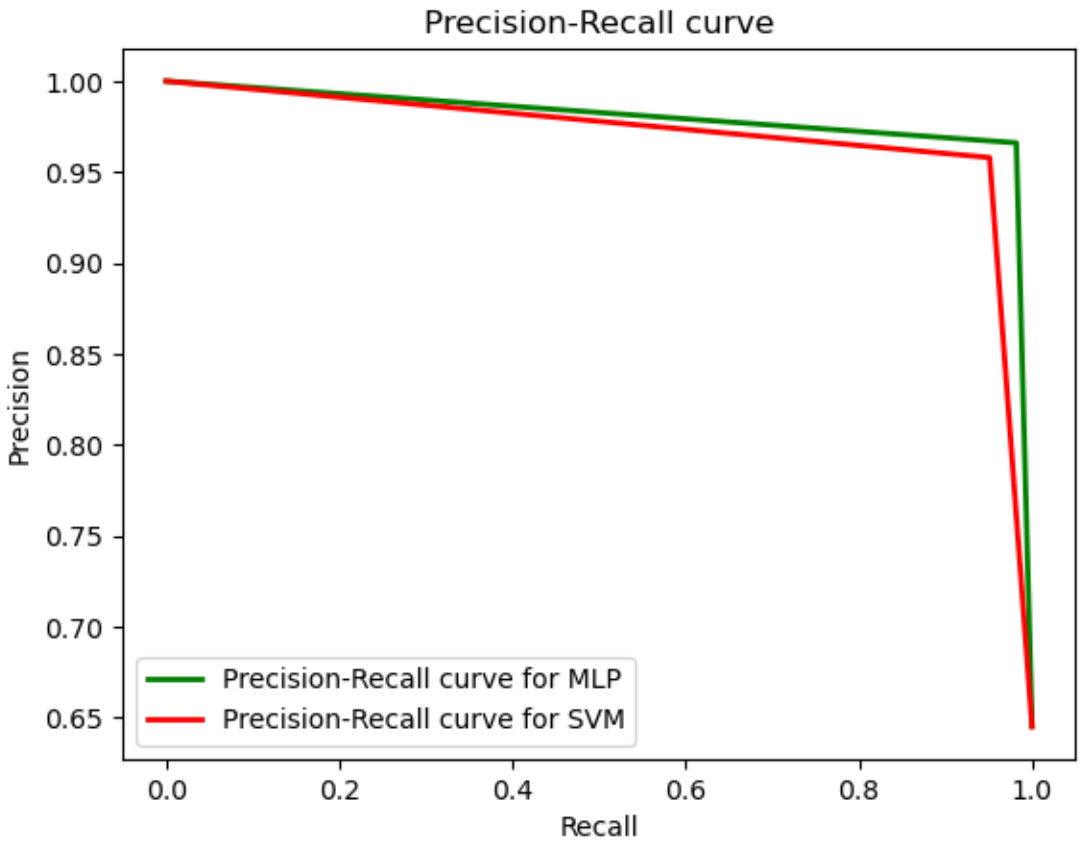
[90]:
```
0.9824253075571178
```

[91]:
```
from sklearn.metrics import precision_recall_curve

precision_mlp, recall_mlp, _ = precision_recall_curve(y_test, y_pred_mlp)
precision_svm, recall_svm, _ = precision_recall_curve(y_test, y_pred_svm)

plt.figure()
plt.plot(recall_mlp, precision_mlp, color='green', lw=2,␣
 ↪label='Precision-Recall curve for MLP')
plt.plot(recall_svm, precision_svm, color='red', lw=2, label='Precision-Recall␣
 ↪curve for SVM')
plt.xlabel('Recall')
plt.ylabel('Precision')
plt.title('Precision-Recall curve')
plt.legend(loc="lower left")
```

```
plt.show()
```



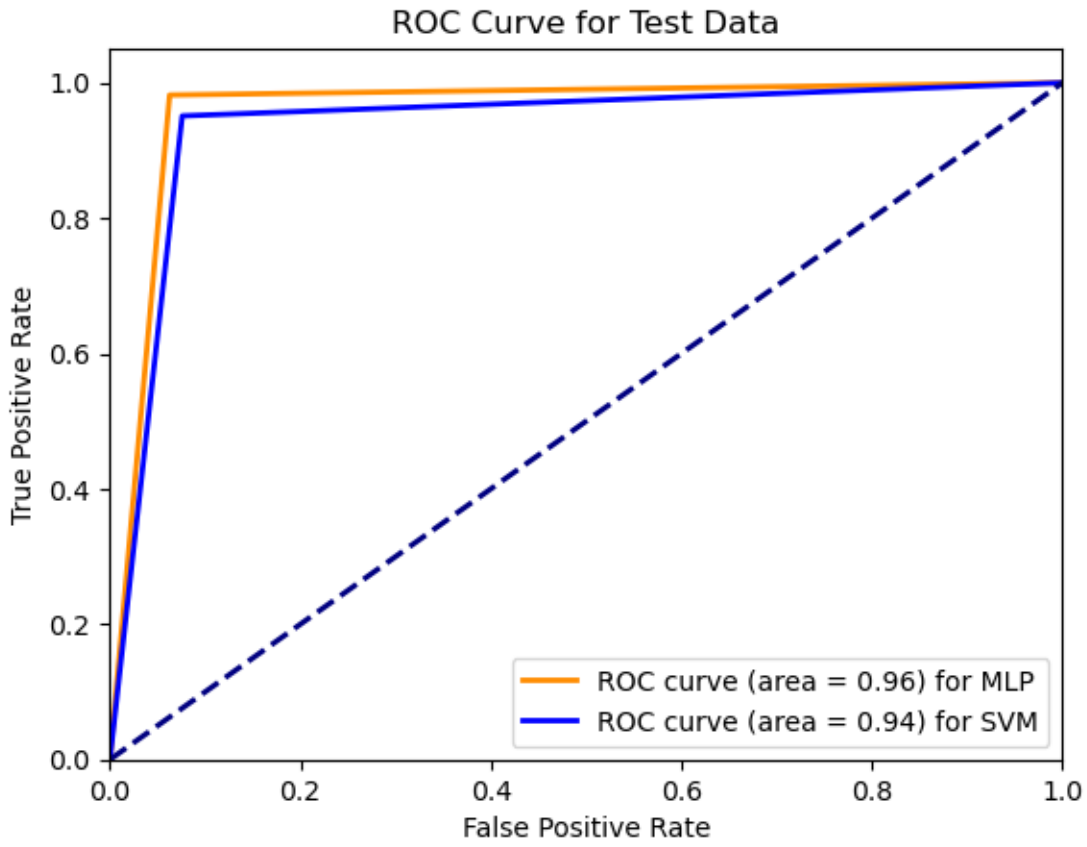
[92]:
```
from sklearn.metrics import roc_curve, auc

fpr_mlp, tpr_mlp, _ = roc_curve(y_test, y_pred_mlp)
roc_auc_mlp = auc(fpr_mlp, tpr_mlp)

fpr_svm, tpr_svm, _ = roc_curve(y_test, y_pred_svm)
roc_auc_svm = auc(fpr_svm, tpr_svm)

plt.figure()
plt.plot(fpr_mlp, tpr_mlp, color='darkorange', lw=2, label='ROC curve (area =␣
 ↪%0.2f) for MLP' % roc_auc_mlp)
plt.plot(fpr_svm, tpr_svm, color='blue', lw=2, label='ROC curve (area = %0.2f)␣
 ↪for SVM' % roc_auc_svm)
plt.plot([0, 1], [0, 1], color='navy', lw=2, linestyle='--')
plt.xlim([0.0, 1.0])
plt.ylim([0.0, 1.05])
plt.xlabel('False Positive Rate')
plt.ylabel('True Positive Rate')
```

```
plt.title('ROC Curve for Test Data')
plt.legend(loc="lower right")
plt.show()
```



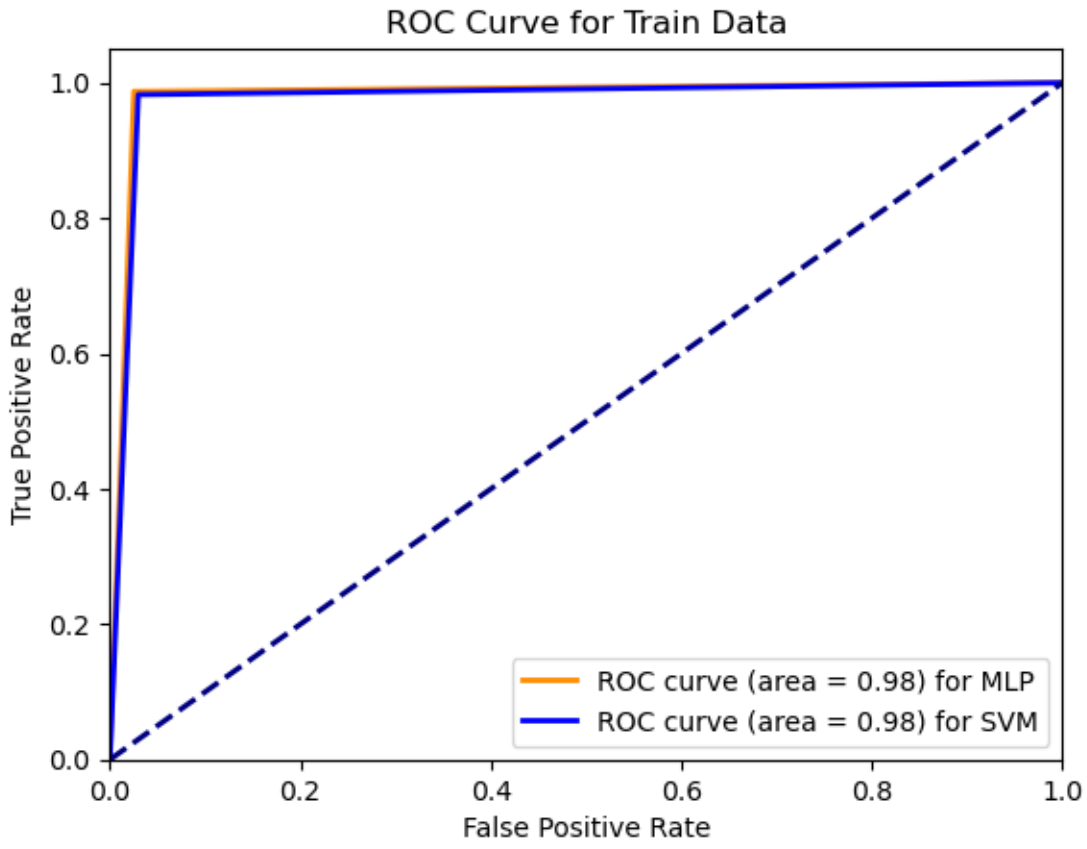
[93]:
```
from sklearn.metrics import roc_curve, auc

fpr_mlp, tpr_mlp, _ = roc_curve(y_train, y_pred_mlp_train)
roc_auc_mlp = auc(fpr_mlp, tpr_mlp)

fpr_svm, tpr_svm, _ = roc_curve(y_train, y_pred_svm_train)
roc_auc_svm = auc(fpr_svm, tpr_svm)

plt.figure()
plt.plot(fpr_mlp, tpr_mlp, color='darkorange', lw=2, label='ROC curve (area =␣
 ↪%0.2f) for MLP' % roc_auc_mlp)
plt.plot(fpr_svm, tpr_svm, color='blue', lw=2, label='ROC curve (area = %0.2f)␣
 ↪for SVM' % roc_auc_svm)
plt.plot([0, 1], [0, 1], color='navy', lw=2, linestyle='--')
plt.xlim([0.0, 1.0])
plt.ylim([0.0, 1.05])
```

```
plt.xlabel('False Positive Rate')
plt.ylabel('True Positive Rate')
plt.title('ROC Curve for Train Data')
plt.legend(loc="lower right")
plt.show()
```



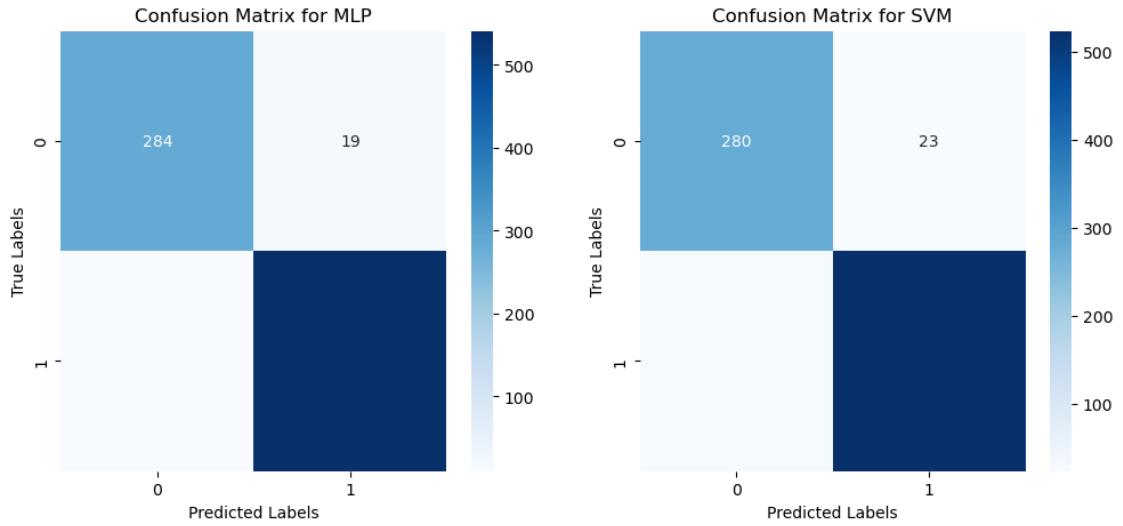
[94]:
```
import matplotlib.pyplot as plt
import seaborn as sns
from sklearn.metrics import confusion_matrix

cnfusn_mlp = confusion_matrix(y_test, y_pred_mlp)
cnfusn_svm = confusion_matrix(y_test, y_pred_svm)

fig, axis = plt.subplots(1, 2, figsize=(12, 5))
sns.heatmap(cnfusn_mlp, annot=True, fmt='d', cmap='Blues', ax=axis[0])
axis[0].set_title('Confusion Matrix for MLP')
axis[0].set_xlabel('Predicted Labels')
axis[0].set_ylabel('True Labels')

sns.heatmap(cnfusn_svm, annot=True, fmt='d', cmap='Blues', ax=axis[1])
```

```
axis[1].set_title('Confusion Matrix for SVM')
axis[1].set_xlabel('Predicted Labels')
axis[1].set_ylabel('True Labels')
plt.show()
```



[95]:
```
# We will create a DataFrame with test features and labels
test_bank_data = pd.DataFrame(X_test_scaled)
test_bank_data.reset_index(drop=True, inplace=True)
y_test.reset_index(drop=True, inplace=True)
test_bank_data['True_Label'] = y_test  # Add the true labels as a new column in␣
 ↪the DataFrame

# Save the DataFrame to a CSV file
test_bank_data.to_csv('test_data.csv', index=False)  # Set index=False not to␣
 ↪save the index

from joblib import dump

# Saving the models to file
dump(mlp_grid_search, 'mlp_grid_search.joblib')
dump(svm_grid_search, 'svm_grid_search.joblib')
```

[95]:
```
['svm_grid_search.joblib']
```

```
[CV] END activation=tanh, alpha=0.0001, hidden_layer_sizes=(50,),
learning_rate_init=0.01, solver=adam; total time=   0.5s
[CV] END activation=tanh, alpha=0.0001, hidden_layer_sizes=(100,),
learning_rate_init=0.001, solver=adam; total time=   4.8s
[CV] END activation=tanh, alpha=0.0001, hidden_layer_sizes=(100, 100),
```

```
learning_rate_init=0.01, solver=adam; total time=   1.0s
[CV] END activation=tanh, alpha=0.05, hidden_layer_sizes=(50,),
learning_rate_init=0.01, solver=adam; total time=   0.5s
[CV] END activation=tanh, alpha=0.05, hidden_layer_sizes=(100,),
learning_rate_init=0.001, solver=adam; total time=   2.9s
[CV] END activation=tanh, alpha=0.05, hidden_layer_sizes=(100, 100),
learning_rate_init=0.001, solver=adam; total time=   2.9s
[CV] END activation=relu, alpha=0.0001, hidden_layer_sizes=(100,),
learning_rate_init=0.001, solver=adam; total time=   3.8s
[CV] END activation=relu, alpha=0.0001, hidden_layer_sizes=(100, 100),
learning_rate_init=0.001, solver=adam; total time=   2.8s
[CV] END activation=relu, alpha=0.05, hidden_layer_sizes=(50, 50),
learning_rate_init=0.001, solver=adam; total time=   1.7s
[CV] END activation=relu, alpha=0.05, hidden_layer_sizes=(100, 100),
learning_rate_init=0.01, solver=adam; total time=   0.9s
[CV] END activation=tanh, alpha=0.0001, hidden_layer_sizes=(50,),
learning_rate_init=0.001, solver=adam; total time=   3.8s
[CV] END activation=tanh, alpha=0.0001, hidden_layer_sizes=(50, 50),
learning_rate_init=0.01, solver=adam; total time=   1.0s
[CV] END activation=tanh, alpha=0.0001, hidden_layer_sizes=(100, 100),
learning_rate_init=0.001, solver=adam; total time=   6.8s
[CV] END activation=tanh, alpha=0.05, hidden_layer_sizes=(50, 50),
learning_rate_init=0.001, solver=adam; total time=   3.0s
[CV] END activation=relu, alpha=0.0001, hidden_layer_sizes=(50,),
learning_rate_init=0.001, solver=adam; total time=   3.3s
[CV] END activation=relu, alpha=0.0001, hidden_layer_sizes=(100,),
learning_rate_init=0.01, solver=adam; total time=   0.9s
[CV] END activation=relu, alpha=0.0001, hidden_layer_sizes=(50, 50),
learning_rate_init=0.01, solver=adam; total time=   0.5s
[CV] END activation=relu, alpha=0.0001, hidden_layer_sizes=(100, 100),
learning_rate_init=0.001, solver=adam; total time=   5.8s
[CV] END activation=relu, alpha=0.05, hidden_layer_sizes=(100,),
learning_rate_init=0.001, solver=adam; total time=   4.6s
[CV] END activation=tanh, alpha=0.0001, hidden_layer_sizes=(50,),
learning_rate_init=0.01, solver=adam; total time=   0.7s
[CV] END activation=tanh, alpha=0.0001, hidden_layer_sizes=(100,),
learning_rate_init=0.01, solver=adam; total time=   1.0s
[CV] END activation=tanh, alpha=0.0001, hidden_layer_sizes=(100,),
learning_rate_init=0.01, solver=adam; total time=   1.1s
[CV] END activation=tanh, alpha=0.0001, hidden_layer_sizes=(50, 50),
learning_rate_init=0.01, solver=adam; total time=   0.7s
[CV] END activation=tanh, alpha=0.0001, hidden_layer_sizes=(50, 50),
learning_rate_init=0.01, solver=adam; total time=   0.7s
[CV] END activation=tanh, alpha=0.0001, hidden_layer_sizes=(100, 100),
learning_rate_init=0.001, solver=adam; total time=   4.6s
[CV] END activation=tanh, alpha=0.05, hidden_layer_sizes=(50, 50),
learning_rate_init=0.001, solver=adam; total time=   2.6s
[CV] END activation=relu, alpha=0.0001, hidden_layer_sizes=(50,),
```

```
learning_rate_init=0.001, solver=adam; total time=   2.6s
[CV] END activation=relu, alpha=0.0001, hidden_layer_sizes=(50, 50),
learning_rate_init=0.001, solver=adam; total time=   2.8s
[CV] END activation=relu, alpha=0.05, hidden_layer_sizes=(50,),
learning_rate_init=0.001, solver=adam; total time=   2.3s
[CV] END activation=relu, alpha=0.05, hidden_layer_sizes=(100,),
learning_rate_init=0.01, solver=adam; total time=   0.6s
[CV] END activation=relu, alpha=0.05, hidden_layer_sizes=(50, 50),
learning_rate_init=0.01, solver=adam; total time=   0.4s
[CV] END activation=relu, alpha=0.05, hidden_layer_sizes=(100, 100),
learning_rate_init=0.001, solver=adam; total time=   3.2s
[CV] END activation=tanh, alpha=0.0001, hidden_layer_sizes=(100,),
learning_rate_init=0.001, solver=adam; total time=   4.5s
[CV] END activation=tanh, alpha=0.0001, hidden_layer_sizes=(100, 100),
learning_rate_init=0.001, solver=adam; total time=   7.9s
[CV] END activation=tanh, alpha=0.05, hidden_layer_sizes=(50, 50),
learning_rate_init=0.01, solver=adam; total time=   0.6s
[CV] END activation=tanh, alpha=0.05, hidden_layer_sizes=(100, 100),
learning_rate_init=0.001, solver=adam; total time=   5.0s
[CV] END activation=relu, alpha=0.0001, hidden_layer_sizes=(100,),
learning_rate_init=0.01, solver=adam; total time=   0.7s
[CV] END activation=relu, alpha=0.0001, hidden_layer_sizes=(50, 50),
learning_rate_init=0.01, solver=adam; total time=   0.4s
[CV] END activation=relu, alpha=0.0001, hidden_layer_sizes=(50, 50),
learning_rate_init=0.01, solver=adam; total time=   0.6s
[CV] END activation=relu, alpha=0.0001, hidden_layer_sizes=(100, 100),
learning_rate_init=0.001, solver=adam; total time=   5.4s
[CV] END activation=relu, alpha=0.05, hidden_layer_sizes=(100,),
learning_rate_init=0.01, solver=adam; total time=   0.6s
[CV] END activation=relu, alpha=0.05, hidden_layer_sizes=(50, 50),
learning_rate_init=0.001, solver=adam; total time=   2.9s
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