

BANK CHURN PREDICTION PROJECT

Members: Mateo Pérez, Iñigo Peña, Gotzon Viteri, Josu Viteri

Dataset Description

URL: <https://www.kaggle.com/datasets/shubhammeshram579/bank-customer-churn-prediction/data>

The bank customer churn dataset is a CSV file which contains information about a study related to customer churn in a banking institution. The information is divided into 18 different variables, organized in 18 columns, being the first one the number of rows.

The attributes analyzed by this study is splitted into the different columns, which are:

QUANTITATIVE VARIABLES:

- Customer identification: a unique id for each customer.
- Age: Customer's age.
- Credit Score: A value between 300 and 850 which expresses the level of probability of a customer to pay off the debt to the bank.
- Tenure: Number of years a customer has been a client of the bank.
- Account Balance: Customer account balance.
- Estimated yearly salary: An estimation of the customers salary.

QUALITATIVE VARIABLES:

- Surname: Surname of the customer.
- Geography: Country where the customer lives.

BOOLEAN VARIABLES (1 for Yes, 0 for No):

- HasCrCard: If customer has or not a Credit Card.
- IsActiveMember: If the customer is an active member or not.
- Exited: If the customer has exited the bank. Gender: If the customer is male or female.

PROBLEM DESCRIPTION:

The primary objective of this project is to apply the skills and knowledge we will acquire throughout the course, including machine learning techniques, model training processes, and data analysis strategies. Our goal is to design, develop, and train a predictive model capable of identifying patterns and forecasting when a customer is most likely to leave the banking platform. By leveraging these tools, we aim to gain insights into customer behavior and provide actionable intelligence that can help mitigate customer attrition and improve overall retention rates.

⚠ EXTRA FEATURES ⚠ :

- This project includes an additional interpretability section, which aims to provide additional insight into our models' way of working.

⚠ Discussions and Report ⚠ :

- We have added explanations and conclusions for each step. Final conclusions for each section and also a final general conclusion of the whole project have been included in the final report document, as we believe this approach makes the content more interpretable and easier to follow. The LaTeX document is attached in the zip file.

1. Exploratory Data Analysis(EDA)

```
In [42]: import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import seaborn as sns
plt.style.use('ggplot')
```

Step 1: Data understanding

- Dataframe shape
- Data types
- Description

```
In [43]: df = pd.read_csv(r'src\rawDataset.csv')
df.head()
```

Out[43]:

	RowNumber	CustomerId	Surname	CreditScore	Geography	Gender	Age	Tenure
0	1	15634602	Hargrave	619	France	Female	42	2
1	2	15647311	Hill	608	Spain	Female	41	1
2	3	15619304	Onio	502	France	Female	42	8
3	4	15701354	Boni	699	France	Female	39	1
4	5	15737888	Mitchell	850	Spain	Female	43	2



In [5]: `df.shape`

Out[5]: `(10000, 18)`

In this data we have 10.000 rows and 18 columns (features)

In [6]: `df.dtypes`

Out[6]:

RowNumber	int64
CustomerId	int64
Surname	object
CreditScore	int64
Geography	object
Gender	object
Age	int64
Tenure	int64
Balance	float64
NumOfProducts	int64
HasCrCard	int64
IsActiveMember	int64
EstimatedSalary	float64
Exited	int64
Complain	int64
Satisfaction Score	int64
Card Type	object
Point Earned	int64
dtype: object	

The dataset consists of numerical and categorical data types. Numerical columns include integers (int64) like RowNumber, CreditScore, Age, and floats (float64) like Balance and EstimatedSalary. Categorical columns are represented as object types, such as Surname, Geography, Gender, and Card Type.

In [7]: `df.describe()`

Out[7]:

	RowNumber	CustomerId	CreditScore	Age	Tenure	Bal
count	10000.00000	1.000000e+04	10000.000000	10000.000000	10000.000000	10000.00
mean	5000.50000	1.569094e+07	650.528800	38.921800	5.012800	76485.88
std	2886.89568	7.193619e+04	96.653299	10.487806	2.892174	62397.40
min	1.00000	1.556570e+07	350.000000	18.000000	0.000000	0.00
25%	2500.75000	1.562853e+07	584.000000	32.000000	3.000000	0.00
50%	5000.50000	1.569074e+07	652.000000	37.000000	5.000000	97198.54
75%	7500.25000	1.575323e+07	718.000000	44.000000	7.000000	127644.24
max	10000.00000	1.581569e+07	850.000000	92.000000	10.000000	250898.09



This table summarizes the dataset's key statistics. All columns have 10,000 values, meaning there is no missing data. The CreditScore averages around 650, with a range from 350 to 850, while the Age has a mean of 39, spanning 18 to 92. The Balance varies significantly, averaging ~76,485 but ranging from 0 to ~250,898. Features like HasCrCard and IsActiveMember are binary, showing proportions of about 70.55% and 51.51% respectively for a value of 1. Satisfaction scores average at 3, with most customers having between 1 and 4 products. Percentiles reveal that 25% of customers are aged 32 or younger, and the median balance is ~97,198.

Step2: Data Preparation

- Dropping irrelevant columns and rows

In [44]:

```
df.drop(columns=['RowNumber', 'Surname', 'CustomerId'], inplace=True)
df.head()
```

Out[44]:

	CreditScore	Geography	Gender	Age	Tenure	Balance	NumOfProducts	HasCrCa
0	619	France	Female	42	2	0.00		1
1	608	Spain	Female	41	1	83807.86		1
2	502	France	Female	42	8	159660.80		3
3	699	France	Female	39	1	0.00		2
4	850	Spain	Female	43	2	125510.82		1



'Row number', 'Surname' and 'CustomerId' columns seem to act as identifiers. They don't have much analytical value since they are unique or nearly unique, so we get rid of them.

In [9]:

```
df.shape
```

```
Out[9]: (10000, 15)
```

we've reduced the number of features from 18 to 15, as there was irrelevant data for modeling

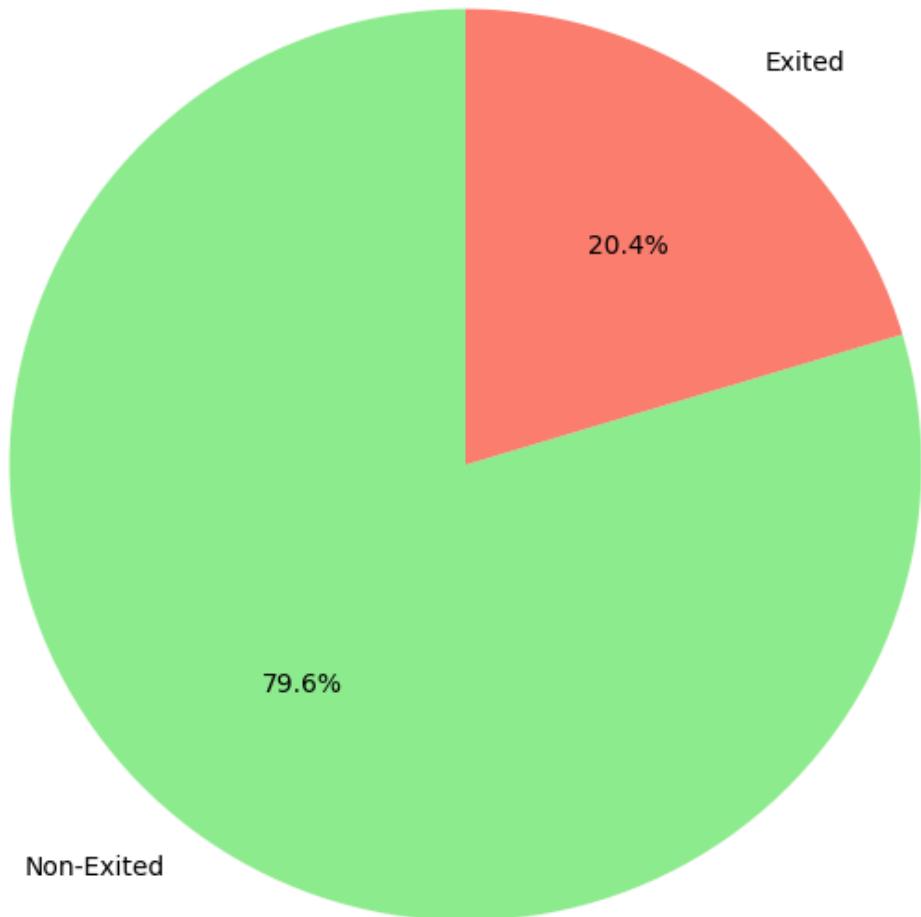
Step 3: Feature Understanding

- Plotting Feature Distributions
- Histogram
- Boxplot
- KDE

```
In [10]: churn_counts = df['Exited'].value_counts()  
print("Exited Clients: ", churn_counts[1])  
print("Non-Exited Clients: ", churn_counts[0])  
  
plt.figure(figsize=(8, 8))  
plt.pie(churn_counts, labels=['Non-Exited', 'Exited'], autopct='%1.1f%%', colors  
plt.title('Proportion of Exited vs Non-Exited Clients')  
plt.show()
```

Exited Clients: 2038
Non-Exited Clients: 7962

Proportion of Exited vs Non-Exited Clients

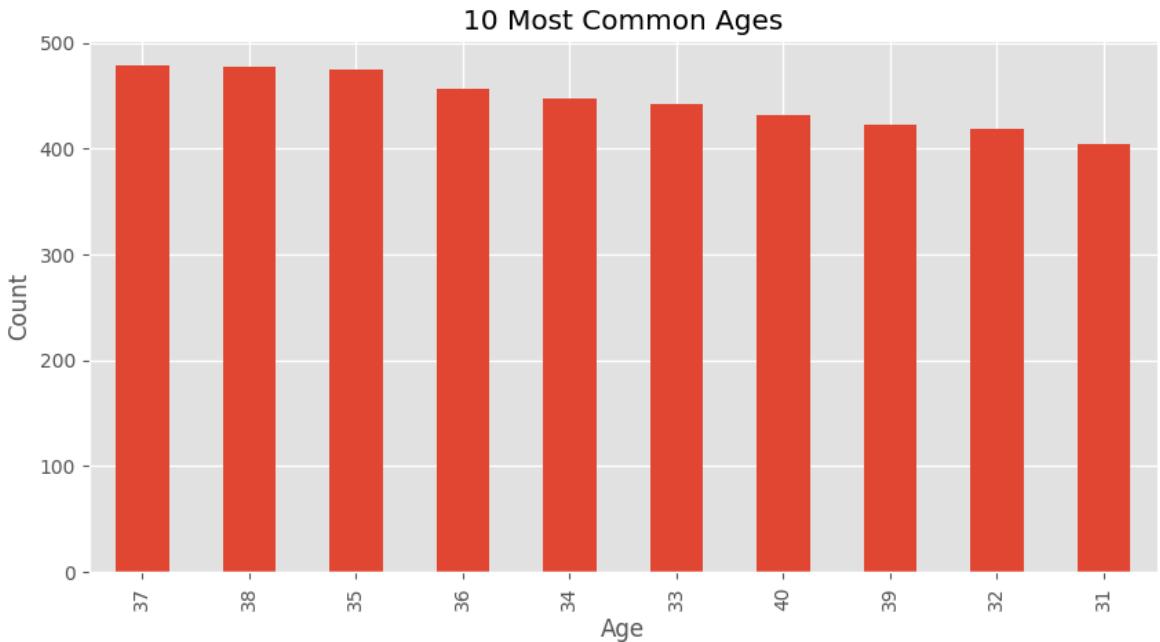


This chart shows the distribution of churned vs non-churned clients. We can see that our dataset is completed by 2038 clients who churned and 7962 who not (20.4% - 79.6%), this indicates a moderate imbalance between the classes. This imbalance can affect model's performance and lead to poor recall for the minority class or misleading performance metrics. To address this imbalance we could undersample non-exited clients, adjust class weights or use metrics suitable for imbalanced data.

```
In [11]: ax = df['Age'].value_counts() \
    .head(10) \
    .plot(kind='bar', figsize=(10,5), title='10 Most Common Ages')

ax.set_xlabel('Age')
ax.set_ylabel('Count')
```

```
Out[11]: Text(0, 0.5, 'Count')
```

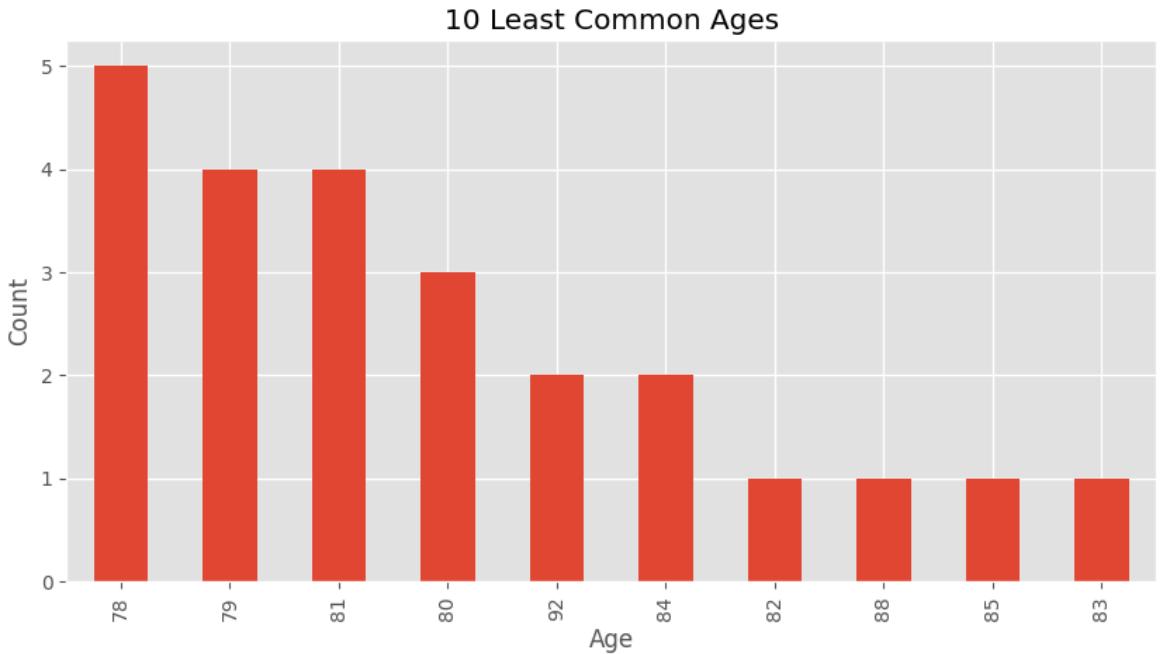


In this plot we can see how the most common clients over our dataset are middle aged clients, in between the range of 30 to 40 years old.

```
In [12]: ax = df['Age'].value_counts() \
    .tail(10) \
    .plot(kind='bar', figsize=(10,5), title='10 Least Common Ages')
```

```
ax.set_xlabel('Age')
ax.set_ylabel('Count')
```

```
Out[12]: Text(0, 0.5, 'Count')
```



On the other side, the 10 least common ages in the dataset predominantly belong to elderly clients, with ages around 75 years old and older. We can see that there are very few customers in this age group, which will might be treated as outliers later.

```
In [13]: ax = df['CreditScore'].plot(kind='kde',
                                 title='Credit Score Distribution')

ax.set_xlabel('Credit Score')
ax.set_ylabel('Count')
```

```
Out[13]: Text(0, 0.5, 'Count')
```

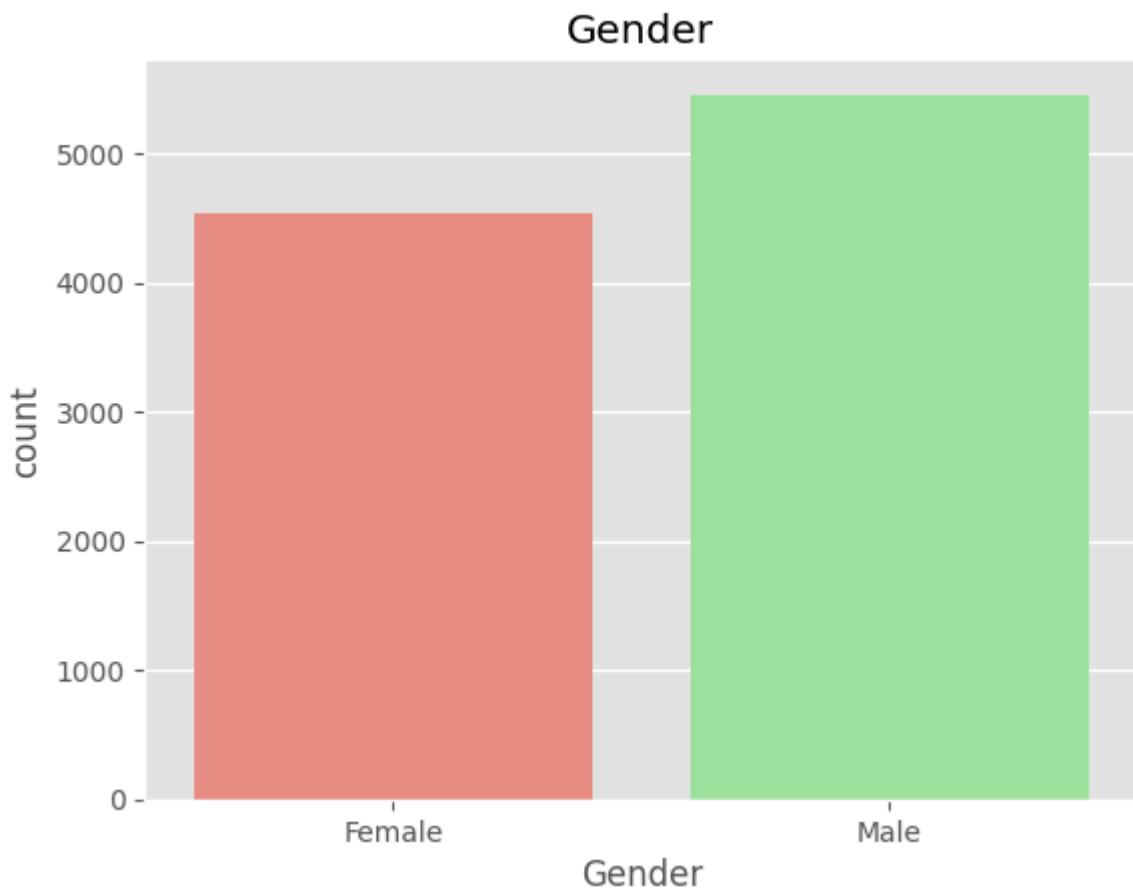


The credit score distribution shows a peak around 700, indicating most customers have a high credit rating. Scores range from 400 to 900, covering a wide spectrum of creditworthiness.

```
In [45]: gender_counts = df['Gender'].value_counts()
print(gender_counts)

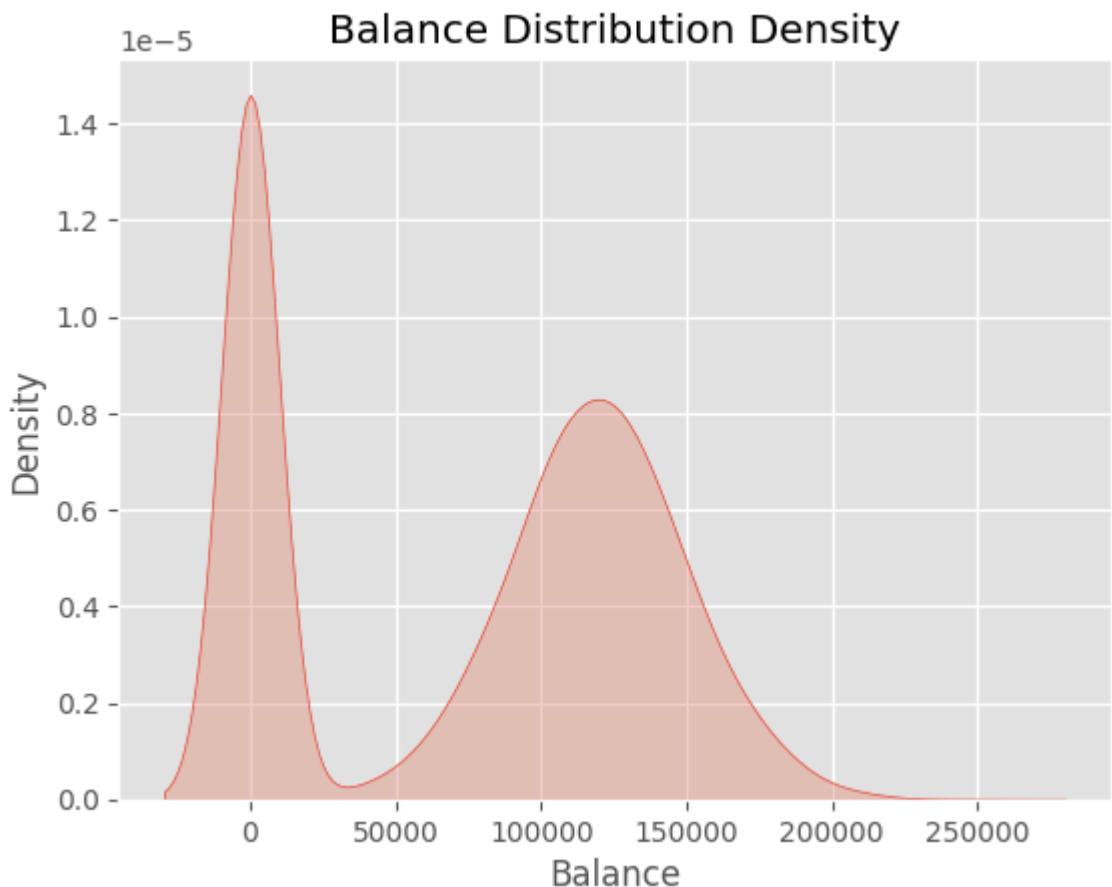
sns.countplot(data=df, x='Gender', hue='Gender', legend=False, palette=['salmon'])
plt.title("Gender")
plt.show()
```

```
Gender
Male      5457
Female    4543
Name: count, dtype: int64
```



The data is also balanced looking at the customers gender, showing a small difference of 5457 male customers over 4543 female customers.

```
In [13]: sns.kdeplot(data=df, x='Balance', fill=True)
plt.title("Balance Distribution Density")
plt.show()
```



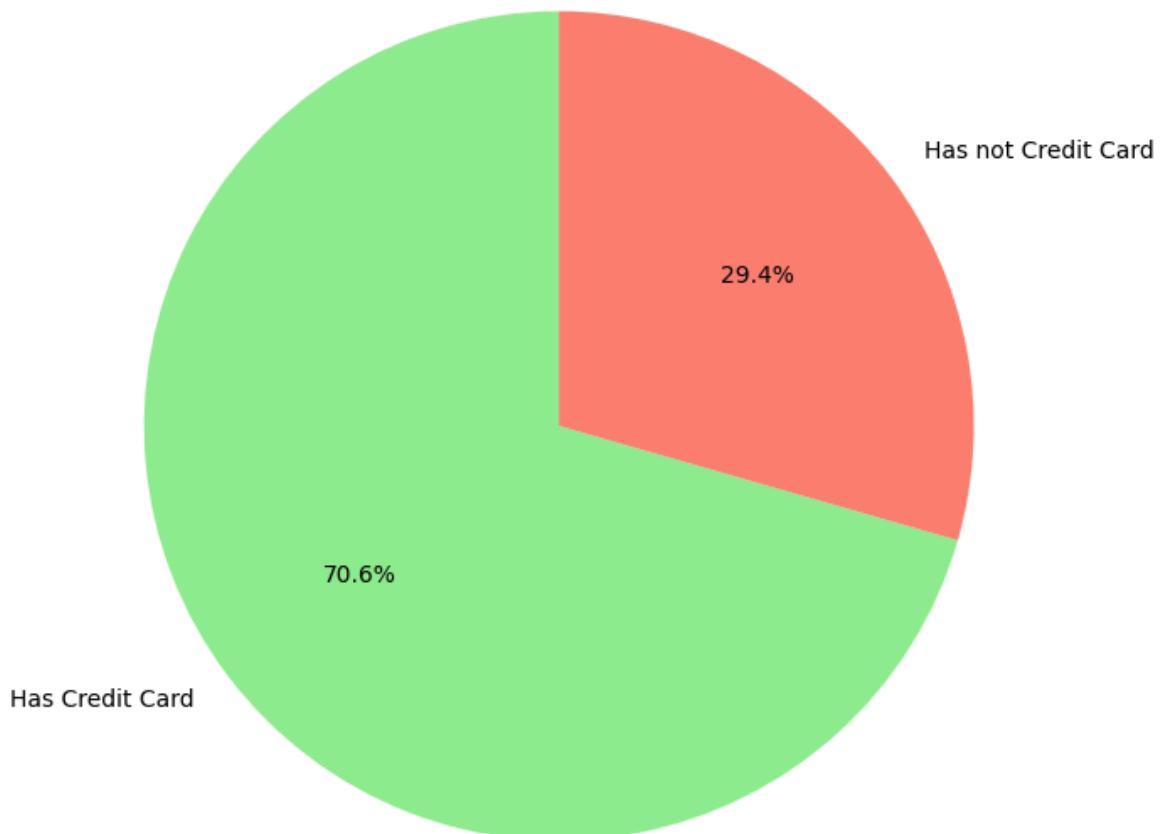
The red curve represents the distribution of all clients, showing a broader range of balances with a peak near zero, and a smaller peak around 125,000.

```
In [14]: has_cr_card_counts = df['HasCrCard'].value_counts()
print(f"Clients with a credit card (HasCrCard = 1): {has_cr_card_counts[1]}")
print(f"Clients without a credit card (HasCrCard = 0): {has_cr_card_counts[0]}")

plt.figure(figsize=(8, 8))
plt.pie(has_cr_card_counts, labels=["Has Credit Card", "Has not Credit Card"], a
plt.title('Card Type Distribution')
plt.show()
plt.show()
```

```
Clients with a credit card (HasCrCard = 1): 7055
Clients without a credit card (HasCrCard = 0): 2945
```

Card Type Distribution



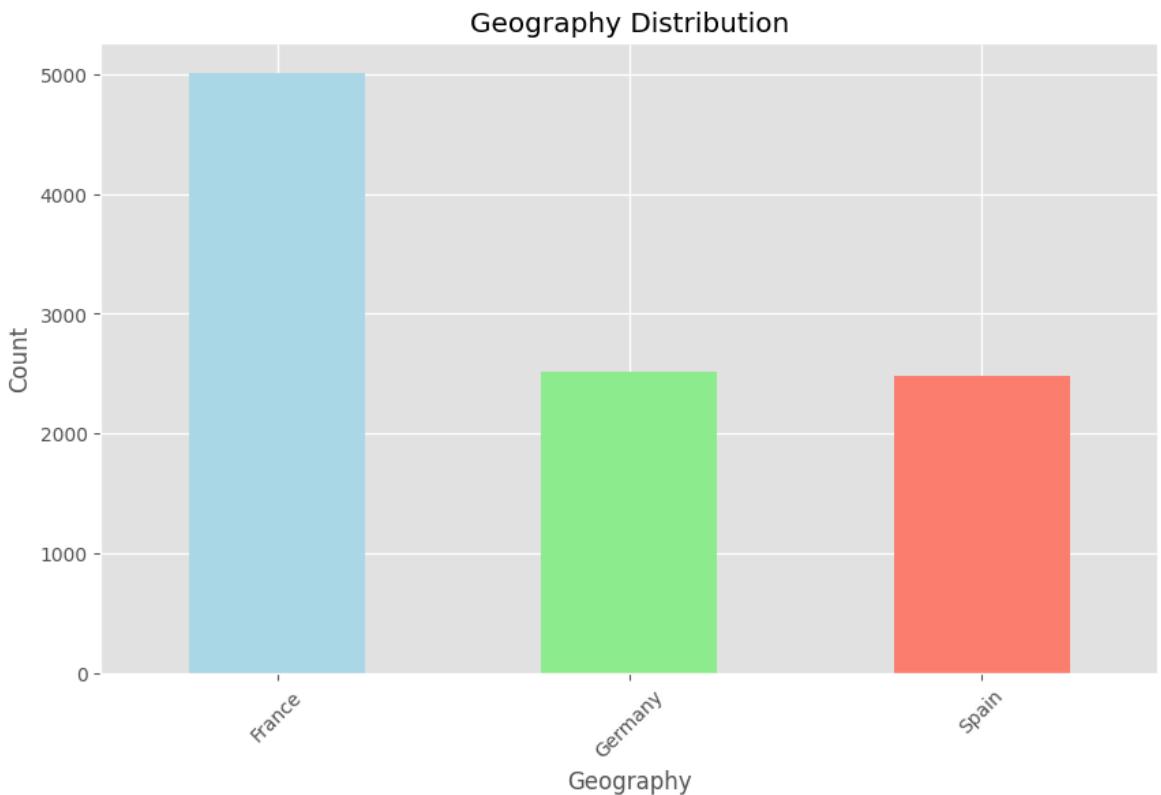
There appears to be a potential imbalance in the dataset between clients who have a credit card and those who do not. This imbalance might hinder the model's predictions if the group with fewer samples is underrepresented. This would be something to take into account later.

```
In [15]: geography_counts = df['Geography'].value_counts()
print("Geography Distribution:\n",geography_counts)

geography_counts.plot(kind='bar', stacked=True, figsize=(10, 6), color=['lightblue', 'lightorange'])
plt.title('Geography Distribution')
plt.xlabel('Geography')
plt.ylabel('Count')
plt.xticks(rotation=45)

plt.show()
```

```
Geography Distribution:
Geography
France      5014
Germany    2509
Spain       2477
Name: count, dtype: int64
```

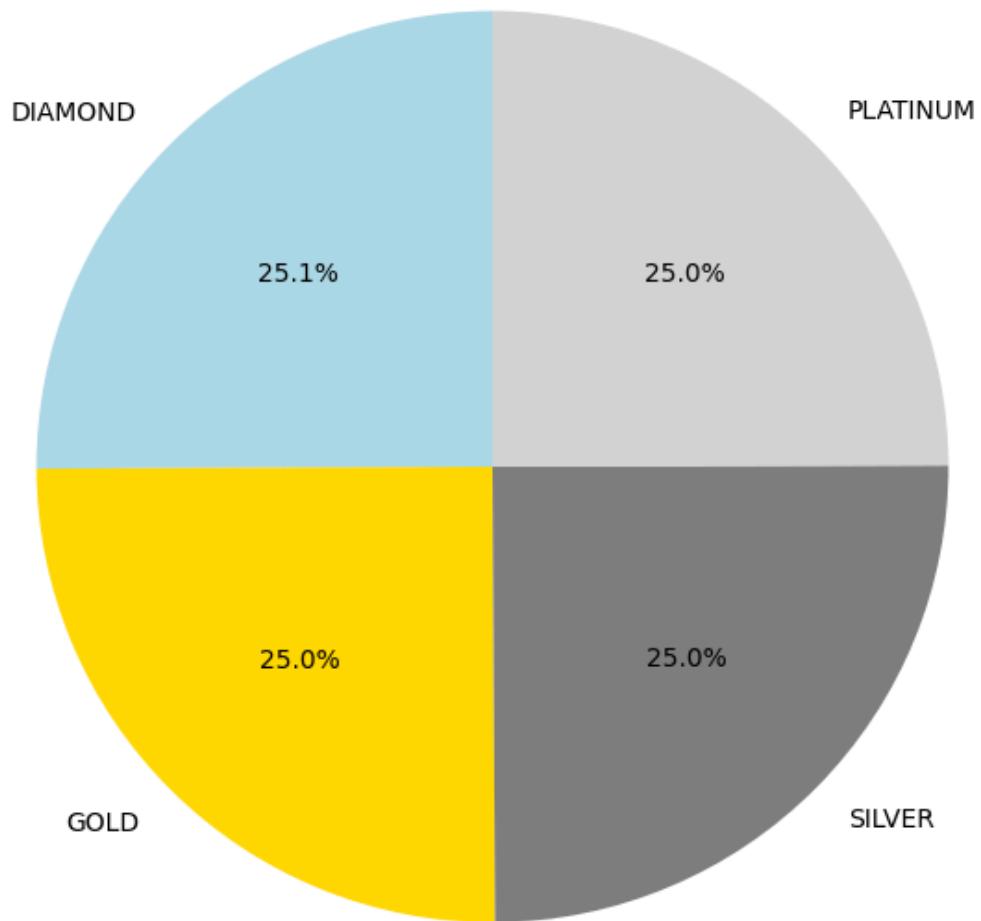


We can see that France has the largest number of clients, while Germany and Spain have similar client counts. This also could mean that German and Spanish customers are undersampled in the dataset.

```
In [16]: card_type_counts = df['Card Type'].value_counts()  
print("Card Type Distribution:\n", card_type_counts)  
  
plt.figure(figsize=(8, 8))  
plt.pie(card_type_counts, labels=card_type_counts.index, autopct='%1.1f%%', colors=[#4CAF50, #FF9800, #FFC107, #FFB74D])  
plt.title('Card Type Distribution')  
plt.show()
```

```
Card Type Distribution:  
Card Type  
DIAMOND      2507  
GOLD         2502  
SILVER        2496  
PLATINUM      2495  
Name: count, dtype: int64
```

Card Type Distribution



```
In [17]: num_of_products_counts = df['NumOfProducts'].value_counts()
print("Number of Products Distribution:\n", num_of_products_counts)

num_of_products_counts.plot(kind='bar', stacked=True, color=['orange','salmon',
plt.title('Number of Products Distribution')
plt.xlabel('Number of Products')
plt.ylabel('Count')
plt.xticks(rotation=0)

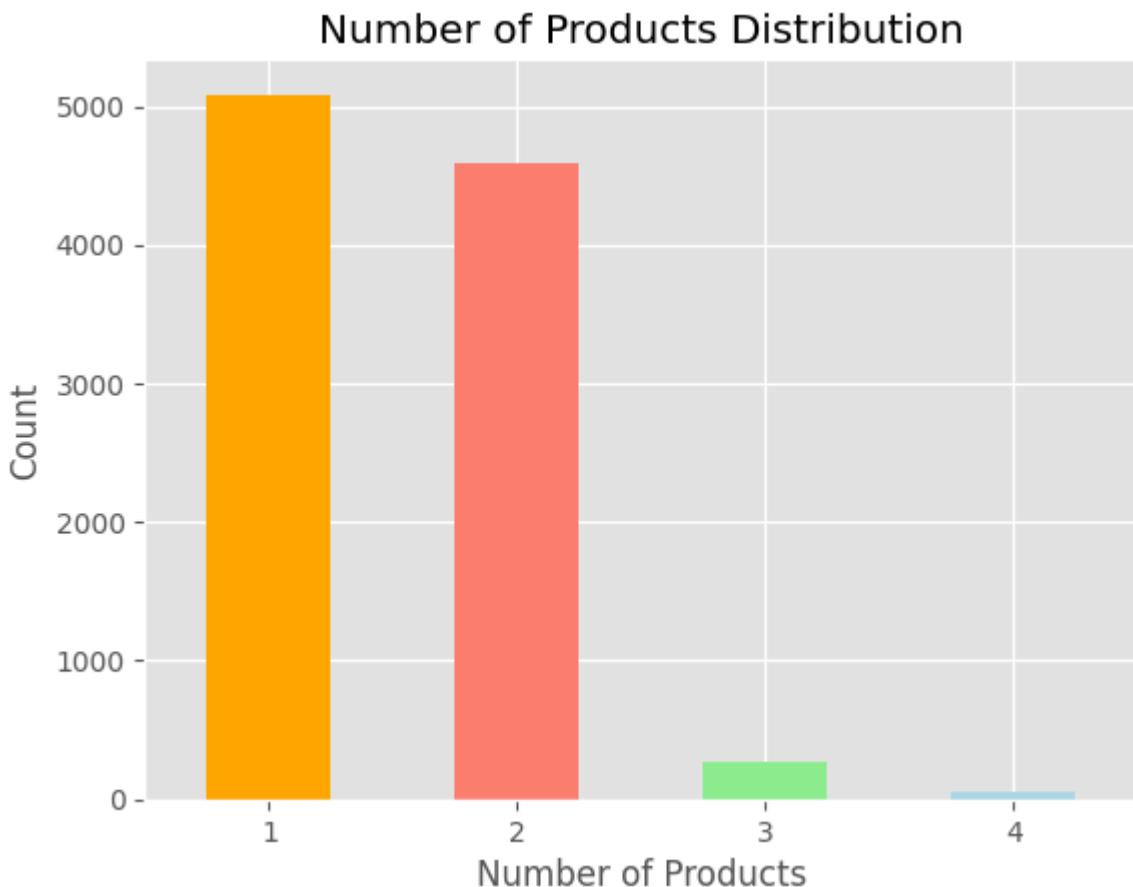
plt.show()
```

Number of Products Distribution:

NumOfProducts

1	5084
2	4590
3	266
4	60

Name: count, dtype: int64

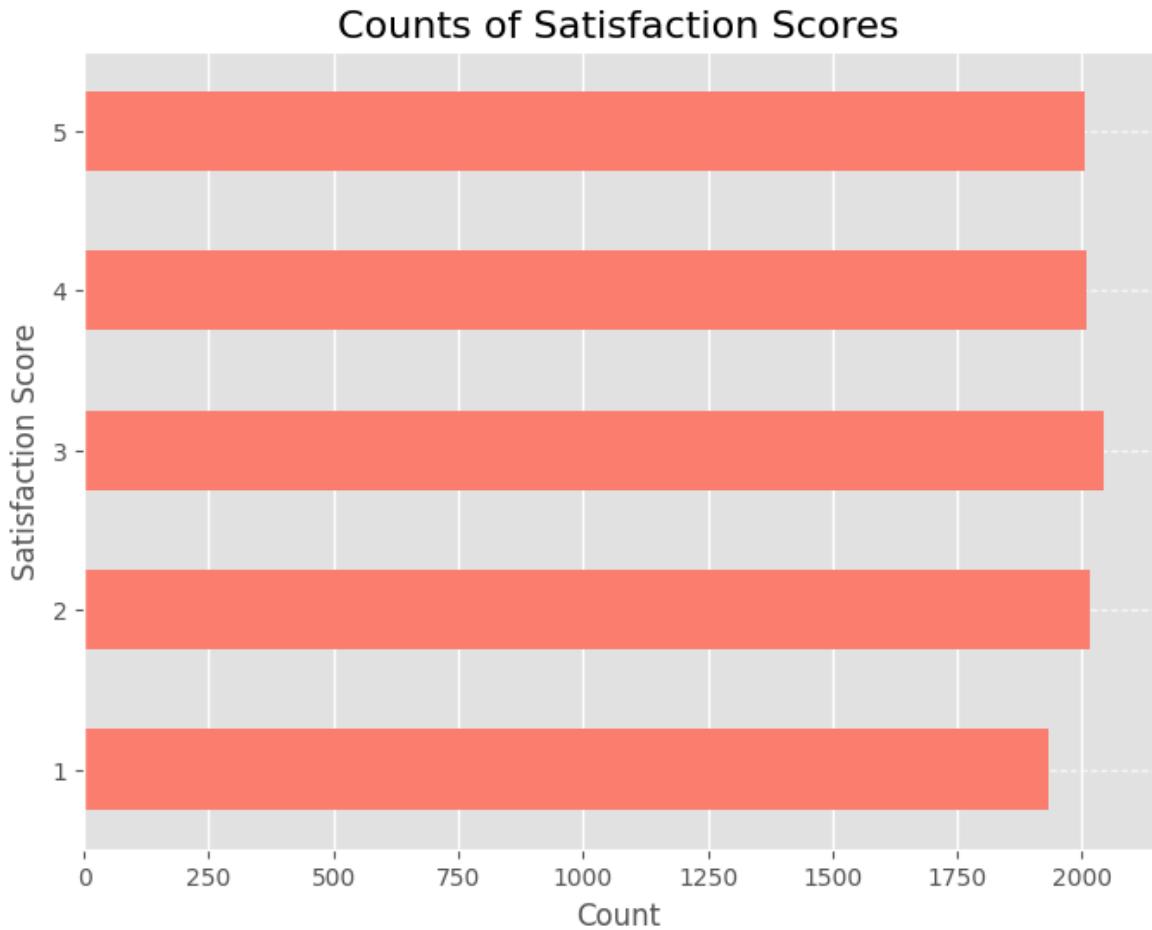


The dataset reveals that the majority of clients have either 1 or 2 products, while very few have 3 or 4 products. This also indicates a significant imbalance in the NumOfProducts feature, with higher product categories being underrepresented. To manage this, we could consider grouping 3 and 4 into a single category or maybe doing just 2 categories (1 product / more than 1 product).

```
In [18]: satisfaction_score_counts = df['Satisfaction Score'].value_counts()
print("Satisfaction Distribution:\n", satisfaction_score_counts)

plt.figure(figsize=(8, 6))
df['Satisfaction Score'].value_counts().sort_index().plot(kind='barh', color='salmon')
plt.title('Counts of Satisfaction Scores', fontsize=16)
plt.xlabel('Count', fontsize=12)
plt.ylabel('Satisfaction Score', fontsize=12)
plt.xticks(rotation=0)
plt.grid(axis='y', linestyle='--', alpha=0.7)
plt.show()
```

```
Satisfaction Distribution:
Satisfaction Score
3    2042
2    2014
4    2008
5    2004
1    1932
Name: count, dtype: int64
```



Satisfaction scores are balanced in the dataset, so it shouldn't disturb the modeling.

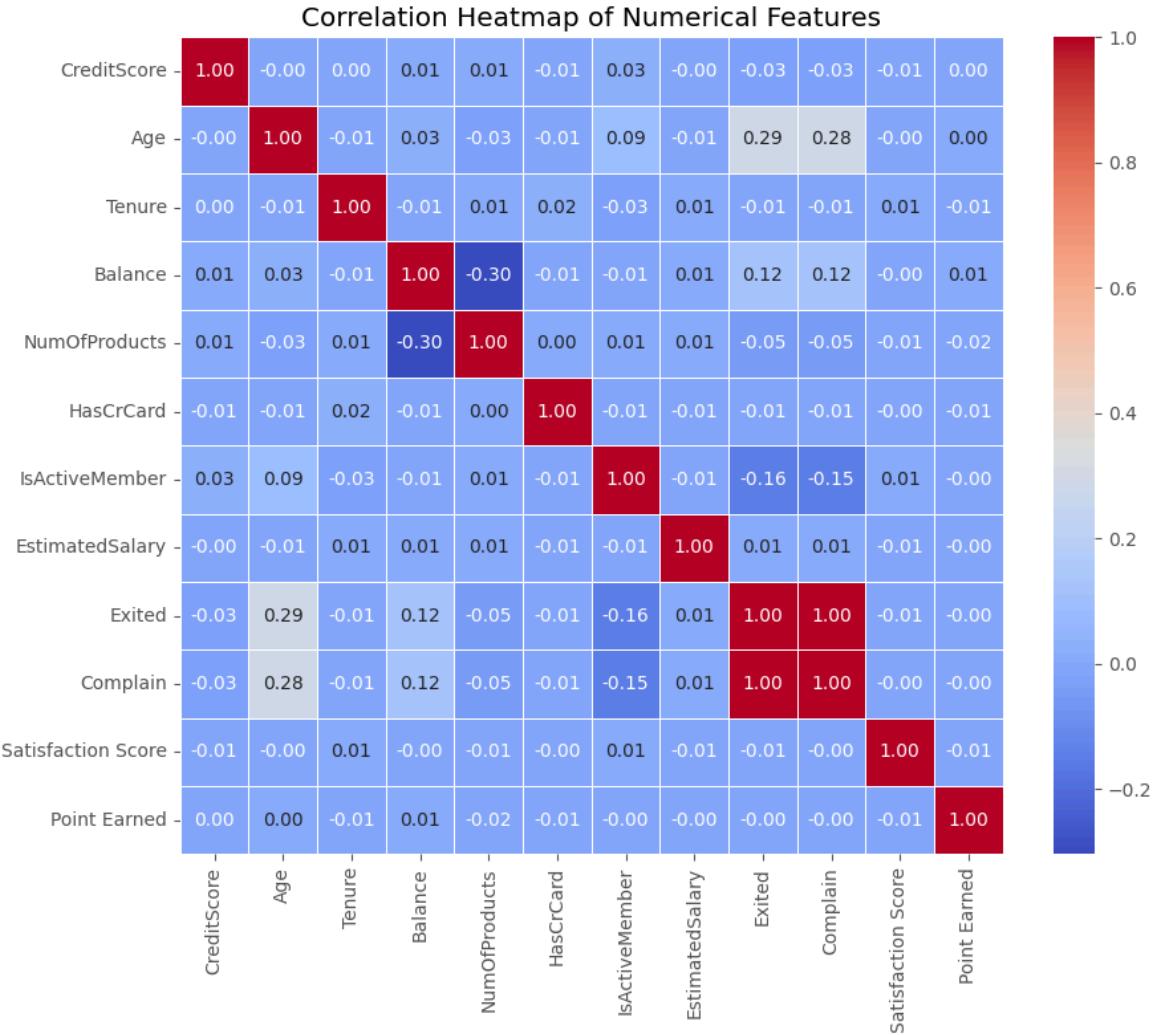
Step 4: Feature Relationships

- Heatmap Correlation
- Pairplot
- Scatterplot
- Groupby comparisons

```
In [19]: numerical_features = df.select_dtypes(include=['float64', 'int64'])

# Compute the correlation matrix
correlation_matrix = numerical_features.corr()

# Plot the heatmap
plt.figure(figsize=(10, 8))
sns.heatmap(correlation_matrix, annot=True, fmt=".2f", cmap="coolwarm", cbar=True)
plt.title('Correlation Heatmap of Numerical Features')
plt.show()
```



As we can see in this *Correlation Heatmap* not many features have big correlations between others. This are some of the most correlated features shown by the plot:

- Complain & Exit
- Number of Products & Balance
- Age & exit
- Is Active Member & Exit
- Balance & Exit

```
In [20]: complain_not_churned = df[(df['Complain'] == 1) & (df['Exited'] == 0)]
complain_not_churned_count = complain_not_churned.shape[0]

not_complain_churned = df[(df['Complain'] == 0) & (df['Exited'] == 1)]
not_complain_churned_count = not_complain_churned.shape[0]

complain_churned = df[(df['Complain'] == 1) & (df['Exited'] == 1)]
complain_churned_count = complain_churned.shape[0]

not_complain_not_churned = df[(df['Complain'] == 0) & (df['Exited'] == 0)]
not_complain_not_churned_count = not_complain_not_churned.shape[0]

fig, axes = plt.subplots(1, 2, figsize=(12, 6))

axes[0].bar(['Complain Not Churned', 'Not Complain Churned'],
```

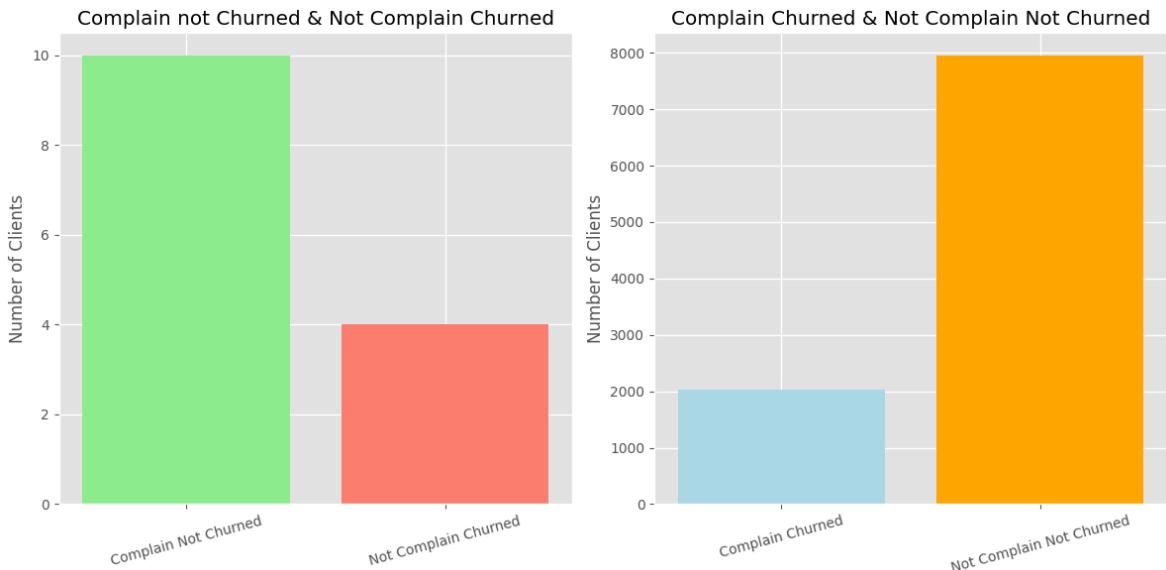
```

        [complain_not_churned_count, not_complain_churned_count],
        color=['lightgreen', 'salmon'])
axes[0].set_title("Complain not Churned & Not Complain Churned")
axes[0].set_ylabel("Number of Clients")
axes[0].set_xticks([0, 1])
axes[0].set_xticklabels(['Complain Not Churned', 'Not Complain Churned'], rotation=45)

axes[1].bar(['Complain Churned', 'Not Complain Not Churned'],
            [complain_churned_count, not_complain_not_churned_count],
            color=['lightblue', 'orange'])
axes[1].set_title("Complain Churned & Not Complain Not Churned")
axes[1].set_ylabel("Number of Clients")
axes[1].set_xticks([0, 1])
axes[1].set_xticklabels(['Complain Churned', 'Not Complain Not Churned'], rotation=45)

plt.tight_layout()
plt.show()

```



As the previous correlation heatmap shows, the exit and complain features have a 100% correlation. Just 10 people complained and not churned and 4 people did not complain when they churned. This could lead to some potential issues, such as high predictive power of features. If complaints strongly correlate with churn, it might dominate predictions in a machine learning model, leading to biased outcomes. On other side, if complaints almost always lead to churn, it may highlight weaknesses in the bank's issue resolution process. Addressing complaints promptly and effectively could improve retention.

```
In [21]: plt.figure(figsize=(15, 4))
sns.scatterplot(
    data=df,
    x='Balance',
    y='NumOfProducts',
    hue='Exited',
    palette=['lightgreen', 'salmon'],
)
plt.title('Balance & Number of Products')
plt.show()
```



In this scatterplot we can see how clients with 3 or more products have a high tendency of churning. In the feature understanding we saw how just 324 clients have 3 or more products, and we said that we might get together every client with 2 or more products.

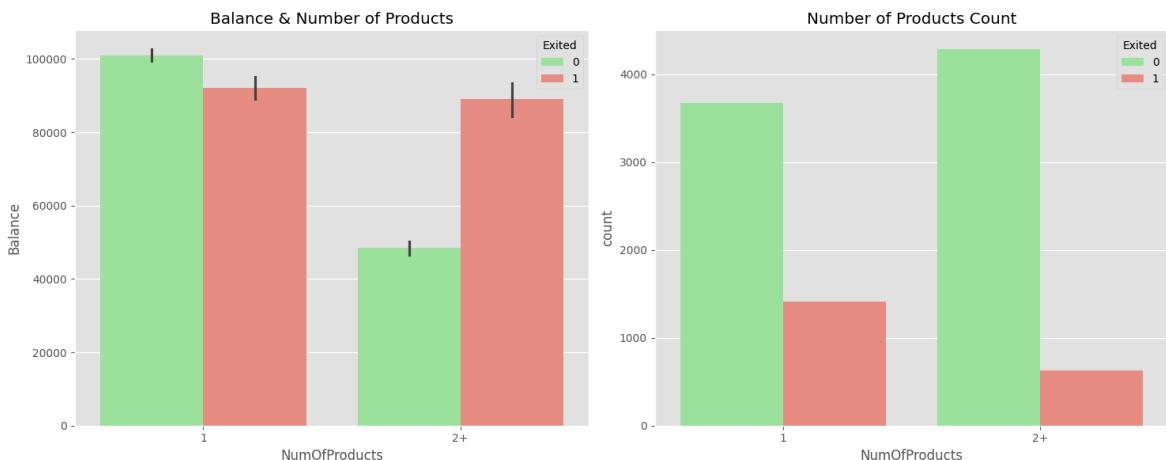
```
In [22]: aid_df = df[['Balance', 'NumOfProducts', 'Exited']].copy()
aid_df['NumOfProducts'] = aid_df['NumOfProducts'].apply(lambda x: '2+' if x >= 2
```

```
In [23]: fig, axes = plt.subplots(1, 2, figsize=(15, 6))

sns.barplot(data=aid_df, x='NumOfProducts', y='Balance', hue='Exited', palette=[]
axes[0].set_title("Balance & Number of Products")

sns.countplot(data=aid_df, x='NumOfProducts', hue='Exited', palette=['lightgreen'
axes[1].set_title("Number of Products Count"))

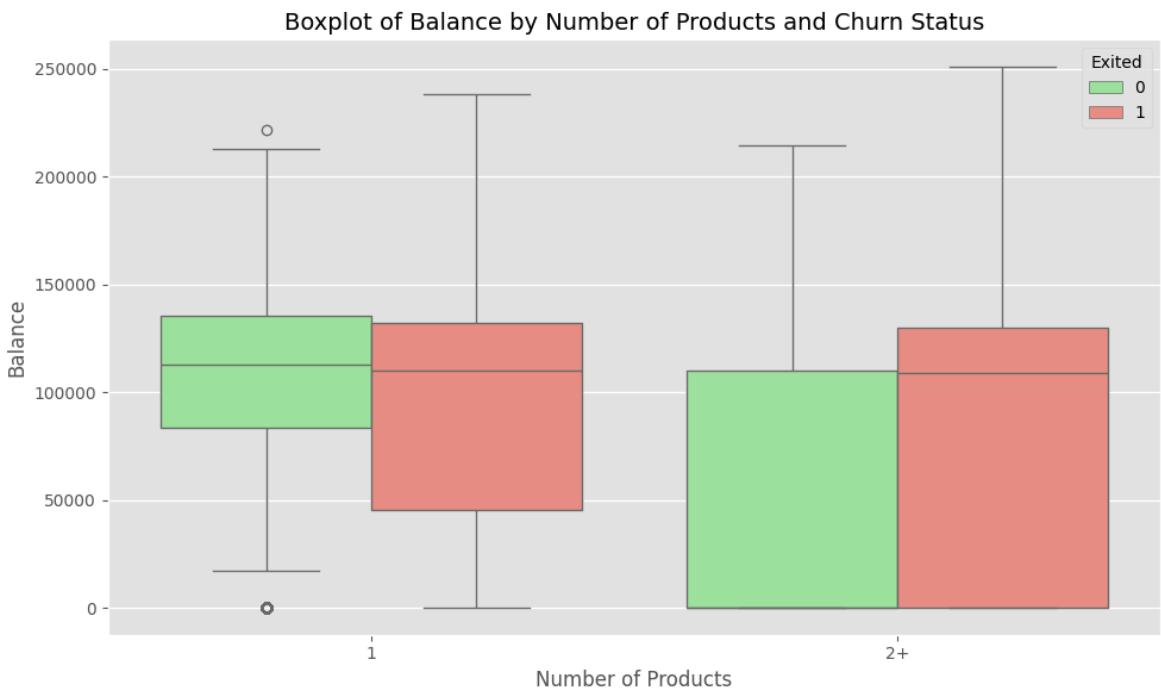
plt.tight_layout()
plt.show()
```



```
In [24]: plt.figure(figsize=(10, 6))
sns.boxplot(data=aid_df, x='NumOfProducts', y='Balance', hue='Exited', palette=[

plt.title("Boxplot of Balance by Number of Products and Churn Status", fontsize=
plt.xlabel("Number of Products", fontsize=12)
plt.ylabel("Balance", fontsize=12)
plt.legend(title='Exited')

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

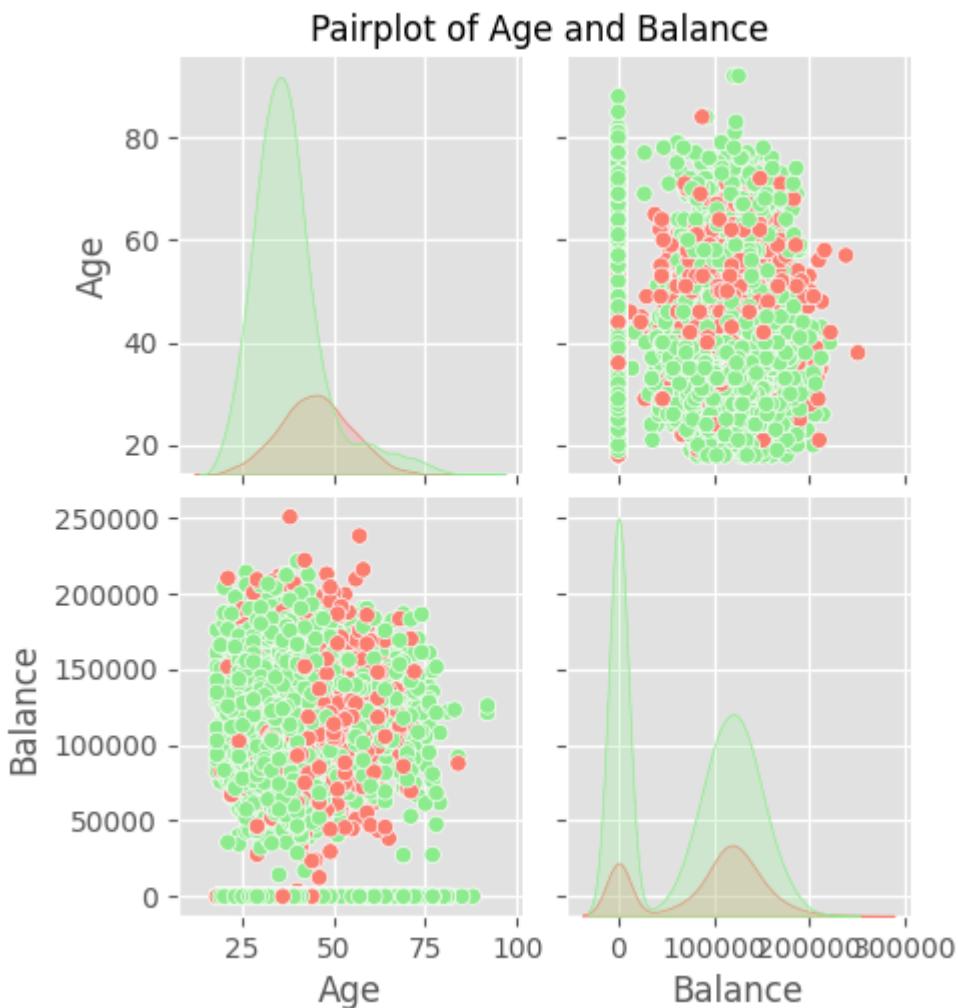


Customers with 2+ products tend to have higher balances on average, and a many of these customers churn. This suggests that while having more products may increase a customer's financial engagement with the bank, it also correlates with a higher risk of them leaving.

Customers with only 1 product generally have lower balances, but a relatively higher proportion of these customers also churn. This indicates that having just one product may also contribute to a higher risk of churn.

The majority of customers own 2 or more products, and they exhibit a relatively stable balance. This suggests that while churn is present, it does not dominate the behavior of the majority of customers with multiple products.

```
In [25]: sns.pairplot(df, vars=['Age', 'Balance'], hue='Exited', palette=['lightgreen', 'red'])
plt.suptitle('Pairplot of Age and Balance', y=1.02)
plt.show()
```



The pairplot shows the relationships between Age and Balance, with each point colored based on whether the customer churned or not. Many conclusion can be taken from this plot:

Churned clients are more concentrated in the middle age range (around 30-60 years old).

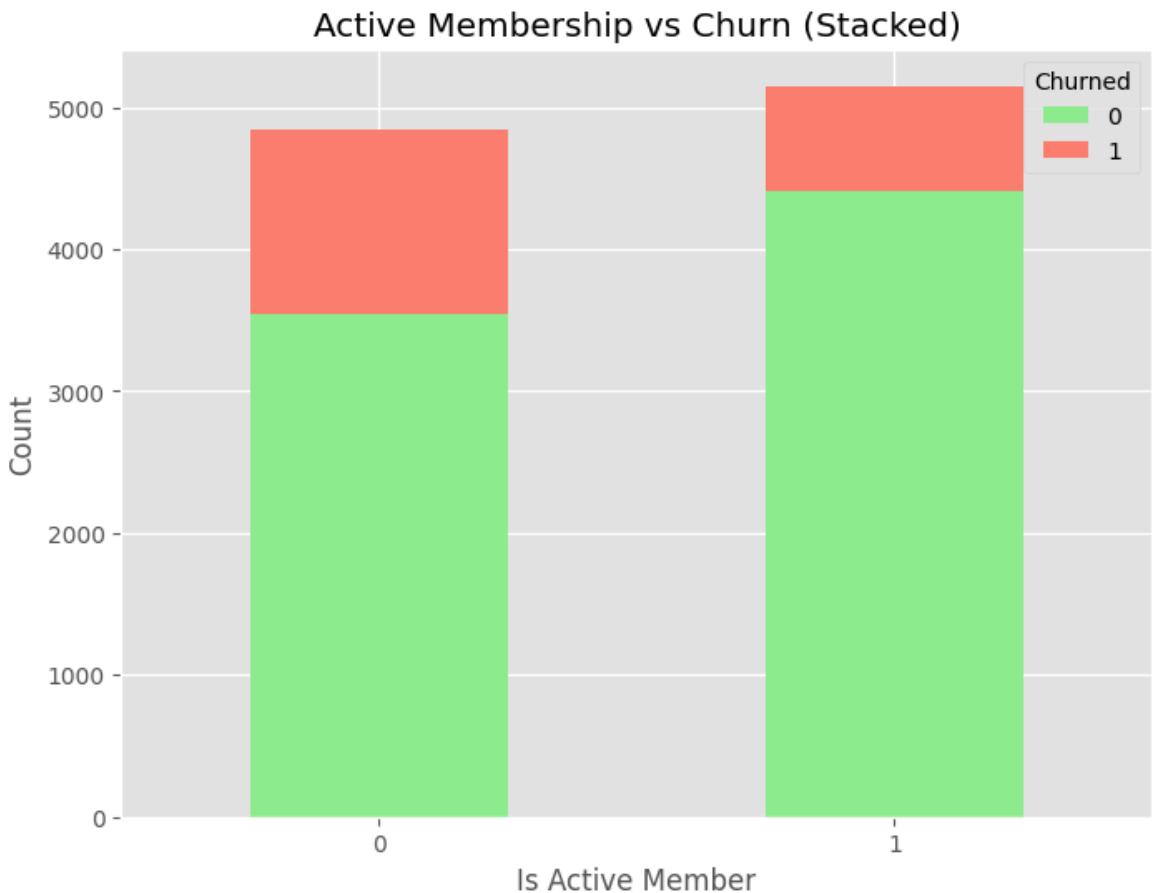
The churn rate closely follows the distribution of clients in balance range.

Churned clients with low balances are concentrated in the younger age groups, while in the 40-60 age range, churned clients have slightly higher balances (5,000-20,000).

```
In [26]: grouped_data = df.groupby(['IsActiveMember', 'Exited']).size().unstack(fill_value=0)

grouped_data.plot(
    kind='bar',
    stacked=True,
    color=['lightgreen', 'salmon'],
    figsize=(8, 6)
)

plt.title("Active Membership vs Churn (Stacked)")
plt.xlabel("Is Active Member")
plt.ylabel("Count")
plt.legend(title="Churned")
plt.xticks(rotation=0)
plt.show()
```



Non-active members show a slightly higher tendency to churn, as seen by their relatively larger proportion of exited clients compared to active members. This could indicate that engagement plays a role in customer retention.

EDA Conclusion

At the beginig of the analysis, we found that the data was clean, with no missing or duplicated entries, allowing for a straightforward analysis.

The EDA highlighted key patterns in the data. For feature understanding, we noticed an uneven age distribution, with very few elderly individuals who could be treated as outliers. Most clients have 1 or 2 products, while 3 or 4 is rare, and there is an imbalance in clients with credit cards.

In feature correlation, almost every client who complained churned, with only a few exceptions. There is also a clear link between balance and the number of products, as well as between non-active clients and churn. These insights will guide the next steps in analyzing and addressing customer churn.

2. Feature Engineering

In this section, we will apply some feature engineering techniques to improve the dataset's usability and try to improve the model's performance. By transforming variables, such as creating categories or simplifying values, we aim to enhance interpretability, address imbalances, and potentially improve our predictive power. These

changes may influence the model's outcomes, making this process a crucial step in the analysis. In this stage we will be applying the following techniques:

- Data Cleaning
- Feature Transformation
- Feature Encoding
- Feature Scaling

Data Cleaning

```
In [52]: import pandas as pd
import numpy as np
import seaborn as sns
from sklearn.preprocessing import OneHotEncoder, MinMaxScaler, StandardScaler
import matplotlib.pyplot as plt
```

```
In [54]: df= pd.read_csv(r'src/rawDataset.csv')
print(df.isnull().sum())
```

```
RowNumber      0
CustomerId     0
Surname        0
CreditScore    0
Geography      0
Gender          0
Age             0
Tenure          0
Balance         0
NumOfProducts   0
HasCrCard       0
IsActiveMember  0
EstimatedSalary 0
Exited          0
Complain        0
Satisfaction Score 0
Card Type       0
Point Earned    0
dtype: int64
```

```
In [55]: duplicates = df.duplicated().sum()
if duplicates > 0:
    print(f"There are {duplicates} duplicated rows in the dataset.")
else:
    print("No duplicated rows found in the dataset.")

df.drop(columns=['RowNumber', 'Surname', 'CustomerId'], inplace= True)
```

No duplicated rows found in the dataset.

RESULT:

As shown, our dataset seems to be complete and reliable. There are no missing values, ensuring every column is fully populated, and there are no duplicate records, which maintains the accuracy of our analysis.

FEATURE TRANSFORMATION

We have decided to transform the Age column into a categorical variable because its distribution does not appear to be normal. This could be due to the presence of outliers, which can significantly affect the distribution's shape and make it look skewed. By categorizing the Age column (Like this: <30, '30-40', '40-50', '50-60', '>60'), we can mitigate the influence of these outliers and make the data more suitable for modeling.

```
In [56]: dfFeature = df  
  
bins = [0, 30, 40, 50, 60, 100]  
labels = ['<30', '30-40', '40-50', '50-60', '>60']  
  
dfFeature['Age'] = pd.cut(dfFeature['Age'], bins=bins, labels=labels, right=False)  
dfFeature.head()
```

Out[56]:

	CreditScore	Geography	Gender	Age	Tenure	Balance	NumOfProducts	HasCrCard
0	619	France	Female	40-50	2	0.00		1
1	608	Spain	Female	40-50	1	83807.86		1
2	502	France	Female	40-50	8	159660.80		3
3	699	France	Female	30-40	1	0.00		2
4	850	Spain	Female	40-50	2	125510.82		1

EXPLANATION:

We have also decided to transform NumOfProducts column as it only has 4.3% of the values corresponding to a value higher than 2. Simplifying it to a binary variable (Like this: "more than one product: yes/no") could improve interpretability and address potential class imbalance, making the data more manageable for analysis.

```
In [57]: dfFeature['NumOfProducts'] = np.where(dfFeature['NumOfProducts'] > 1, 1, 0)  
dfFeature.head()
```

Out[57]:

	CreditScore	Geography	Gender	Age	Tenure	Balance	NumOfProducts	HasCrCard
0	619	France	Female	40-50	2	0.00	0	
1	608	Spain	Female	40-50	1	83807.86	0	
2	502	France	Female	40-50	8	159660.80	1	
3	699	France	Female	30-40	1	0.00	1	
4	850	Spain	Female	40-50	2	125510.82	0	

FEATURE ENCODING

Now we will split our categorical columns including the new Age column. We will be using OneHotEncoder for having the categorical columns as separate binary columns.

In [58]:

```
encoder = OneHotEncoder(sparse_output=False, dtype=int)
catcols = ['Gender', 'Geography', 'Card Type', 'Age']
encData = encoder.fit_transform(dfFeature[catcols])
encDF = pd.DataFrame(encData, columns=encoder.get_feature_names_out(catcols))
dfFeature = pd.concat([dfFeature.drop(columns= catcols),encDF],axis=1)

dfFeature.head()
```

Out[58]:

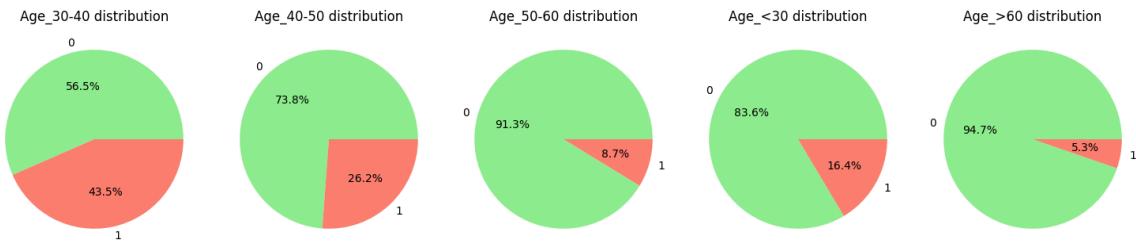
	CreditScore	Tenure	Balance	NumOfProducts	HasCrCard	IsActiveMember	EstimateSalary
0	619	2	0.00	0	1	1	1
1	608	1	83807.86	0	0	0	1
2	502	8	159660.80	1	1	0	0
3	699	1	0.00	1	0	0	0
4	850	2	125510.82	0	1	1	1

5 rows × 25 columns

In [7]:

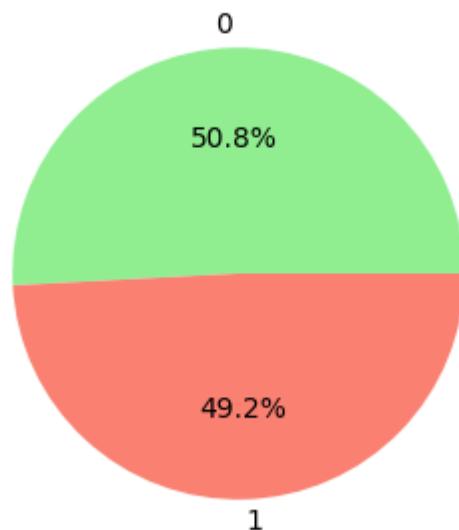
```
ageCols = dfFeature.filter(like='Age', axis=1)
plt.figure(figsize=(15, 10))
for i, column in enumerate(ageCols, 1):
    plt.subplot(2, 5, i)
    dfFeature[column].value_counts().plot.pie(autopct='%1.1f%%', colors=['lightgreen', 'lightblue'])
    plt.title(f'{column} distribution')
    plt.ylabel('')
```

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



```
In [21]: column = 'NumOfProducts'  
plt.figure(figsize=(15, 10))  
plt.subplot(2, 5, i)  
dfFeature[column].value_counts().plot.pie(autopct='%1.1f%%', colors=['lightgreen', 'red'])  
plt.title(f'{column} distribution')  
plt.ylabel('')  
plt.tight_layout()  
plt.show()
```

NumOfProducts distribution



We can observe how now we only have binary values, which might help our model to make better predictions as having columns with that small categories that could harm the performance.

PCA

```
In [46]: # Importing Libraries  
from sklearn.preprocessing import scale  
from sklearn import decomposition  
import pandas as pd  
from sklearn.preprocessing import OneHotEncoder  
import matplotlib.pyplot as plt  
import plotly.express as px  
import seaborn as sns  
import numpy as np
```

```
In [49]: df= pd.read_csv(r'src/rawDataset.csv')
df.drop(columns=['RowNumber','Surname','CustomerId', 'Complain'], inplace= True)
```

We also drop the Complain colum because of its perfect correlation with the target feature. PCA attempts to reduce dimensionality by finding directions (principal components) that maximize variance. If a feature like Complain perfectly correlates with the target or other features, it will dominate the variance structure, skewing the PCA results.

Data Preparation

```
In [50]: encoder = OneHotEncoder(sparse_output=False, dtype=int)
catcols = ['Gender', 'Geography', 'Card Type']
encData = encoder.fit_transform(df[catcols])
encDF = pd.DataFrame(encData, columns=encoder.get_feature_names_out(catcols))
df = pd.concat([df.drop(columns= catcols),encDF],axis=1)
```

```
In [51]: x = df.loc[:, df.columns != 'Exited']
y = df['Exited'].to_numpy()
```

Data Scaling

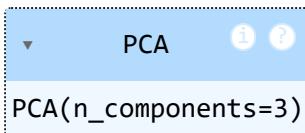
```
In [52]: x_scaled = scale(x)
print(pd.DataFrame(x_scaled, columns=x.columns).head().to_string(index=False))
```

	CreditScore	Age	Tenure	Balance	NumOfProducts	HasCrCard	IsActiveMemb	EstimatedSalary	Satisfaction	Score	Point	Earned	Gender_Female	Gender_Male	Geography_France	Geography_Germany	Geography_Spain	Card Type_DIAMOND	Card Type_GOLD	Card Type_PLATINUM	Card Type_SILVER
43	-0.326221	0.293517	-1.041760	-1.225848		-0.911583	0.646092	0.9702	0.021886		-0.721130	-0.630839	1.095988	-1.095988							
43	0.997204	-0.578736		-0.573809			1.728824		-0.57658	-0.576734			-0.577658								
43	-0.440036	0.198164	-1.387538	0.117350		-0.911583	-1.547768	0.9702	0.216534		-0.009816	-0.666251	1.095988	-1.095988							
43	-1.002804	-0.578736		1.742740			1.728824		-0.57658	-0.576734			-0.577658								
70	-1.536794	0.293517	1.032908	1.333053		2.527057	0.646092	-1.0306	0.240687		-0.009816	-1.015942	1.095988	-1.095988							
70	0.997204	-0.578736		-0.573809			1.728824		-0.57658	-0.576734			-0.577658								
70	0.501521	0.007457	-1.387538	-1.225848		0.807737	-1.547768	-1.0306	-0.108918		1.412812	-1.135457	1.095988	-1.095988							
70	0.997204	-0.578736		-0.573809			-0.578428		-0.57658	-0.576734			1.731128								
43	2.063884	0.388871	-1.041760	0.785728		-0.911583	0.646092	0.9702	-0.365276		1.412812	-0.803472	1.095988	-1.095988							
43	-1.002804	-0.578736		1.742740			-0.578428		-0.57658	-0.576734			1.731128								

PCA Analysis

```
In [53]: pca = decomposition.PCA(n_components=3)
pca.fit(x_scaled)
```

```
Out[53]:
```



```
In [54]:
```

```
scores = pca.transform(x_scaled)

scores_df = pd.DataFrame(scores, columns=[f'PC{i+1}' for i in range(scores.shape[1])])
scores_df
```

```
Out[54]:
```

	PC1	PC2	PC3
0	-1.449904	-1.420653	-0.579166
1	-1.541320	0.623536	1.716155
2	-1.593522	-0.817461	-0.698323
3	-1.318095	-1.764661	-0.215819
4	-1.316640	0.928896	1.541587
...
9995	1.307059	-1.484943	-0.282853
9996	1.404345	-0.987678	-0.775338
9997	-1.378106	-1.709192	-0.413513
9998	1.177377	1.632630	-0.278352
9999	-1.527208	-0.447248	-1.329827

10000 rows × 3 columns

```
In [55]:
```

```
Exit = pd.DataFrame(y, columns=['Exit'])

scores_df = pd.concat([scores_df, Exit], axis=1)
scores_df
```

Out[55]:

	PC1	PC2	PC3	Exit
0	-1.449904	-1.420653	-0.579166	1
1	-1.541320	0.623536	1.716155	0
2	-1.593522	-0.817461	-0.698323	1
3	-1.318095	-1.764661	-0.215819	0
4	-1.316640	0.928896	1.541587	0
...
9995	1.307059	-1.484943	-0.282853	0
9996	1.404345	-0.987678	-0.775338	0
9997	-1.378106	-1.709192	-0.413513	1
9998	1.177377	1.632630	-0.278352	1
9999	-1.527208	-0.447248	-1.329827	0

10000 rows × 4 columns

In [56]:

```
fig = px.scatter(
    scores_df,
    x='PC1',
    y='PC2',
    color='Exit',          # Color by 'Exit'
    size=scores_df['PC3'].abs(), # Represent PC3 with absolute size
    opacity=0.7,            # Adjust opacity for better visibility
    hover_data=['PC3']      # Include PC3 in hover information
)

fig.show()
```

In [57]:

```
fig = px.scatter_3d(scores_df, x='PC1', y='PC2', z='PC3',
                     color='Exit')

fig.show()
```

We can see 6 groups defined in the 3D scatter plot, which suggest that the data can be divided into 6 distinct subgroups based on the first three principal components.

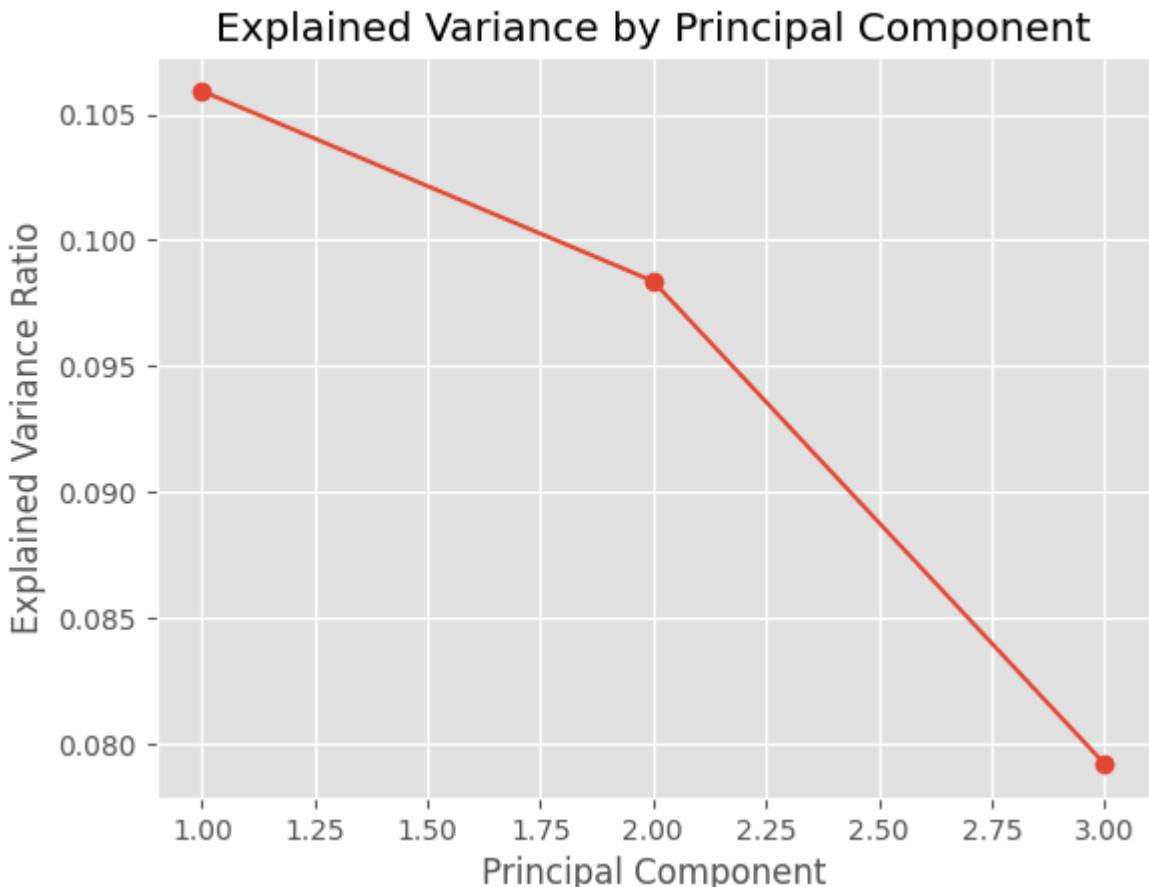
Explained Variance

In [58]:

```
explained_variance = pca.explained_variance_ratio_
print('Explained Variance: ', explained_variance)

plt.plot(range(1, len(explained_variance) + 1), explained_variance, marker='o')
plt.xlabel('Principal Component')
plt.ylabel('Explained Variance Ratio')
plt.title('Explained Variance by Principal Component')
plt.show()
```

Explained Variance: [0.10592038 0.09837363 0.07922671]



These values suggest that the dataset's variance is distributed across many dimensions, and we may need more components to capture a significant proportion of variance.

```
In [59]: cumulative_variance = explained_variance.cumsum()
print('Cumulative Variance: ', cumulative_variance)
```

```
Cumulative Variance:  [0.10592038 0.20429401 0.28352072]
```

Three components capture only 28.35%, indicating that significant variance remains in higher dimensions.

```
In [60]: pca = decomposition.PCA(n_components=10)
pca.fit(x_scaled)

explained_variance = pca.explained_variance_ratio_
print('Explained Variance: ', explained_variance)

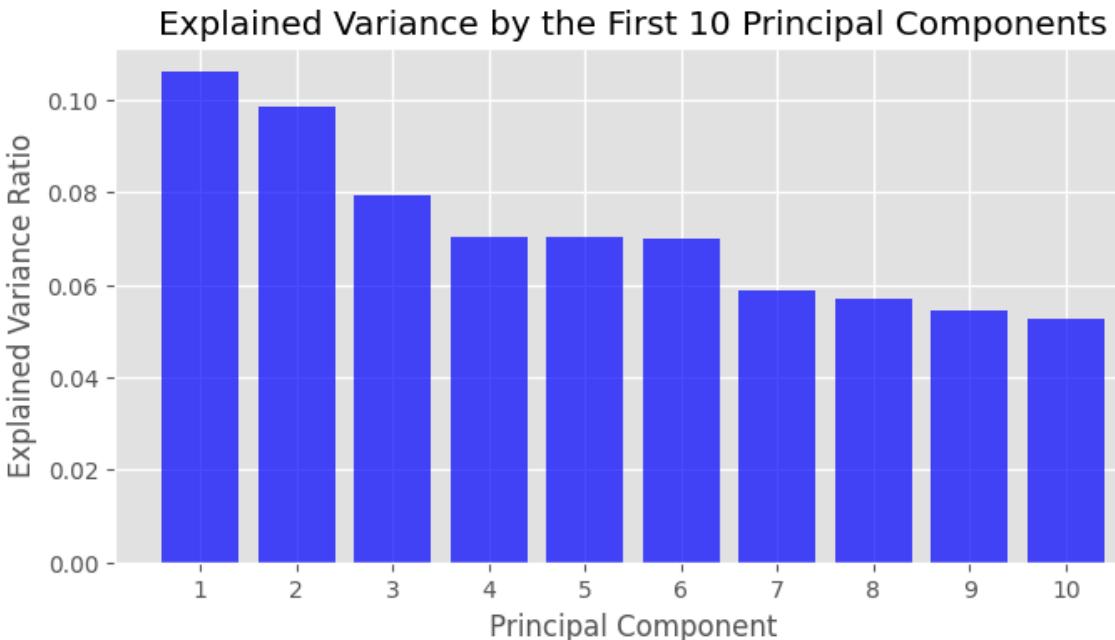
cumulative_variance = explained_variance.cumsum()
print('Cumulative Variance: ', cumulative_variance)

plt.figure(figsize=(8, 4))
plt.bar(range(1, 11), explained_variance, alpha=0.7, color='blue')
plt.title('Explained Variance by the First 10 Principal Components')
plt.xlabel('Principal Component')
plt.ylabel('Explained Variance Ratio')
plt.xticks(range(1, 11))
plt.show()
```

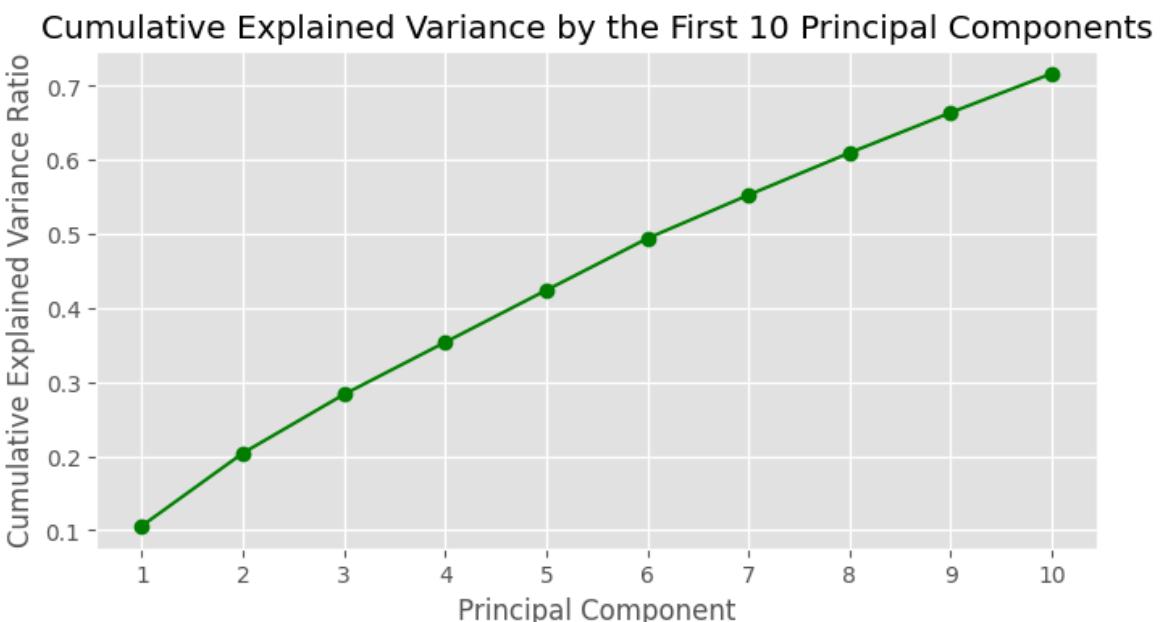
```

Explained Variance: [0.10592038 0.09837363 0.07922671 0.0703642 0.07024081 0.06
993868
0.05867969 0.05694834 0.05433165 0.05274557]
Cumulative Variance: [0.10592038 0.20429401 0.28352072 0.35388492 0.42412573 0.4
9406441
0.5527441 0.60969244 0.66402409 0.71676966]

```



```
In [61]: plt.figure(figsize=(8, 4))
plt.plot(range(1, 11), cumulative_variance, marker='o', linestyle='--', color='green')
plt.title('Cumulative Explained Variance by the First 10 Principal Components')
plt.xlabel('Principal Component')
plt.ylabel('Cumulative Explained Variance Ratio')
plt.xticks(range(1, 11))
plt.grid(True)
plt.show()
```



After testing various numbers of principal components (PCs), we observed that using 10 PCs captured over 70% of the cumulative variance in the data. This indicates that 10 PCs sufficiently represent the majority of the variability in the dataset, so we stay with it even if the dimensionality reduction isn't that big.

```
In [62]: scores = pca.transform(x_scaled)

scores_df = pd.DataFrame(scores, columns=[f'PC{i+1}' for i in range(scores.shape[1])])
scores_df = pd.concat([scores_df, Exit], axis=1)
scores_df
```

```
Out[62]:
```

	PC1	PC2	PC3	PC4	PC5	PC6	PC7	I
0	-1.449904	-1.420653	-0.579166	1.890479	0.394268	0.549733	-1.052197	0.509
1	-1.541320	0.623536	1.716155	1.870597	0.334356	0.600690	-2.034446	-0.159
2	-1.593522	-0.817461	-0.698323	1.835221	0.364414	0.420861	1.915883	0.423
3	-1.318095	-1.764661	-0.215819	-0.988621	-0.530080	1.950536	0.160156	0.264
4	-1.316640	0.928896	1.541587	-0.932987	-0.698928	1.860912	-1.903192	-0.075
...
9995	1.307059	-1.484943	-0.282853	2.092147	0.389727	0.383789	1.336956	0.843
9996	1.404345	-0.987678	-0.775338	-0.806948	1.638382	-0.730150	-0.329279	-0.930
9997	-1.378106	-1.709192	-0.413513	-0.108876	-1.541884	-1.002284	-1.203041	0.076
9998	1.177377	1.632630	-0.278352	-0.998328	-0.537873	1.365209	1.567210	1.162
9999	-1.527208	-0.447248	-1.329827	2.075562	0.378409	0.577626	-0.129008	-1.323

10000 rows × 11 columns



Retrieve the loadings values

```
In [63]: loadings = pca.components_.T

selected_columns = x.columns

columns = [f'PC{i+1}' for i in range(pca.n_components_)]
df_loadings = pd.DataFrame(loadings, columns=columns, index=selected_columns).to

# Step 4: Display the Loadings DataFrame
print("PCA Loadings DataFrame:")
print(df_loadings)
```

PCA Loadings DataFrame:

	PC1	PC2	PC3	PC4	PC5	PC6
PC7	PC8	PC9	PC10			
CreditScore	-0.003197	0.011345	0.014776	0.001870	-0.035921	0.037027
0.026615	0.235893	-0.231481	0.605471			
Age	-0.041709	0.076372	-0.010245	-0.026261	0.021745	0.010084
0.439282	0.415262	0.153168	-0.095515			
Tenure	0.021519	-0.005748	0.016719	0.010194	-0.062902	0.024852
0.285366	-0.103325	0.321627	0.132842			
Balance	-0.027605	0.489158	-0.311919	-0.006732	0.010817	-0.047659
0.162370	-0.195624	-0.010185	0.034340			
NumOfProducts	-0.019590	-0.186871	0.213083	-0.051270	0.007995	-0.007377
0.531891	0.567927	-0.043190	-0.117082			
HasCrCard	0.006981	-0.006405	-0.015618	0.023215	-0.003035	-0.045170
0.219947	-0.029043	0.429031	0.470351			
IsActiveMember	0.030647	-0.012675	0.040994	-0.073289	-0.013131	0.001121
0.460112	0.509446	0.100171	0.024665			
EstimatedSalary	-0.012440	0.009704	-0.011952	-0.049503	-0.028725	-0.019766
0.161733	-0.011810	-0.340188	-0.478595			
Satisfaction Score	0.003212	-0.003626	-0.002336	-0.030179	-0.011885	0.030181
0.080015	-0.068219	0.557213	-0.306809			
Point Earned	-0.019806	0.013448	-0.041030	-0.013076	0.024784	0.008271
0.081048	-0.084179	-0.442607	0.200589			
Gender_Female	-0.699447	-0.062151	0.015941	-0.021613	-0.022506	0.051388
0.018105	-0.030102	0.015158	0.012422			
Gender_Male	0.699447	0.062151	-0.015941	0.021613	0.022506	-0.051388
0.018105	0.030102	-0.015158	-0.012422			
Geography_France	0.049253	-0.588392	-0.459144	0.020291	0.023172	0.029174
0.093326	-0.047221	-0.000052	0.010492			
Geography_Germany	-0.083463	0.590888	-0.231586	-0.071777	-0.007986	-0.064020
0.276106	0.263206	0.014189	-0.042743			
Geography_Spain	0.026773	0.088090	0.764394	0.048583	-0.018820	0.030504
0.169196	-0.209642	-0.014189	0.030775			
Card Type_DIAMOND	-0.026442	0.052694	-0.031019	0.821593	0.157917	0.179577
0.016724	0.087785	-0.003312	-0.045589			
Card Type_GOLD	0.069646	0.037124	-0.023163	-0.409416	-0.241841	0.714217
0.019224	-0.032195	-0.003872	0.012309			
Card Type_PLATINUM	-0.026640	-0.033098	0.046115	-0.365085	0.714084	-0.308702
0.003035	-0.045226	0.017950	0.032638			
Card Type_SILVER	-0.016585	-0.056832	0.008137	-0.048018	-0.630102	-0.585969
0.039023	-0.010473	-0.010756	0.000703			

Loading values help to interpret and understand how the original data is represented in the reduced space created by PCA, helping with model interpretation and decisions on feature selection.

FEATURE SELECTION

Previous Explanation:

For feature selection we have been researching on different methods, we are applying . Our purpose for each of them is to find which selects the best features for our models, a brief explanation about each of them could be:

- Filther Methods: Are statistical feature selection techniques to find more relevant features on a dataset without using any prediction model, depending on the input

variables we are applying:

- Chi-square: This method is used to determine the independence of two categorical variables. Then its ideal in our case for columns like: Gender, Geography,....
- Anova test: As it uses means from numeric features between categorical groups defined by the target variable. Its ideal for example for Balance and Credit Score columns
- Variance Threshold Feature Selection:
 - Univariate Feature Selection with SelectKBest:
- Wrapper methods: These methods evaluate feature subsets by training a predictive model with different combinations of features. The subset that results in the best model performance is selected:
 - Recursive Feature Elimination (RFE):
 - Feature Selection Sequential Feature Selection (SFS):
- Embedded methods: These methods perform feature selection during model training, automatically selecting the most relevant features based on model performance.
 - Feature Selection via SelectFromModel:

```
In [22]: from sklearn.preprocessing import LabelEncoder  
from sklearn.feature_selection import chi2, f_classif
```

```
In [12]: numerical_cols = [  
    'CreditScore', 'Tenure', 'Balance',  
    'EstimatedSalary', 'Satisfaction Score', 'Point Earned'  
]  
categorical_cols = [  
    'HasCrCard', 'NumOfProducts', 'IsActiveMember', 'Complain', 'Gender_Female',  
    'Geography_France', 'Geography_Germany', 'Geography_Spain',  
    'Card Type_DIAMOND', 'Card Type_GOLD', 'Card Type_PLATINUM', 'Card Type_SILV',  
    'Age_30-40', 'Age_40-50', 'Age_50-60', 'Age_<30', 'Age_>60', 'Exited'  
]  
dfFeature[categorical_cols] = dfFeature[categorical_cols].astype('category')  
dfFeature[numerical_cols] = dfFeature[numerical_cols].apply(pd.to_numeric)  
print(dfFeature.dtypes)
```

```

CreditScore           int64
Tenure               int64
Balance              float64
NumOfProducts         category
HasCrCard             category
IsActiveMember        category
EstimatedSalary       float64
Exited                category
Complain              category
Satisfaction Score   int64
Point Earned          int64
Gender_Female          category
Gender_Male             category
Geography_France        category
Geography_Germany       category
Geography_Spain          category
Card Type_DIAMOND        category
Card Type_GOLD             category
Card Type_PLATINUM         category
Card Type_SILVER            category
Age_30-40                  category
Age_40-50                  category
Age_50-60                  category
Age_<30                     category
Age_>60                     category
dtype: object

```

CHI-SQUARE

```

In [37]: dfFeature['Exited'] = dfFeature['Exited'].astype('category')
cats = dfFeature.select_dtypes(include=['object', 'category']).columns
le = LabelEncoder()

if not cats.empty:
    chi2Score, chi2Val = chi2(dfFeature[cats], le.fit_transform(dfFeature['E
    chi2Results = pd.DataFrame({'Feature': dfFeature[cats].columns, 'Chi2 Sc
    chi2Sel = chi2Results[chi2Results['p-Value'] < 0.05]
    print("Características categóricas seleccionadas:")
    print(chi2Sel)

```

Características categóricas seleccionadas:

	Feature	Chi2 Score	p-Value
0	NumOfProducts	174.301778	8.505154e-40
2	IsActiveMember	118.543911	1.318038e-27
3	Exited	7962.000000	0.000000e+00
4	Complain	7887.606705	0.000000e+00
5	Gender_Female	61.623587	4.158076e-15
6	Gender_Male	51.302173	7.918794e-13
7	Geography_France	54.644909	1.443979e-13
8	Geography_Germany	225.008895	7.309210e-51
9	Geography_Spain	20.972597	4.658998e-06
14	Age_30-40	241.537191	1.817748e-54
15	Age_40-50	176.021186	3.582693e-40
16	Age_50-60	681.068598	3.913292e-150
17	Age_<30	166.304621	4.745970e-38
18	Age_>60	18.560097	1.646309e-05

Results:

Chi-square test revealed several significant categorical features that are strongly related to the target variable Exited (whether a customer left the bank). Features like NumOfProducts, IsActiveMember, Complain, and demographics such as Gender and Geography show strong relationships with the likelihood of customer churn. All features have p-values below 0.05, indicating statistical significance.

ANOVA TEST

```
In [38]: nums = dfFeature.select_dtypes(include=['float64', 'int64']).columns

if not nums.empty:
    annScore, annPVal = f_classif(dfFeature[nums], le.fit_transform(dfFeature['Exited']))
    annResults = pd.DataFrame({'Feature': nums, 'F-Score': annScore, 'p-Value': annPVal})
    annSel = annResults[annResults['p-Value'] < 0.05]
    print(annSel)

    Feature      F-Score      p-Value
0  CreditScore  7.170810  7.422037e-03
2      Balance  142.581456  1.209208e-32
```

Results:

The results we obtained from the ANNOVA test evaluate the relationship between numeric features and the target variable Exited. We established a minimum p-value < 0.05 because we wanted to check which features influenced more the target variable results.

In the results, Balance and CreditScore have p-values of 1.2e-32 and 0.0074, respectively, indicating strong evidence that these features affect customer exit. We only have those features as p-value < 0.05 rejects the null hypothesis, confirming the feature's relevance.

```
In [39]: selectedFeatures = list(annSel['Feature'])+list(chi2Sel['Feature'])
print(selectedFeatures)

dffSel = dfFeature[selectedFeatures]
dffSel.head()
```

['CreditScore', 'Balance', 'NumOfProducts', 'IsActiveMember', 'Exited', 'Complain', 'Gender_Female', 'Gender_Male', 'Geography_France', 'Geography_Germany', 'Geography_Spain', 'Age_30-40', 'Age_40-50', 'Age_50-60', 'Age_<30', 'Age_>60']

```
Out[39]:
```

	CreditScore	Balance	NumOfProducts	IsActiveMember	Exited	Complain	Gender_Female	Gender_Male	Geography_France	Geography_Germany	Geography_Spain	Age_30-40	Age_40-50	Age_50-60	Age_<30	Age_>60	
0	619	0.00	0	1	1	1											
1	608	83807.86	0	1	0	1											
2	502	159660.80	1	0	1	1											
3	699	0.00	1	0	0	0											
4	850	125510.82	0	1	0	0											

Variance Threshold Feature Selection

```
In [59]: from sklearn.feature_selection import VarianceThreshold
import pandas as pd
import numpy as np
import seaborn as sns
from sklearn.preprocessing import StandardScaler
import matplotlib.pyplot as plt
from sklearn.feature_selection import SelectKBest, mutual_info_regression
from sklearn.feature_selection import RFE
from sklearn.ensemble import RandomForestClassifier
from sklearn.feature_selection import SelectFromModel
from sklearn.feature_selection import SequentialFeatureSelector
```

```
In [60]: rawFeatureSel_df = dfFeature
featselDf = rawFeatureSel_df.drop(columns=['Exited', 'Complain'])
scaler = StandardScaler()
featselDf[['CreditScore', 'Balance', 'EstimatedSalary']] = scaler.fit_transform(
featselDf.head()
featselDf.head()
```

Out[60]:

	CreditScore	Tenure	Balance	NumOfProducts	HasCrCard	IsActiveMember	Estima
0	-0.326221	2	-1.225848	0	1	1	
1	-0.440036	1	0.117350	0	0	1	
2	-1.536794	8	1.333053	1	1	0	
3	0.501521	1	-1.225848	1	0	0	
4	2.063884	2	0.785728	0	1	1	

5 rows × 23 columns



```
In [61]: featselDf.var()
```

```
Out[61]: CreditScore      1.000100
Tenure           8.364673
Balance          1.000100
NumOfProducts    0.249954
HasCrCard        0.207791
IsActiveMember   0.249797
EstimatedSalary  1.000100
Satisfaction Score 1.976607
Point Earned     51042.032975
Gender_Female    0.247936
Gender_Male       0.247936
Geography_France 0.250023
Geography_Germany 0.187968
Geography_Spain   0.186363
Card Type_DIAMOND 0.187868
Card Type_GOLD    0.187619
Card Type_PLATINUM 0.187268
Card Type_SILVER   0.187319
Age_30-40         0.245747
Age_40-50         0.193280
Age_50-60         0.079356
Age_<30           0.137185
Age_>60           0.049838
dtype: float64
```

Here we have the variability of each feature, with higher values indicating more variability. Features with very low variance, such as Age_>60 (0.0498), contribute little to differentiate between data points and can usually be removed.

```
In [62]: selector = VarianceThreshold(1)
selector.fit(featselDf)
featselDf.columns[selector.get_support()]
```

```
Out[62]: Index(['Tenure', 'Satisfaction Score', 'Point Earned'], dtype='object')
```

Setting a threshold of 1 selects the three features with variability above that level: Tenure, Satisfaction Score, and Point Earned, indicating these have meaningful variance in the dataset. Lower threshold selections would include more features with smaller variances.

Univariate Feature Selection with SelectKBest

```
In [63]: from sklearn.feature_selection import SelectKBest, mutual_info_regression
selector = SelectKBest(mutual_info_regression, k=2)

selector.fit(featselDf, rawFeatureSel_df['Exited'])
featselDf.columns[selector.get_support()]
```

```
Out[63]: Index(['Age_50-60', 'Age_<30'], dtype='object')
```

Age_50-60 and Age_<30 have the highest relevance for predicting the target. These features were chosen over others as they provide the most useful information for the model.

Recursive Feature Elimination (RFE)

```
In [64]: rfe = RFE(estimator=RandomForestClassifier(), n_features_to_select=5)
X = featselDF
y = rawFeatureSel_df['Exited']

rfe.fit(X, y)

X.columns[rfe.get_support()]
```

```
Out[64]: Index(['CreditScore', 'Tenure', 'Balance', 'EstimatedSalary', 'Point Earned'],
dtype='object')
```

We choose a Random Forest for Recursive Feature Elimination (RFE) because it automatically shows which features are most important. The output indicates that CreditScore, Tenure, Balance, EstimatedSalary, and Point Earned are the top five features selected by the RFE method, meaning they have the highest relevance for predicting churn in the dataset. These features are considered the most influential in the model's performance.

Feature Selection via SelectFromModel

```
In [65]: sfm = SelectFromModel(estimator=RandomForestClassifier())
sfm.fit(X, y)

X.columns[sfm.get_support()]
```

```
Out[65]: Index(['CreditScore', 'Tenure', 'Balance', 'EstimatedSalary',
                 'Satisfaction Score', 'Point Earned', 'Age_50-60'],
                dtype='object')
```

In the selection via SelectFromModel we also used a Random Forest as estimator but we see how the outcome differs compared to the other methods. In this model we see how 'CreditScore', 'Tenure', 'Balance', 'EstimatedSalary', 'Satisfaction Score', 'Point Earned' and 'Age_50-60' might be the most influential in the model's performance.

Feature Selection Sequential Feature Selection (SFS)

```
In [66]: vt = VarianceThreshold(threshold=0.1)
X_reduced = vt.fit_transform(X)

sfs_selector = SequentialFeatureSelector(estimator=RandomForestClassifier(), n_f
sfs_selector.fit(X_reduced, y)

selected_columns = X.columns[vt.get_support()][sfs_selector.get_support()]
print(selected_columns)
```

```
Index(['Age_30-40', 'Age_40-50', 'Age_<30'], dtype='object')
```

These age-related features were identified as the most relevant for predicting churn in the dataset by SFS, which is a method for selecting features by iteratively adding or removing them based on their importance, using again as a estimator, a RandomForestClassifier

3. Classification

After selecting the most important features by feature selection we are going to begin with classification. We will be training our models for which **EXITED** is going to be our target as our main task is to predict if a client will leave or not a Bank. We will be using the following algorithms:

- Logistic Regression
- Decision Tree Classifier
- Random Forest Classifier
- Support Vector Machine (SVM)
- Naive Bayes

As our dataset is imbalanced, we are expecting to have low values in some of our metrics due to our imbalanced dataset. We are going to be applying `class_weight='balanced'` parameter to our models to have more reliable results as the model will be penalized more for misclassifying the minority class, like that we could adjust the model to the data. We are also applying Stratified K-Fold Cross-Validation to handle class imbalance, ensuring fair performance evaluation. Our goal metric is to maximize the ROC-AUC score, as we want to prioritize model discrimination ability for imbalanced classes.

We are using 5 metrics to evaluate our models: **accuracy, precision, recall, f1, roc-auc**. As each of them can tell us important information about our models. As for example:

- Accuracy gives us the overall percentage of correct predictions, but it may not be reliable in imbalanced datasets, as it can be high even if the model fails to identify minority class cases (e.g., churn).
- Precision helps us understand how many of the predicted "churn" cases are actually correct. It's crucial when the cost of false positives (e.g., offering incentives to non-churning customers) is high.
- Recall shows us how many actual "churn" cases were correctly identified. It's important when the goal is to identify as many churners as possible, even if that means some non-churners are incorrectly labeled.
- F1-Score balances both precision and recall, providing a single metric that helps us evaluate the trade-off between the two, especially when dealing with imbalanced classes.
- ROC-AUC measures the model's ability to distinguish between churners and non-churners. It provides insight into the model's overall discriminatory power, regardless of threshold, and is especially useful when we care about both true positive and false positive rates.

Each of these metrics gives us a different perspective on how well our model is performing and could be interesting in our project perspective as maybe we will be having clients that seem to be churning but finally no, and contrary.

```
In [8]: import optuna
from sklearn.linear_model import LogisticRegression
from sklearn.ensemble import RandomForestClassifier
from sklearn.tree import DecisionTreeClassifier
from sklearn.metrics import accuracy_score, precision_score, recall_score, f1_score
from sklearn.model_selection import train_test_split, cross_val_score, StratifiedKFold
from sklearn.preprocessing import StandardScaler
from sklearn.metrics import confusion_matrix, ConfusionMatrixDisplay
from sklearn.svm import SVC
from sklearn.naive_bayes import GaussianNB
import matplotlib.pyplot as plt
```

Logistic Regression

```
In [9]: X = dfFeature.drop(['Exited', 'Complain'], axis=1)
y = dfFeature['Exited']

X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_state=42)

y_train.value_counts()
```

```
Out[9]: Exited
0    6370
1    1630
Name: count, dtype: int64
```

The hyperparameters that are going to be tuned are:

- Solver: Different solvers (lbfgs, liblinear, saga, sag) to account for varying dataset sizes and characteristics, ensuring flexibility in optimization.
- C (Inverse of Regularization Strength): A logarithmic scale (1e-6 to 1e2) to explore a wide range, allowing the model to generalize well without overfitting or underfitting.
- max_iter: The iteration range (100 to 5000) ensures the model converges even for complex datasets, preventing early stopping.

```
In [25]: scaler = StandardScaler()
X_train_scaled = scaler.fit_transform(X_train)
X_test_scaled = scaler.transform(X_test)

def objective(trial):
    solver = trial.suggest_categorical("solver", ["lbfgs", "liblinear", "saga", "sag"])
    C = trial.suggest_float("C", 1e-6, 1e2, log=True)
    max_iter = trial.suggest_int('max_iter', 100, 1000)
    model = LogisticRegression(
        solver=solver,
        C=C,
        random_state=42,
        class_weight='balanced',
        max_iter=max_iter
    )
    skf = StratifiedKFold(n_splits=5, shuffle=True, random_state=42)
```

```
score = cross_val_score(model, X_train_scaled, y_train, cv=skf, scoring="roc_auc")
return score

logisticStudy = optuna.create_study(direction='maximize')
logisticStudy.optimize(objective,n_trials=500, n_jobs=-1)
print("Best hyperparameters:", logisticStudy.best_params)

best_params = logisticStudy.best_params
logistic_model = LogisticRegression(**best_params, class_weight='balanced', random_state=42)
logistic_model.fit(X_train_scaled, y_train)

y_pred = logistic_model.predict(X_test_scaled)
y_pred_proba = logistic_model.predict_proba(X_test_scaled)[:, 1]
```

```
[I 2024-12-23 09:54:59,938] A new study created in memory with name: no-name-34e00638-062f-4ea7-9551-f19bc9e4c0bc
[I 2024-12-23 09:55:04,964] Trial 19 finished with value: 0.7947602353824967 and parameters: {'solver': 'liblinear', 'C': 0.0005521973204912225, 'max_iter': 178}. Best is trial 19 with value: 0.7947602353824967.
[I 2024-12-23 09:55:04,970] Trial 4 finished with value: 0.7888771176238311 and parameters: {'solver': 'lbfgs', 'C': 1.3492732821427087e-05, 'max_iter': 132}. Best is trial 19 with value: 0.7947602353824967.
[I 2024-12-23 09:55:04,982] Trial 12 finished with value: 0.7886122641600293 and parameters: {'solver': 'liblinear', 'C': 6.667536721715285e-06, 'max_iter': 493}. Best is trial 19 with value: 0.7947602353824967.
[I 2024-12-23 09:55:05,026] Trial 0 finished with value: 0.7961196559794279 and parameters: {'solver': 'sag', 'C': 0.07718099694163663, 'max_iter': 360}. Best is trial 0 with value: 0.7961196559794279.
[I 2024-12-23 09:55:05,039] Trial 18 finished with value: 0.7959540021766138 and parameters: {'solver': 'saga', 'C': 0.0026656663431239786, 'max_iter': 833}. Best is trial 0 with value: 0.7961196559794279.
[I 2024-12-23 09:55:05,091] Trial 13 finished with value: 0.7961047278751048 and parameters: {'solver': 'liblinear', 'C': 5.48123513328014, 'max_iter': 780}. Best is trial 0 with value: 0.7961196559794279.
[I 2024-12-23 09:55:05,107] Trial 15 finished with value: 0.796116766668914 and parameters: {'solver': 'lbfgs', 'C': 0.023922433593923428, 'max_iter': 958}. Best is trial 0 with value: 0.7961196559794279.
[I 2024-12-23 09:55:05,138] Trial 2 finished with value: 0.7884181988038255 and parameters: {'solver': 'lbfgs', 'C': 1.0267308459296932e-06, 'max_iter': 443}. Best is trial 0 with value: 0.7961196559794279.
[I 2024-12-23 09:55:05,142] Trial 6 finished with value: 0.7961095433926284 and parameters: {'solver': 'sag', 'C': 0.23309785835319696, 'max_iter': 874}. Best is trial 0 with value: 0.7961196559794279.
[I 2024-12-23 09:55:05,164] Trial 8 finished with value: 0.796107617185619 and parameters: {'solver': 'liblinear', 'C': 0.2653960819220067, 'max_iter': 395}. Best is trial 0 with value: 0.7961196559794279.
[I 2024-12-23 09:55:05,210] Trial 10 finished with value: 0.7961056909786095 and parameters: {'solver': 'sag', 'C': 19.214718992066793, 'max_iter': 923}. Best is trial 0 with value: 0.7961196559794279.
[I 2024-12-23 09:55:05,237] Trial 7 finished with value: 0.7944669703653052 and parameters: {'solver': 'liblinear', 'C': 0.0004678441902243169, 'max_iter': 894}. Best is trial 0 with value: 0.7961196559794279.
[I 2024-12-23 09:55:05,238] Trial 1 finished with value: 0.7886459727826949 and parameters: {'solver': 'sag', 'C': 7.279946901305493e-06, 'max_iter': 957}. Best is trial 0 with value: 0.7961196559794279.
[I 2024-12-23 09:55:05,313] Trial 11 finished with value: 0.7896996080168736 and parameters: {'solver': 'saga', 'C': 4.452588499697638e-05, 'max_iter': 821}. Best is trial 0 with value: 0.7961196559794279.
[I 2024-12-23 09:55:05,320] Trial 17 finished with value: 0.7961095433926284 and parameters: {'solver': 'saga', 'C': 0.39748471246791556, 'max_iter': 786}. Best is trial 0 with value: 0.7961196559794279.
[I 2024-12-23 09:55:05,362] Trial 3 finished with value: 0.7938756248133987 and parameters: {'solver': 'saga', 'C': 0.00033539777227982107, 'max_iter': 696}. Best is trial 0 with value: 0.7961196559794279.
[I 2024-12-23 09:55:05,412] Trial 5 finished with value: 0.7961032832198476 and parameters: {'solver': 'saga', 'C': 72.2905136778406, 'max_iter': 357}. Best is trial 0 with value: 0.7961196559794279.
[I 2024-12-23 09:55:05,417] Trial 20 finished with value: 0.7961100249443808 and parameters: {'solver': 'saga', 'C': 0.3224703712592116, 'max_iter': 388}. Best is trial 0 with value: 0.7961196559794279.
[I 2024-12-23 09:55:05,463] Trial 9 finished with value: 0.7961052094268571 and parameters: {'solver': 'sag', 'C': 13.433825798766824, 'max_iter': 726}. Best is trial 0 with value: 0.7961196559794279.
[I 2024-12-23 09:55:05,512] Trial 14 finished with value: 0.7897646175034432 and
```

```
parameters: {'solver': 'liblinear', 'C': 4.668487487142869e-05, 'max_iter': 350}.  
Best is trial 0 with value: 0.7961196559794279.  
[I 2024-12-23 09:55:05,537] Trial 16 finished with value: 0.7961047278751047 and  
parameters: {'solver': 'saga', 'C': 0.6099255842394941, 'max_iter': 718}. Best is  
trial 0 with value: 0.7961196559794279.  
[I 2024-12-23 09:55:05,562] Trial 22 finished with value: 0.7900371757952828 and  
parameters: {'solver': 'lbfgs', 'C': 5.555277850003724e-05, 'max_iter': 233}. Bes  
t is trial 0 with value: 0.7961196559794279.  
[I 2024-12-23 09:55:05,610] Trial 23 finished with value: 0.796105209426857 and p  
arameters: {'solver': 'saga', 'C': 0.7524144336473763, 'max_iter': 655}. Best is  
trial 0 with value: 0.7961196559794279.  
[I 2024-12-23 09:55:05,662] Trial 24 finished with value: 0.7923105816182066 and  
parameters: {'solver': 'saga', 'C': 0.00017532751019378227, 'max_iter': 477}. Bes  
t is trial 0 with value: 0.7961196559794279.  
[I 2024-12-23 09:55:05,666] Trial 21 finished with value: 0.7961047278751048 and  
parameters: {'solver': 'sag', 'C': 12.228514226342742, 'max_iter': 783}. Best is  
trial 0 with value: 0.7961196559794279.  
[I 2024-12-23 09:55:05,700] Trial 26 finished with value: 0.7961085802891237 and  
parameters: {'solver': 'lbfgs', 'C': 4.481799708220492, 'max_iter': 841}. Best is  
trial 0 with value: 0.7961196559794279.  
[I 2024-12-23 09:55:05,762] Trial 27 finished with value: 0.796109061840876 and p  
arameters: {'solver': 'lbfgs', 'C': 15.961557482430804, 'max_iter': 762}. Best is  
trial 0 with value: 0.7961196559794279.  
[I 2024-12-23 09:55:05,798] Trial 25 finished with value: 0.7936637420423573 and  
parameters: {'solver': 'liblinear', 'C': 0.00031541299097484927, 'max_iter': 19  
6}. Best is trial 0 with value: 0.7961196559794279.  
[I 2024-12-23 09:55:05,844] Trial 31 finished with value: 0.7961080987373711 and  
parameters: {'solver': 'lbfgs', 'C': 0.06253709296809765, 'max_iter': 653}. Best  
is trial 0 with value: 0.7961196559794279.  
[I 2024-12-23 09:55:05,901] Trial 30 finished with value: 0.7961105064961331 and  
parameters: {'solver': 'lbfgs', 'C': 0.06576197555537898, 'max_iter': 661}. Best  
is trial 0 with value: 0.7961196559794279.  
[I 2024-12-23 09:55:05,963] Trial 32 finished with value: 0.7961105064961331 and  
parameters: {'solver': 'lbfgs', 'C': 0.06456117211613047, 'max_iter': 664}. Best  
is trial 0 with value: 0.7961196559794279.  
[I 2024-12-23 09:55:06,000] Trial 29 finished with value: 0.7961056909786094 and  
parameters: {'solver': 'sag', 'C': 6.543672798465175, 'max_iter': 647}. Best is t  
rial 0 with value: 0.7961196559794279.  
[I 2024-12-23 09:55:06,000] Trial 33 finished with value: 0.796127360807466 and p  
arameters: {'solver': 'lbfgs', 'C': 0.01247698991215766, 'max_iter': 638}. Best i  
s trial 33 with value: 0.796127360807466.  
[I 2024-12-23 09:55:06,052] Trial 34 finished with value: 0.796116766668914 and p  
arameters: {'solver': 'lbfgs', 'C': 0.02872815500058855, 'max_iter': 649}. Best i  
s trial 33 with value: 0.796127360807466.  
[I 2024-12-23 09:55:06,073] Trial 28 finished with value: 0.7961056909786095 and  
parameters: {'solver': 'sag', 'C': 18.45999004876207, 'max_iter': 647}. Best is t  
rial 33 with value: 0.796127360807466.  
[I 2024-12-23 09:55:06,120] Trial 35 finished with value: 0.7961259161522088 and  
parameters: {'solver': 'lbfgs', 'C': 0.017301077153034486, 'max_iter': 291}. Best  
is trial 33 with value: 0.796127360807466.  
[I 2024-12-23 09:55:06,160] Trial 36 finished with value: 0.7961105064961332 and  
parameters: {'solver': 'lbfgs', 'C': 0.02545851945702013, 'max_iter': 613}. Best  
is trial 33 with value: 0.796127360807466.  
[I 2024-12-23 09:55:06,264] Trial 40 finished with value: 0.7961235083934471 and  
parameters: {'solver': 'lbfgs', 'C': 0.030698183220981733, 'max_iter': 611}. Best  
is trial 33 with value: 0.796127360807466.  
[I 2024-12-23 09:55:06,272] Trial 39 finished with value: 0.7961100249443808 and  
parameters: {'solver': 'lbfgs', 'C': 0.02028307414113134, 'max_iter': 581}. Best  
is trial 33 with value: 0.796127360807466.  
[I 2024-12-23 09:55:06,311] Trial 42 finished with value: 0.7961196559794281 and
```

```
parameters: {'solver': 'lbfgs', 'C': 0.0321803256895109, 'max_iter': 578}. Best is trial 33 with value: 0.796127360807466.  
[I 2024-12-23 09:55:06,315] Trial 37 finished with value: 0.796123508393447 and parameters: {'solver': 'lbfgs', 'C': 0.029167069433244572, 'max_iter': 582}. Best is trial 33 with value: 0.796127360807466.  
[I 2024-12-23 09:55:06,357] Trial 43 finished with value: 0.7961124327031427 and parameters: {'solver': 'lbfgs', 'C': 0.02553328234675228, 'max_iter': 575}. Best is trial 33 with value: 0.796127360807466.  
[I 2024-12-23 09:55:06,359] Trial 38 finished with value: 0.7961080987373712 and parameters: {'solver': 'lbfgs', 'C': 0.022722911738525035, 'max_iter': 611}. Best is trial 33 with value: 0.796127360807466.  
[I 2024-12-23 09:55:06,391] Trial 41 finished with value: 0.7961254346004566 and parameters: {'solver': 'lbfgs', 'C': 0.033230398320138035, 'max_iter': 588}. Best is trial 33 with value: 0.796127360807466.  
[I 2024-12-23 09:55:06,445] Trial 44 finished with value: 0.7961239899451995 and parameters: {'solver': 'lbfgs', 'C': 0.030452664037747792, 'max_iter': 613}. Best is trial 33 with value: 0.796127360807466.  
[I 2024-12-23 09:55:06,494] Trial 45 finished with value: 0.7961201375311805 and parameters: {'solver': 'lbfgs', 'C': 0.027157707295408357, 'max_iter': 590}. Best is trial 33 with value: 0.796127360807466.  
[I 2024-12-23 09:55:06,590] Trial 47 finished with value: 0.7961297685662277 and parameters: {'solver': 'lbfgs', 'C': 0.0368193590515366, 'max_iter': 571}. Best is trial 47 with value: 0.7961297685662277.  
[I 2024-12-23 09:55:06,593] Trial 46 finished with value: 0.7961283239109708 and parameters: {'solver': 'sag', 'C': 0.029543674724364068, 'max_iter': 583}. Best is trial 47 with value: 0.7961297685662277.  
[I 2024-12-23 09:55:06,635] Trial 48 finished with value: 0.7961360287390086 and parameters: {'solver': 'sag', 'C': 0.015205890320610742, 'max_iter': 579}. Best is trial 48 with value: 0.7961360287390086.  
[I 2024-12-23 09:55:06,664] Trial 49 finished with value: 0.7961090618408762 and parameters: {'solver': 'lbfgs', 'C': 0.022346116404834422, 'max_iter': 563}. Best is trial 48 with value: 0.7961360287390086.  
[I 2024-12-23 09:55:06,703] Trial 50 finished with value: 0.7961158035654091 and parameters: {'solver': 'lbfgs', 'C': 0.02465632240806261, 'max_iter': 586}. Best is trial 48 with value: 0.7961360287390086.  
[I 2024-12-23 09:55:06,755] Trial 51 finished with value: 0.796112914254895 and parameters: {'solver': 'lbfgs', 'C': 0.008273047894406362, 'max_iter': 551}. Best is trial 48 with value: 0.7961360287390086.  
[I 2024-12-23 09:55:06,789] Trial 54 finished with value: 0.7961177297724186 and parameters: {'solver': 'lbfgs', 'C': 0.011123526431773405, 'max_iter': 569}. Best is trial 48 with value: 0.7961360287390086.  
[I 2024-12-23 09:55:06,796] Trial 53 finished with value: 0.7961191744276757 and parameters: {'solver': 'lbfgs', 'C': 0.007611480983857371, 'max_iter': 587}. Best is trial 48 with value: 0.7961360287390086.  
[I 2024-12-23 09:55:06,842] Trial 55 finished with value: 0.796073427011201 and parameters: {'solver': 'lbfgs', 'C': 0.004514597561830368, 'max_iter': 309}. Best is trial 48 with value: 0.7961360287390086.  
[I 2024-12-23 09:55:06,859] Trial 52 finished with value: 0.796116766668914 and parameters: {'solver': 'lbfgs', 'C': 0.013582849653833693, 'max_iter': 986}. Best is trial 48 with value: 0.7961360287390086.  
[I 2024-12-23 09:55:06,889] Trial 56 finished with value: 0.7959082547601392 and parameters: {'solver': 'lbfgs', 'C': 0.0020387017575809207, 'max_iter': 994}. Best is trial 48 with value: 0.7961360287390086.  
[I 2024-12-23 09:55:06,927] Trial 57 finished with value: 0.7960257533877165 and parameters: {'solver': 'lbfgs', 'C': 0.003937864186023608, 'max_iter': 576}. Best is trial 48 with value: 0.7961360287390086.  
[I 2024-12-23 09:55:06,952] Trial 58 finished with value: 0.7959930078685556 and parameters: {'solver': 'lbfgs', 'C': 0.0033235183761264825, 'max_iter': 290}. Best is trial 48 with value: 0.7961360287390086.  
[I 2024-12-23 09:55:07,047] Trial 62 finished with value: 0.7960792056322292 and
```

```
parameters: {'solver': 'lbfgs', 'C': 0.004822568104936704, 'max_iter': 528}. Best is trial 48 with value: 0.7961360287390086.  
[I 2024-12-23 09:55:07,067] Trial 63 finished with value: 0.7959804875229941 and parameters: {'solver': 'lbfgs', 'C': 0.0034093897260276174, 'max_iter': 509}. Best is trial 48 with value: 0.7961360287390086.  
[I 2024-12-23 09:55:07,093] Trial 64 finished with value: 0.7961133958066473 and parameters: {'solver': 'lbfgs', 'C': 0.005671128293073248, 'max_iter': 509}. Best is trial 48 with value: 0.7961360287390086.  
[I 2024-12-23 09:55:07,102] Trial 59 finished with value: 0.7960676483901725 and parameters: {'solver': 'lbfgs', 'C': 0.004445310051037664, 'max_iter': 538}. Best is trial 48 with value: 0.7961360287390086.  
[I 2024-12-23 09:55:07,135] Trial 65 finished with value: 0.7959087363118915 and parameters: {'solver': 'lbfgs', 'C': 0.0021489679985634783, 'max_iter': 526}. Best is trial 48 with value: 0.7961360287390086.  
[I 2024-12-23 09:55:07,140] Trial 61 finished with value: 0.7959915632132987 and parameters: {'solver': 'lbfgs', 'C': 0.0031662678588491974, 'max_iter': 488}. Best is trial 48 with value: 0.7961360287390086.  
[I 2024-12-23 09:55:07,146] Trial 60 finished with value: 0.7960806502874863 and parameters: {'solver': 'lbfgs', 'C': 0.0046120354722363486, 'max_iter': 539}. Best is trial 48 with value: 0.7961360287390086.  
[I 2024-12-23 09:55:07,316] Trial 66 finished with value: 0.796128805462723 and parameters: {'solver': 'sag', 'C': 0.006099721907769537, 'max_iter': 508}. Best is trial 48 with value: 0.7961360287390086.  
[I 2024-12-23 09:55:07,362] Trial 67 finished with value: 0.796134102531999 and parameters: {'solver': 'sag', 'C': 0.006867130011020221, 'max_iter': 509}. Best is trial 48 with value: 0.7961360287390086.  
[I 2024-12-23 09:55:07,460] Trial 69 finished with value: 0.7960873920120195 and parameters: {'solver': 'sag', 'C': 0.0051022825432772, 'max_iter': 536}. Best is trial 48 with value: 0.7961360287390086.  
[I 2024-12-23 09:55:07,467] Trial 68 finished with value: 0.7960825764944959 and parameters: {'solver': 'sag', 'C': 0.0046972774992108494, 'max_iter': 523}. Best is trial 48 with value: 0.7961360287390086.  
[I 2024-12-23 09:55:07,491] Trial 70 finished with value: 0.7960907628742862 and parameters: {'solver': 'sag', 'C': 0.005314804689243706, 'max_iter': 484}. Best is trial 48 with value: 0.7961360287390086.  
[I 2024-12-23 09:55:07,500] Trial 72 finished with value: 0.7960849842532578 and parameters: {'solver': 'sag', 'C': 0.00466373288306864, 'max_iter': 512}. Best is trial 48 with value: 0.7961360287390086.  
[I 2024-12-23 09:55:07,541] Trial 71 finished with value: 0.7960782425287245 and parameters: {'solver': 'sag', 'C': 0.004853013138153211, 'max_iter': 503}. Best is trial 48 with value: 0.7961360287390086.  
[I 2024-12-23 09:55:07,567] Trial 73 finished with value: 0.7959164411399293 and parameters: {'solver': 'sag', 'C': 0.0020192210677431265, 'max_iter': 515}. Best is trial 48 with value: 0.7961360287390086.  
[I 2024-12-23 09:55:07,620] Trial 74 finished with value: 0.7955480540493688 and parameters: {'solver': 'sag', 'C': 0.0011594960474696234, 'max_iter': 468}. Best is trial 48 with value: 0.7961360287390086.  
[I 2024-12-23 09:55:07,665] Trial 75 finished with value: 0.795897660621587 and parameters: {'solver': 'sag', 'C': 0.0022853449155386322, 'max_iter': 517}. Best is trial 48 with value: 0.7961360287390086.  
[I 2024-12-23 09:55:07,906] Trial 76 finished with value: 0.7961071356338666 and parameters: {'solver': 'sag', 'C': 0.16143729361307932, 'max_iter': 527}. Best is trial 48 with value: 0.7961360287390086.  
[I 2024-12-23 09:55:07,917] Trial 77 finished with value: 0.7961080987373713 and parameters: {'solver': 'sag', 'C': 0.12374868737360396, 'max_iter': 512}. Best is trial 48 with value: 0.7961360287390086.  
[I 2024-12-23 09:55:07,927] Trial 78 finished with value: 0.7961100249443808 and parameters: {'solver': 'sag', 'C': 0.14961432493439022, 'max_iter': 522}. Best is trial 48 with value: 0.7961360287390086.  
[I 2024-12-23 09:55:08,014] Trial 81 finished with value: 0.7961119511513902 and
```

```
parameters: {'solver': 'sag', 'C': 0.13384844321568415, 'max_iter': 706}. Best is trial 48 with value: 0.7961360287390086.  
[I 2024-12-23 09:55:08,047] Trial 79 finished with value: 0.7961109880478856 and parameters: {'solver': 'sag', 'C': 0.1778595389082983, 'max_iter': 445}. Best is trial 48 with value: 0.7961360287390086.  
[I 2024-12-23 09:55:08,070] Trial 80 finished with value: 0.7961105064961332 and parameters: {'solver': 'sag', 'C': 0.14132780659082844, 'max_iter': 446}. Best is trial 48 with value: 0.7961360287390086.  
[I 2024-12-23 09:55:08,097] Trial 84 finished with value: 0.7955336074967978 and parameters: {'solver': 'sag', 'C': 0.0010993542632021815, 'max_iter': 691}. Best is trial 48 with value: 0.7961360287390086.  
[I 2024-12-23 09:55:08,155] Trial 82 finished with value: 0.7961080987373712 and parameters: {'solver': 'sag', 'C': 0.15404301283832858, 'max_iter': 431}. Best is trial 48 with value: 0.7961360287390086.  
[I 2024-12-23 09:55:08,203] Trial 85 finished with value: 0.7961085802891237 and parameters: {'solver': 'sag', 'C': 0.1535301759476414, 'max_iter': 431}. Best is trial 48 with value: 0.7961360287390086.  
[I 2024-12-23 09:55:08,254] Trial 83 finished with value: 0.7961105064961332 and parameters: {'solver': 'sag', 'C': 0.1417807587608743, 'max_iter': 446}. Best is trial 48 with value: 0.7961360287390086.  
[I 2024-12-23 09:55:08,300] Trial 86 finished with value: 0.7953380974853367 and parameters: {'solver': 'sag', 'C': 0.0009091870204092657, 'max_iter': 437}. Best is trial 48 with value: 0.7961360287390086.  
[I 2024-12-23 09:55:08,362] Trial 87 finished with value: 0.7961143589101519 and parameters: {'solver': 'sag', 'C': 0.10338528304017246, 'max_iter': 441}. Best is trial 48 with value: 0.7961360287390086.  
[I 2024-12-23 09:55:08,420] Trial 88 finished with value: 0.7961109880478856 and parameters: {'solver': 'sag', 'C': 0.15171436935586444, 'max_iter': 445}. Best is trial 48 with value: 0.7961360287390086.  
[I 2024-12-23 09:55:08,469] Trial 90 finished with value: 0.7961124327031426 and parameters: {'solver': 'sag', 'C': 0.185981120347394, 'max_iter': 698}. Best is trial 48 with value: 0.7961360287390086.  
[I 2024-12-23 09:55:08,517] Trial 89 finished with value: 0.7961085802891237 and parameters: {'solver': 'sag', 'C': 0.15349786365817375, 'max_iter': 407}. Best is trial 48 with value: 0.7961360287390086.  
[I 2024-12-23 09:55:08,573] Trial 91 finished with value: 0.7961105064961332 and parameters: {'solver': 'sag', 'C': 0.17655056754557402, 'max_iter': 460}. Best is trial 48 with value: 0.7961360287390086.  
[I 2024-12-23 09:55:08,601] Trial 92 finished with value: 0.796109061840876 and parameters: {'solver': 'sag', 'C': 0.21042067497354025, 'max_iter': 427}. Best is trial 48 with value: 0.7961360287390086.  
[I 2024-12-23 09:55:08,679] Trial 95 finished with value: 0.7961071356338666 and parameters: {'solver': 'sag', 'C': 0.16111404369457333, 'max_iter': 432}. Best is trial 48 with value: 0.7961360287390086.  
[I 2024-12-23 09:55:08,704] Trial 93 finished with value: 0.7961105064961332 and parameters: {'solver': 'sag', 'C': 0.14148853922504884, 'max_iter': 414}. Best is trial 48 with value: 0.7961360287390086.  
[I 2024-12-23 09:55:08,728] Trial 97 finished with value: 0.7954734135277518 and parameters: {'solver': 'liblinear', 'C': 0.001080861079961804, 'max_iter': 404}. Best is trial 48 with value: 0.7961360287390086.  
[I 2024-12-23 09:55:08,778] Trial 94 finished with value: 0.7961100249443807 and parameters: {'solver': 'sag', 'C': 0.12265175741806748, 'max_iter': 412}. Best is trial 48 with value: 0.7961360287390086.  
[I 2024-12-23 09:55:08,831] Trial 96 finished with value: 0.7961095433926284 and parameters: {'solver': 'sag', 'C': 0.12057607572472198, 'max_iter': 432}. Best is trial 48 with value: 0.7961360287390086.  
[I 2024-12-23 09:55:08,848] Trial 98 finished with value: 0.7961230268416947 and parameters: {'solver': 'liblinear', 'C': 0.050781405526433857, 'max_iter': 428}. Best is trial 48 with value: 0.7961360287390086.  
[I 2024-12-23 09:55:08,871] Trial 99 finished with value: 0.7952586414461962 and
```

```
parameters: {'solver': 'liblinear', 'C': 0.000879487928971851, 'max_iter': 409}.  
Best is trial 48 with value: 0.7961360287390086.  
[I 2024-12-23 09:55:08,931] Trial 101 finished with value: 0.7961263977039613 and  
parameters: {'solver': 'liblinear', 'C': 0.049398274834287076, 'max_iter': 681}.  
Best is trial 48 with value: 0.7961360287390086.  
[I 2024-12-23 09:55:08,971] Trial 100 finished with value: 0.796125916152209 and  
parameters: {'solver': 'liblinear', 'C': 0.049403203180512965, 'max_iter': 739}.  
Best is trial 48 with value: 0.7961360287390086.  
[I 2024-12-23 09:55:09,008] Trial 102 finished with value: 0.7961254346004565 and  
parameters: {'solver': 'liblinear', 'C': 0.05628327923937667, 'max_iter': 629}. B  
est is trial 48 with value: 0.7961360287390086.  
[I 2024-12-23 09:55:09,042] Trial 103 finished with value: 0.7961273608074659 and  
parameters: {'solver': 'liblinear', 'C': 0.05472157870766911, 'max_iter': 627}. B  
est is trial 48 with value: 0.7961360287390086.  
[I 2024-12-23 09:55:09,051] Trial 104 finished with value: 0.7961273608074659 and  
parameters: {'solver': 'liblinear', 'C': 0.047031465554507094, 'max_iter': 131}.  
Best is trial 48 with value: 0.7961360287390086.  
[I 2024-12-23 09:55:09,137] Trial 107 finished with value: 0.7961297685662279 and  
parameters: {'solver': 'liblinear', 'C': 0.046238166880369316, 'max_iter': 612}.  
Best is trial 48 with value: 0.7961360287390086.  
[I 2024-12-23 09:55:09,180] Trial 109 finished with value: 0.796123508393447 and  
parameters: {'solver': 'liblinear', 'C': 0.04452786943191626, 'max_iter': 625}. B  
est is trial 48 with value: 0.7961360287390086.  
[I 2024-12-23 09:55:09,214] Trial 108 finished with value: 0.7961225452899423 and  
parameters: {'solver': 'saga', 'C': 0.055185936502456706, 'max_iter': 127}. Best  
is trial 48 with value: 0.7961360287390086.  
[I 2024-12-23 09:55:09,228] Trial 112 finished with value: 0.7961177297724187 and  
parameters: {'solver': 'liblinear', 'C': 0.01395088752992545, 'max_iter': 617}. B  
est is trial 48 with value: 0.7961360287390086.  
[I 2024-12-23 09:55:09,252] Trial 105 finished with value: 0.7961350656355037 and  
parameters: {'solver': 'saga', 'C': 0.04747762597979597, 'max_iter': 618}. Best i  
s trial 48 with value: 0.7961360287390086.  
[I 2024-12-23 09:55:09,280] Trial 106 finished with value: 0.7961172482206663 and  
parameters: {'solver': 'liblinear', 'C': 0.01382314707462705, 'max_iter': 628}. B  
est is trial 48 with value: 0.7961360287390086.  
[I 2024-12-23 09:55:09,295] Trial 111 finished with value: 0.796123508393447 and  
parameters: {'solver': 'liblinear', 'C': 0.044126926109971196, 'max_iter': 610}.  
Best is trial 48 with value: 0.7961360287390086.  
[I 2024-12-23 09:55:09,324] Trial 110 finished with value: 0.7961249530487042 and  
parameters: {'solver': 'liblinear', 'C': 0.04373904819804588, 'max_iter': 614}. B  
est is trial 48 with value: 0.7961360287390086.  
[I 2024-12-23 09:55:09,394] Trial 113 finished with value: 0.7961297685662279 and  
parameters: {'solver': 'saga', 'C': 0.0396074970300623, 'max_iter': 619}. Best is  
trial 48 with value: 0.7961360287390086.  
[I 2024-12-23 09:55:09,544] Trial 114 finished with value: 0.796131213221485 and  
parameters: {'solver': 'saga', 'C': 0.04225181115838924, 'max_iter': 620}. Best i  
s trial 48 with value: 0.7961360287390086.  
[I 2024-12-23 09:55:09,556] Trial 118 finished with value: 0.7961148404619044 and  
parameters: {'solver': 'lbfgs', 'C': 0.04483367480163869, 'max_iter': 629}. Best  
is trial 48 with value: 0.7961360287390086.  
[I 2024-12-23 09:55:09,614] Trial 120 finished with value: 0.7961292870144754 and  
parameters: {'solver': 'liblinear', 'C': 0.016206592319767992, 'max_iter': 620}.  
Best is trial 48 with value: 0.7961360287390086.  
[I 2024-12-23 09:55:09,615] Trial 117 finished with value: 0.7961321763249896 and  
parameters: {'solver': 'saga', 'C': 0.04039270772679537, 'max_iter': 612}. Best i  
s trial 48 with value: 0.7961360287390086.  
[I 2024-12-23 09:55:09,618] Trial 115 finished with value: 0.7961418073600369 and  
parameters: {'solver': 'saga', 'C': 0.04487960597783652, 'max_iter': 619}. Best i  
s trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:09,650] Trial 116 finished with value: 0.796134102531999 and
```

```
parameters: {'solver': 'saga', 'C': 0.042592118654074536, 'max_iter': 618}. Best
is trial 115 with value: 0.7961418073600369.
[I 2024-12-23 09:55:09,685] Trial 119 finished with value: 0.79612206373819 and p
arameters: {'solver': 'saga', 'C': 0.015629737174613616, 'max_iter': 616}. Best i
s trial 115 with value: 0.7961418073600369.
[I 2024-12-23 09:55:09,741] Trial 121 finished with value: 0.7961119511513902 and
parameters: {'solver': 'liblinear', 'C': 0.012780907134258473, 'max_iter': 737}.
Best is trial 115 with value: 0.7961418073600369.
[I 2024-12-23 09:55:09,777] Trial 122 finished with value: 0.7961129142548949 and
parameters: {'solver': 'liblinear', 'C': 0.014753212719216572, 'max_iter': 752}.
Best is trial 115 with value: 0.7961418073600369.
[I 2024-12-23 09:55:09,840] Trial 123 finished with value: 0.7961162851171615 and
parameters: {'solver': 'liblinear', 'C': 0.014094066917186192, 'max_iter': 121}.
Best is trial 115 with value: 0.7961418073600369.
[I 2024-12-23 09:55:09,846] Trial 124 finished with value: 0.7961109880478855 and
parameters: {'solver': 'liblinear', 'C': 0.014806016384710092, 'max_iter': 121}.
Best is trial 115 with value: 0.7961418073600369.
[I 2024-12-23 09:55:09,878] Trial 125 finished with value: 0.7961100249443808 and
parameters: {'solver': 'liblinear', 'C': 0.43433908654320147, 'max_iter': 745}. B
est is trial 115 with value: 0.7961418073600369.
[I 2024-12-23 09:55:09,914] Trial 126 finished with value: 0.7961090618408762 and
parameters: {'solver': 'liblinear', 'C': 0.4388235459410664, 'max_iter': 767}. Be
st is trial 115 with value: 0.7961418073600369.
[I 2024-12-23 09:55:09,978] Trial 128 finished with value: 0.7961056909786095 and
parameters: {'solver': 'liblinear', 'C': 0.5542025382207825, 'max_iter': 729}. Be
st is trial 115 with value: 0.7961418073600369.
[I 2024-12-23 09:55:10,053] Trial 131 finished with value: 0.7961071356338667 and
parameters: {'solver': 'liblinear', 'C': 0.334984287255984, 'max_iter': 737}. Bes
t is trial 115 with value: 0.7961418073600369.
[I 2024-12-23 09:55:10,070] Trial 127 finished with value: 0.7961191744276758 and
parameters: {'solver': 'liblinear', 'C': 0.013685371837299303, 'max_iter': 749}.
Best is trial 115 with value: 0.7961418073600369.
[I 2024-12-23 09:55:10,076] Trial 130 finished with value: 0.7961071356338666 and
parameters: {'solver': 'liblinear', 'C': 0.37330341193802435, 'max_iter': 679}. B
est is trial 115 with value: 0.7961418073600369.
[I 2024-12-23 09:55:10,093] Trial 133 finished with value: 0.7961095433926284 and
parameters: {'solver': 'saga', 'C': 0.3992885670054717, 'max_iter': 677}. Best is
trial 115 with value: 0.7961418073600369.
[I 2024-12-23 09:55:10,148] Trial 129 finished with value: 0.7961095433926284 and
parameters: {'solver': 'liblinear', 'C': 0.4146881168692681, 'max_iter': 675}. Be
st is trial 115 with value: 0.7961418073600369.
[I 2024-12-23 09:55:10,198] Trial 132 finished with value: 0.7961100249443808 and
parameters: {'solver': 'saga', 'C': 0.48837510674711143, 'max_iter': 750}. Best i
s trial 115 with value: 0.7961418073600369.
[I 2024-12-23 09:55:10,272] Trial 134 finished with value: 0.7961239899451995 and
parameters: {'solver': 'saga', 'C': 0.008899741885359148, 'max_iter': 554}. Best
is trial 115 with value: 0.7961418073600369.
[I 2024-12-23 09:55:10,346] Trial 135 finished with value: 0.7961273608074659 and
parameters: {'solver': 'saga', 'C': 0.008879641726577812, 'max_iter': 559}. Best
is trial 115 with value: 0.7961418073600369.
[I 2024-12-23 09:55:10,401] Trial 137 finished with value: 0.7961105064961331 and
parameters: {'solver': 'saga', 'C': 0.33648368576943505, 'max_iter': 671}. Best i
s trial 115 with value: 0.7961418073600369.
[I 2024-12-23 09:55:10,412] Trial 136 finished with value: 0.7961211006346852 and
parameters: {'solver': 'saga', 'C': 0.008004201216105842, 'max_iter': 551}. Best
is trial 115 with value: 0.7961418073600369.
[I 2024-12-23 09:55:10,495] Trial 138 finished with value: 0.7961225452899423 and
parameters: {'solver': 'saga', 'C': 0.007740775246136307, 'max_iter': 669}. Best
is trial 115 with value: 0.7961418073600369.
[I 2024-12-23 09:55:10,543] Trial 139 finished with value: 0.7961085802891237 and
```

```
parameters: {'solver': 'saga', 'C': 0.4655761630249471, 'max_iter': 553}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:10,588] Trial 141 finished with value: 0.7961278423592182 and parameters: {'solver': 'saga', 'C': 0.008848920553441017, 'max_iter': 553}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:10,602] Trial 140 finished with value: 0.7961206190829329 and parameters: {'solver': 'saga', 'C': 0.009790338657651, 'max_iter': 559}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:10,658] Trial 142 finished with value: 0.7961090618408762 and parameters: {'solver': 'saga', 'C': 0.43860420406873024, 'max_iter': 555}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:10,704] Trial 143 finished with value: 0.796109061840876 and parameters: {'solver': 'saga', 'C': 0.5236643842684083, 'max_iter': 670}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:10,758] Trial 144 finished with value: 0.7961056909786095 and parameters: {'solver': 'saga', 'C': 0.6898534751825447, 'max_iter': 558}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:10,816] Trial 145 finished with value: 0.7961206190829329 and parameters: {'solver': 'saga', 'C': 0.00906514053770827, 'max_iter': 672}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:10,891] Trial 147 finished with value: 0.796123508393447 and parameters: {'solver': 'saga', 'C': 0.007962190250872277, 'max_iter': 557}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:10,896] Trial 148 finished with value: 0.7961172482206662 and parameters: {'solver': 'saga', 'C': 0.008962641157737867, 'max_iter': 669}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:10,957] Trial 146 finished with value: 0.7961172482206663 and parameters: {'solver': 'saga', 'C': 0.08416836854029432, 'max_iter': 556}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:11,041] Trial 149 finished with value: 0.7961182113241709 and parameters: {'solver': 'saga', 'C': 0.08319413472803557, 'max_iter': 555}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:11,073] Trial 151 finished with value: 0.7961211006346852 and parameters: {'solver': 'saga', 'C': 0.00811171138119788, 'max_iter': 549}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:11,092] Trial 150 finished with value: 0.7961172482206663 and parameters: {'solver': 'saga', 'C': 0.00922552175141515, 'max_iter': 564}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:11,125] Trial 152 finished with value: 0.7961172482206663 and parameters: {'solver': 'saga', 'C': 0.009211150078283138, 'max_iter': 558}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:11,174] Trial 153 finished with value: 0.7961143589101521 and parameters: {'solver': 'saga', 'C': 0.007473836648424818, 'max_iter': 562}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:11,227] Trial 154 finished with value: 0.796112914254895 and parameters: {'solver': 'saga', 'C': 0.08861619495181816, 'max_iter': 596}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:11,249] Trial 155 finished with value: 0.7961254346004566 and parameters: {'solver': 'saga', 'C': 0.02877014234537416, 'max_iter': 597}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:11,315] Trial 156 finished with value: 0.7961244714969516 and parameters: {'solver': 'saga', 'C': 0.07646517257656048, 'max_iter': 596}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:11,359] Trial 158 finished with value: 0.796116766668914 and parameters: {'solver': 'saga', 'C': 0.08228724969542009, 'max_iter': 602}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:11,400] Trial 157 finished with value: 0.7961186928759234 and parameters: {'solver': 'saga', 'C': 0.0729856109453047, 'max_iter': 595}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:11,404] Trial 159 finished with value: 0.7961133958066473 and
```

```
parameters: {'solver': 'saga', 'C': 0.08811480082952579, 'max_iter': 594}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:11,495] Trial 161 finished with value: 0.7961138773583998 and parameters: {'solver': 'saga', 'C': 0.0925431132602029, 'max_iter': 597}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:11,543] Trial 162 finished with value: 0.796114358910152 and parameters: {'solver': 'saga', 'C': 0.08999117057986401, 'max_iter': 599}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:11,545] Trial 160 finished with value: 0.7961172482206663 and parameters: {'solver': 'saga', 'C': 0.08524582514313725, 'max_iter': 592}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:11,567] Trial 163 finished with value: 0.7961177297724187 and parameters: {'solver': 'saga', 'C': 0.09297943219457451, 'max_iter': 594}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:11,655] Trial 164 finished with value: 0.7961186928759234 and parameters: {'solver': 'saga', 'C': 0.09333984916284979, 'max_iter': 647}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:11,815] Trial 168 finished with value: 0.7961138773583997 and parameters: {'solver': 'saga', 'C': 0.02246329451058285, 'max_iter': 647}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:11,819] Trial 165 finished with value: 0.7961148404619044 and parameters: {'solver': 'saga', 'C': 0.09036830722404958, 'max_iter': 595}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:11,849] Trial 167 finished with value: 0.796109061840876 and parameters: {'solver': 'saga', 'C': 0.020771842079828476, 'max_iter': 596}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:11,865] Trial 166 finished with value: 0.7961201375311805 and parameters: {'solver': 'saga', 'C': 0.07938998554311741, 'max_iter': 597}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:11,929] Trial 170 finished with value: 0.796107617185619 and parameters: {'solver': 'saga', 'C': 0.021740256268390677, 'max_iter': 649}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:11,933] Trial 169 finished with value: 0.7961037647716 and parameters: {'solver': 'saga', 'C': 0.021650340268366798, 'max_iter': 590}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:12,000] Trial 171 finished with value: 0.796118211324171 and parameters: {'solver': 'saga', 'C': 0.025097824036198296, 'max_iter': 596}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:12,012] Trial 174 finished with value: 0.7961056909786095 and parameters: {'solver': 'saga', 'C': 0.021701167700742072, 'max_iter': 646}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:12,035] Trial 172 finished with value: 0.7961268792557136 and parameters: {'solver': 'saga', 'C': 0.029954197643120645, 'max_iter': 595}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:12,180] Trial 173 finished with value: 0.7961235083934471 and parameters: {'solver': 'saga', 'C': 0.023056206540918372, 'max_iter': 595}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:12,237] Trial 175 finished with value: 0.7961095433926284 and parameters: {'solver': 'saga', 'C': 0.02188394190802045, 'max_iter': 649}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:12,260] Trial 176 finished with value: 0.7961177297724186 and parameters: {'solver': 'saga', 'C': 0.01894870769772806, 'max_iter': 646}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:12,268] Trial 177 finished with value: 0.7961177297724188 and parameters: {'solver': 'saga', 'C': 0.025278496314290255, 'max_iter': 644}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:12,272] Trial 178 finished with value: 0.7961133958066473 and parameters: {'solver': 'saga', 'C': 0.025520583253764016, 'max_iter': 644}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:12,352] Trial 179 finished with value: 0.7961133958066473 and
```

```
parameters: {'solver': 'saga', 'C': 0.019735699525775276, 'max_iter': 646}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:12,399] Trial 180 finished with value: 0.7961201375311804 and parameters: {'solver': 'saga', 'C': 0.019482898640194514, 'max_iter': 640}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:12,458] Trial 182 finished with value: 0.7961158035654091 and parameters: {'solver': 'sag', 'C': 0.022696502562716946, 'max_iter': 643}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:12,515] Trial 183 finished with value: 0.7961148404619045 and parameters: {'solver': 'sag', 'C': 0.01968932902270311, 'max_iter': 634}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:12,623] Trial 181 finished with value: 0.7961095433926284 and parameters: {'solver': 'sag', 'C': 0.020930824424524166, 'max_iter': 642}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:12,660] Trial 184 finished with value: 0.7961047278751047 and parameters: {'solver': 'sag', 'C': 0.021660577971419306, 'max_iter': 642}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:12,686] Trial 186 finished with value: 0.7961321763249897 and parameters: {'solver': 'sag', 'C': 0.032441679463794, 'max_iter': 639}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:12,691] Trial 188 finished with value: 0.7961201375311806 and parameters: {'solver': 'sag', 'C': 0.01956671301446777, 'max_iter': 167}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:12,692] Trial 187 finished with value: 0.7961321763249897 and parameters: {'solver': 'sag', 'C': 0.034135369494384754, 'max_iter': 634}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:12,709] Trial 185 finished with value: 0.7961312132214851 and parameters: {'solver': 'sag', 'C': 0.030556358893169808, 'max_iter': 642}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:12,732] Trial 191 finished with value: 0.7961316947732373 and parameters: {'solver': 'sag', 'C': 0.03683336411642585, 'max_iter': 633}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:12,826] Trial 189 finished with value: 0.7961326578767419 and parameters: {'solver': 'sag', 'C': 0.03552735399509547, 'max_iter': 230}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:12,878] Trial 190 finished with value: 0.7961331394284944 and parameters: {'solver': 'sag', 'C': 0.0358373717099782, 'max_iter': 629}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:12,933] Trial 192 finished with value: 0.7961326578767419 and parameters: {'solver': 'sag', 'C': 0.03598990574121171, 'max_iter': 183}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:12,944] Trial 193 finished with value: 0.7961297685662279 and parameters: {'solver': 'sag', 'C': 0.03442756081208034, 'max_iter': 205}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:12,989] Trial 194 finished with value: 0.7961297685662279 and parameters: {'solver': 'sag', 'C': 0.03309915536564007, 'max_iter': 632}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:13,073] Trial 196 finished with value: 0.7961384364977703 and parameters: {'solver': 'sag', 'C': 0.04446722986201711, 'max_iter': 625}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:13,076] Trial 195 finished with value: 0.7884206065625874 and parameters: {'solver': 'sag', 'C': 1.6418792883782552e-06, 'max_iter': 220}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:13,102] Trial 197 finished with value: 0.7961321763249897 and parameters: {'solver': 'sag', 'C': 0.03806328487909085, 'max_iter': 355}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:13,144] Trial 198 finished with value: 0.7961331394284945 and parameters: {'solver': 'sag', 'C': 0.03761977727383405, 'max_iter': 365}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:13,209] Trial 199 finished with value: 0.7961336209802466 and
```

```
parameters: {'solver': 'sag', 'C': 0.037874441978055416, 'max_iter': 904}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:13,275] Trial 200 finished with value: 0.7961321763249896 and parameters: {'solver': 'sag', 'C': 0.040278911513838486, 'max_iter': 907}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:13,292] Trial 201 finished with value: 0.7961268792557136 and parameters: {'solver': 'liblinear', 'C': 0.037583653453434666, 'max_iter': 574}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:13,302] Trial 202 finished with value: 0.7961239899451994 and parameters: {'solver': 'liblinear', 'C': 0.03711211901488813, 'max_iter': 618}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:13,377] Trial 203 finished with value: 0.7961196559794281 and parameters: {'solver': 'liblinear', 'C': 0.03574103268493644, 'max_iter': 352}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:13,418] Trial 204 finished with value: 0.7961225452899423 and parameters: {'solver': 'liblinear', 'C': 0.03728360970437903, 'max_iter': 864}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:13,466] Trial 205 finished with value: 0.7961321763249897 and parameters: {'solver': 'sag', 'C': 0.038201392628485514, 'max_iter': 239}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:13,531] Trial 206 finished with value: 0.7884104939757876 and parameters: {'solver': 'sag', 'C': 1.4428894460548452e-06, 'max_iter': 620}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:13,559] Trial 207 finished with value: 0.7961336209802468 and parameters: {'solver': 'sag', 'C': 0.036587667605434214, 'max_iter': 618}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:13,668] Trial 209 finished with value: 0.7961369918425133 and parameters: {'solver': 'sag', 'C': 0.04374166253633352, 'max_iter': 620}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:13,673] Trial 210 finished with value: 0.7961283239109708 and parameters: {'solver': 'sag', 'C': 0.03906808963423014, 'max_iter': 371}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:13,711] Trial 208 finished with value: 0.7961321763249896 and parameters: {'solver': 'sag', 'C': 0.034651220547699424, 'max_iter': 705}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:13,751] Trial 211 finished with value: 0.7961278423592184 and parameters: {'solver': 'sag', 'C': 0.03897191114313034, 'max_iter': 620}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:13,807] Trial 212 finished with value: 0.796134102531999 and parameters: {'solver': 'sag', 'C': 0.04022055397478298, 'max_iter': 165}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:13,882] Trial 213 finished with value: 0.796132657876742 and parameters: {'solver': 'sag', 'C': 0.037719162394981666, 'max_iter': 248}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:13,916] Trial 214 finished with value: 0.7961341025319991 and parameters: {'solver': 'sag', 'C': 0.04251791769469447, 'max_iter': 238}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:13,954] Trial 215 finished with value: 0.7961336209802468 and parameters: {'solver': 'sag', 'C': 0.04255059425600134, 'max_iter': 200}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:14,016] Trial 217 finished with value: 0.7961312132214851 and parameters: {'solver': 'sag', 'C': 0.03826259908818361, 'max_iter': 167}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:14,072] Trial 216 finished with value: 0.7961336209802468 and parameters: {'solver': 'sag', 'C': 0.038520365485110335, 'max_iter': 154}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:14,109] Trial 218 finished with value: 0.7961326578767419 and parameters: {'solver': 'sag', 'C': 0.038651585334241276, 'max_iter': 196}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:14,171] Trial 219 finished with value: 0.7961268792557137 and
```

```
parameters: {'solver': 'sag', 'C': 0.0546684294464911, 'max_iter': 265}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:14,217] Trial 220 finished with value: 0.7961263977039612 and parameters: {'solver': 'sag', 'C': 0.039158962662734165, 'max_iter': 892}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:14,271] Trial 222 finished with value: 0.7961297685662277 and parameters: {'solver': 'sag', 'C': 0.054082064925522144, 'max_iter': 924}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:14,354] Trial 223 finished with value: 0.7961403627047798 and parameters: {'solver': 'sag', 'C': 0.04559031948707205, 'max_iter': 858}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:14,401] Trial 221 finished with value: 0.7961365102907609 and parameters: {'solver': 'sag', 'C': 0.0439449664950745, 'max_iter': 885}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:14,463] Trial 224 finished with value: 0.7961259161522087 and parameters: {'solver': 'sag', 'C': 0.05540207861369684, 'max_iter': 164}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:14,519] Trial 225 finished with value: 0.7961336209802468 and parameters: {'solver': 'sag', 'C': 0.05009009693526942, 'max_iter': 917}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:14,587] Trial 226 finished with value: 0.7961350656355037 and parameters: {'solver': 'sag', 'C': 0.05266447310637802, 'max_iter': 253}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:14,638] Trial 227 finished with value: 0.7961369918425134 and parameters: {'solver': 'sag', 'C': 0.04362561213881851, 'max_iter': 929}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:14,663] Trial 228 finished with value: 0.7961254346004564 and parameters: {'solver': 'sag', 'C': 0.054953271065218204, 'max_iter': 243}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:14,753] Trial 229 finished with value: 0.7961124327031428 and parameters: {'solver': 'sag', 'C': 0.062450952459642425, 'max_iter': 261}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:14,771] Trial 230 finished with value: 0.7961206190829329 and parameters: {'solver': 'sag', 'C': 0.05875579680409609, 'max_iter': 922}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:14,866] Trial 232 finished with value: 0.7961153220136568 and parameters: {'solver': 'sag', 'C': 0.06128552872477354, 'max_iter': 909}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:14,956] Trial 231 finished with value: 0.7961196559794281 and parameters: {'solver': 'sag', 'C': 0.05792797645703147, 'max_iter': 921}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:14,957] Trial 233 finished with value: 0.796118211324171 and parameters: {'solver': 'sag', 'C': 0.05990785800922348, 'max_iter': 921}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:14,963] Trial 234 finished with value: 0.796112914254895 and parameters: {'solver': 'sag', 'C': 0.062146960901575767, 'max_iter': 241}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:15,000] Trial 235 finished with value: 0.7961239899451994 and parameters: {'solver': 'sag', 'C': 0.05755419486986548, 'max_iter': 256}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:15,094] Trial 236 finished with value: 0.7961196559794281 and parameters: {'solver': 'sag', 'C': 0.05794939441328699, 'max_iter': 259}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:15,131] Trial 237 finished with value: 0.7961138773583997 and parameters: {'solver': 'sag', 'C': 0.05960744262807489, 'max_iter': 268}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:15,176] Trial 238 finished with value: 0.7961278423592184 and parameters: {'solver': 'sag', 'C': 0.05452280597601634, 'max_iter': 254}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:15,231] Trial 240 finished with value: 0.796116766668914 and
```

```
parameters: {'solver': 'sag', 'C': 0.06079791867031432, 'max_iter': 241}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:15,280] Trial 239 finished with value: 0.7961239899451994 and parameters: {'solver': 'sag', 'C': 0.0575740240187925, 'max_iter': 148}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:15,330] Trial 241 finished with value: 0.7961153220136568 and parameters: {'solver': 'sag', 'C': 0.06124454873266534, 'max_iter': 247}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:15,444] Trial 242 finished with value: 0.7961201375311805 and parameters: {'solver': 'sag', 'C': 0.05852262237090276, 'max_iter': 149}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:15,473] Trial 243 finished with value: 0.7961158035654092 and parameters: {'solver': 'sag', 'C': 0.0668051323998185, 'max_iter': 186}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:15,523] Trial 244 finished with value: 0.7961244714969518 and parameters: {'solver': 'sag', 'C': 0.05739453720134681, 'max_iter': 144}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:15,570] Trial 245 finished with value: 0.796112914254895 and parameters: {'solver': 'sag', 'C': 0.06204682966953281, 'max_iter': 198}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:15,597] Trial 246 finished with value: 0.7961182113241709 and parameters: {'solver': 'sag', 'C': 0.06825562382150728, 'max_iter': 146}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:15,663] Trial 248 finished with value: 0.7961172482206662 and parameters: {'solver': 'sag', 'C': 0.063558386332277, 'max_iter': 945}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:15,709] Trial 247 finished with value: 0.7961133958066473 and parameters: {'solver': 'sag', 'C': 0.061921332906661984, 'max_iter': 251}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:15,737] Trial 249 finished with value: 0.7961186928759234 and parameters: {'solver': 'sag', 'C': 0.0692876814048093, 'max_iter': 142}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:15,791] Trial 250 finished with value: 0.796114358910152 and parameters: {'solver': 'sag', 'C': 0.06526711186932506, 'max_iter': 193}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:15,929] Trial 251 finished with value: 0.7961182113241709 and parameters: {'solver': 'sag', 'C': 0.0638414412653925, 'max_iter': 189}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:16,016] Trial 253 finished with value: 0.7961186928759234 and parameters: {'solver': 'sag', 'C': 0.06929798440417925, 'max_iter': 209}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:16,088] Trial 254 finished with value: 0.7961162851171616 and parameters: {'solver': 'sag', 'C': 0.06719795691645704, 'max_iter': 195}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:16,192] Trial 252 finished with value: 0.796135065635504 and parameters: {'solver': 'sag', 'C': 0.05217205169225756, 'max_iter': 199}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:16,275] Trial 256 finished with value: 0.7961206190829329 and parameters: {'solver': 'sag', 'C': 0.0754845771346899, 'max_iter': 196}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:16,334] Trial 257 finished with value: 0.7961129142548949 and parameters: {'solver': 'sag', 'C': 0.11185535503238721, 'max_iter': 204}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:16,360] Trial 255 finished with value: 0.7961037647715999 and parameters: {'solver': 'sag', 'C': 2.3815434057481695, 'max_iter': 184}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:16,368] Trial 258 finished with value: 0.7961268792557135 and parameters: {'solver': 'sag', 'C': 0.013751418208213231, 'max_iter': 953}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:16,430] Trial 259 finished with value: 0.7961230268416947 and
```

```
parameters: {'solver': 'sag', 'C': 0.027432783245971898, 'max_iter': 194}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:16,514] Trial 261 finished with value: 0.7961316947732373 and parameters: {'solver': 'sag', 'C': 0.0314017183266286, 'max_iter': 204}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:16,554] Trial 262 finished with value: 0.7961244714969518 and parameters: {'solver': 'sag', 'C': 0.029753672614764057, 'max_iter': 192}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:16,589] Trial 263 finished with value: 0.7961239899451995 and parameters: {'solver': 'sag', 'C': 0.028015544693405146, 'max_iter': 219}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:16,590] Trial 260 finished with value: 0.796123508393447 and parameters: {'solver': 'sag', 'C': 0.028148911060164632, 'max_iter': 202}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:16,649] Trial 264 finished with value: 0.7961254346004565 and parameters: {'solver': 'sag', 'C': 0.02655158390923318, 'max_iter': 945}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:16,714] Trial 265 finished with value: 0.7961292870144755 and parameters: {'solver': 'sag', 'C': 0.028497061035643804, 'max_iter': 214}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:16,757] Trial 266 finished with value: 0.796125916152209 and parameters: {'solver': 'sag', 'C': 0.027602625900356555, 'max_iter': 799}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:16,818] Trial 267 finished with value: 0.7961350656355038 and parameters: {'solver': 'sag', 'C': 0.0151975096328157, 'max_iter': 222}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:16,856] Trial 269 finished with value: 0.7961292870144754 and parameters: {'solver': 'sag', 'C': 0.028979205296925076, 'max_iter': 211}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:16,948] Trial 268 finished with value: 0.7961263977039612 and parameters: {'solver': 'sag', 'C': 0.028347027690061668, 'max_iter': 211}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:16,976] Trial 270 finished with value: 0.7961239899451995 and parameters: {'solver': 'sag', 'C': 0.027888542566168836, 'max_iter': 212}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:17,028] Trial 272 finished with value: 0.7961225452899423 and parameters: {'solver': 'sag', 'C': 0.02799039721487573, 'max_iter': 317}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:17,082] Trial 271 finished with value: 0.7961162851171614 and parameters: {'solver': 'sag', 'C': 0.025793592665426874, 'max_iter': 222}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:17,174] Trial 273 finished with value: 0.7961239899451995 and parameters: {'solver': 'sag', 'C': 0.028146951578056648, 'max_iter': 307}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:17,176] Trial 274 finished with value: 0.7961292870144755 and parameters: {'solver': 'sag', 'C': 0.029009732947715822, 'max_iter': 870}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:17,204] Trial 275 finished with value: 0.7961263977039612 and parameters: {'solver': 'sag', 'C': 0.028346951478258033, 'max_iter': 224}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:17,295] Trial 276 finished with value: 0.7961268792557135 and parameters: {'solver': 'sag', 'C': 0.028265170270216668, 'max_iter': 864}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:17,327] Trial 278 finished with value: 0.7961273608074659 and parameters: {'solver': 'sag', 'C': 0.029376043899546966, 'max_iter': 217}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:17,418] Trial 277 finished with value: 0.7961283239109708 and parameters: {'solver': 'sag', 'C': 0.029554319910712525, 'max_iter': 324}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:17,512] Trial 279 finished with value: 0.7961283239109708 and
```

```
parameters: {'solver': 'sag', 'C': 0.029592533933916254, 'max_iter': 306}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:17,530] Trial 280 finished with value: 0.7961254346004565 and parameters: {'solver': 'sag', 'C': 0.028742654640870533, 'max_iter': 307}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:17,635] Trial 281 finished with value: 0.7961278423592184 and parameters: {'solver': 'sag', 'C': 0.029313628606365674, 'max_iter': 866}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:17,643] Trial 283 finished with value: 0.7961206190829329 and parameters: {'solver': 'sag', 'C': 0.01444834957699892, 'max_iter': 308}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:17,726] Trial 284 finished with value: 0.7961177297724186 and parameters: {'solver': 'sag', 'C': 0.015847617806230653, 'max_iter': 861}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:17,844] Trial 286 finished with value: 0.7961292870144755 and parameters: {'solver': 'sag', 'C': 0.01610237526473716, 'max_iter': 226}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:17,876] Trial 285 finished with value: 0.7961100249443808 and parameters: {'solver': 'sag', 'C': 0.1142137984955474, 'max_iter': 806}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:17,922] Trial 288 finished with value: 0.7961263977039612 and parameters: {'solver': 'sag', 'C': 0.013758737311978166, 'max_iter': 863}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:17,951] Trial 282 finished with value: 0.7961066540821142 and parameters: {'solver': 'sag', 'C': 81.89730116312988, 'max_iter': 802}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:17,976] Trial 287 finished with value: 0.7961172482206662 and parameters: {'solver': 'sag', 'C': 0.013965095932384146, 'max_iter': 863}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:18,034] Trial 289 finished with value: 0.796128805462723 and parameters: {'solver': 'sag', 'C': 0.013718489597239066, 'max_iter': 867}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:18,092] Trial 290 finished with value: 0.7961239899451994 and parameters: {'solver': 'sag', 'C': 0.013036976935150761, 'max_iter': 877}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:18,160] Trial 292 finished with value: 0.7961225452899423 and parameters: {'solver': 'sag', 'C': 0.01224191436207847, 'max_iter': 100}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:18,220] Trial 295 finished with value: 0.7961273608074659 and parameters: {'solver': 'sag', 'C': 0.013737152641183862, 'max_iter': 894}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:18,253] Trial 291 finished with value: 0.7961384364977706 and parameters: {'solver': 'sag', 'C': 0.015320928615086663, 'max_iter': 876}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:18,325] Trial 294 finished with value: 0.7961283239109707 and parameters: {'solver': 'sag', 'C': 0.01613176186470908, 'max_iter': 885}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:18,453] Trial 296 finished with value: 0.7961172482206662 and parameters: {'solver': 'sag', 'C': 0.013975053893923025, 'max_iter': 893}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:18,498] Trial 298 finished with value: 0.7961225452899423 and parameters: {'solver': 'sag', 'C': 0.013416167254587085, 'max_iter': 231}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:18,559] Trial 293 finished with value: 0.7961066540821142 and parameters: {'solver': 'sag', 'C': 36.92111164183185, 'max_iter': 887}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:18,581] Trial 299 finished with value: 0.7961369918425133 and parameters: {'solver': 'sag', 'C': 0.015212241082525857, 'max_iter': 175}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:18,583] Trial 297 finished with value: 0.7961066540821142 and
```

```
parameters: {'solver': 'sag', 'C': 98.23851559373792, 'max_iter': 160}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:18,674] Trial 301 finished with value: 0.7961148404619043 and parameters: {'solver': 'sag', 'C': 0.10640910991802392, 'max_iter': 176}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:18,726] Trial 300 finished with value: 0.7961239899451995 and parameters: {'solver': 'sag', 'C': 0.012708408071192747, 'max_iter': 899}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:18,730] Trial 303 finished with value: 0.7915661026090474 and parameters: {'solver': 'sag', 'C': 0.00012947517286796112, 'max_iter': 116}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:18,848] Trial 302 finished with value: 0.7961124327031427 and parameters: {'solver': 'sag', 'C': 0.10134109652387643, 'max_iter': 280}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:18,916] Trial 304 finished with value: 0.7961080987373712 and parameters: {'solver': 'sag', 'C': 0.12451556531562157, 'max_iter': 964}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:19,014] Trial 308 finished with value: 0.7961162851171615 and parameters: {'solver': 'sag', 'C': 0.10886265163138405, 'max_iter': 900}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:19,018] Trial 307 finished with value: 0.790280359430228 and parameters: {'solver': 'sag', 'C': 6.57265615810212e-05, 'max_iter': 175}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:19,077] Trial 306 finished with value: 0.7892796948888098 and parameters: {'solver': 'sag', 'C': 2.857158937692136e-05, 'max_iter': 287}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:19,104] Trial 305 finished with value: 0.7961100249443808 and parameters: {'solver': 'sag', 'C': 0.11565490342978516, 'max_iter': 107}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:19,171] Trial 309 finished with value: 0.796110506496133 and parameters: {'solver': 'sag', 'C': 0.11346533049708672, 'max_iter': 981}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:19,175] Trial 310 finished with value: 0.7961105064961331 and parameters: {'solver': 'sag', 'C': 0.11403612743058629, 'max_iter': 281}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:19,206] Trial 311 finished with value: 0.796112914254895 and parameters: {'solver': 'sag', 'C': 0.10127897714131343, 'max_iter': 171}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:19,299] Trial 312 finished with value: 0.7961090618408762 and parameters: {'solver': 'sag', 'C': 0.11947464587059446, 'max_iter': 282}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:19,311] Trial 314 finished with value: 0.7961109880478856 and parameters: {'solver': 'sag', 'C': 0.10098032273300964, 'max_iter': 837}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:19,421] Trial 313 finished with value: 0.7961148404619044 and parameters: {'solver': 'sag', 'C': 0.10692369565511037, 'max_iter': 832}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:19,474] Trial 315 finished with value: 0.7961095433926284 and parameters: {'solver': 'sag', 'C': 0.11882799332450203, 'max_iter': 934}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:19,619] Trial 320 finished with value: 0.796107617185619 and parameters: {'solver': 'sag', 'C': 0.0990643862696808, 'max_iter': 284}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:19,632] Trial 319 finished with value: 0.7961162851171615 and parameters: {'solver': 'sag', 'C': 0.11015191833436216, 'max_iter': 971}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:19,678] Trial 316 finished with value: 0.7961090618408762 and parameters: {'solver': 'sag', 'C': 0.09825717432711395, 'max_iter': 843}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:19,679] Trial 318 finished with value: 0.7961365102907609 and
```

```
parameters: {'solver': 'sag', 'C': 0.043973647657921236, 'max_iter': 836}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:19,777] Trial 322 finished with value: 0.7961167666689138 and parameters: {'solver': 'sag', 'C': 0.006542812940936967, 'max_iter': 925}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:19,793] Trial 317 finished with value: 0.7961143589101521 and parameters: {'solver': 'sag', 'C': 0.10437440833955126, 'max_iter': 283}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:19,887] Trial 321 finished with value: 0.796137954946018 and parameters: {'solver': 'sag', 'C': 0.04408089004194561, 'max_iter': 280}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:19,921] Trial 324 finished with value: 0.7961345840837515 and parameters: {'solver': 'sag', 'C': 0.04741172271809549, 'max_iter': 165}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:19,927] Trial 323 finished with value: 0.7961263977039612 and parameters: {'solver': 'sag', 'C': 0.0059645869028716585, 'max_iter': 984}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:19,936] Trial 325 finished with value: 0.7961211006346851 and parameters: {'solver': 'sag', 'C': 0.0065247618936505975, 'max_iter': 932}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:19,993] Trial 327 finished with value: 0.796116766668914 and parameters: {'solver': 'sag', 'C': 0.006233288479779262, 'max_iter': 933}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:20,060] Trial 326 finished with value: 0.7961307316697326 and parameters: {'solver': 'sag', 'C': 0.041846321287189764, 'max_iter': 967}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:20,198] Trial 328 finished with value: 0.7961365102907609 and parameters: {'solver': 'sag', 'C': 0.043974381086244074, 'max_iter': 908}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:20,234] Trial 329 finished with value: 0.7961369918425133 and parameters: {'solver': 'sag', 'C': 0.04343749441720031, 'max_iter': 843}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:20,359] Trial 330 finished with value: 0.7961326578767419 and parameters: {'solver': 'sag', 'C': 0.04063803826966558, 'max_iter': 383}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:20,459] Trial 337 finished with value: 0.7961365102907609 and parameters: {'solver': 'sag', 'C': 0.04425283763791692, 'max_iter': 916}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:20,488] Trial 332 finished with value: 0.7960873920120195 and parameters: {'solver': 'sag', 'C': 0.005476895123365827, 'max_iter': 387}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:20,514] Trial 333 finished with value: 0.7961413258082846 and parameters: {'solver': 'sag', 'C': 0.04563089874066343, 'max_iter': 382}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:20,553] Trial 335 finished with value: 0.7961408442565323 and parameters: {'solver': 'sag', 'C': 0.04464534400680511, 'max_iter': 464}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:20,557] Trial 331 finished with value: 0.7961254346004565 and parameters: {'solver': 'sag', 'C': 0.006410935337598825, 'max_iter': 841}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:20,583] Trial 336 finished with value: 0.7961302501179802 and parameters: {'solver': 'sag', 'C': 0.04192872528310756, 'max_iter': 911}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:20,609] Trial 334 finished with value: 0.7961331394284943 and parameters: {'solver': 'sag', 'C': 0.047736773024576594, 'max_iter': 932}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:20,633] Trial 339 finished with value: 0.7960883551155243 and parameters: {'solver': 'sag', 'C': 0.005514222869565452, 'max_iter': 914}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:20,741] Trial 338 finished with value: 0.7961398811530275 and
```

```
parameters: {'solver': 'sag', 'C': 0.04549837693205019, 'max_iter': 933}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:20,866] Trial 340 finished with value: 0.7961384364977704 and parameters: {'solver': 'sag', 'C': 0.04440780935199251, 'max_iter': 913}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:20,876] Trial 341 finished with value: 0.7961321763249897 and parameters: {'solver': 'sag', 'C': 0.043013091541194454, 'max_iter': 382}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:20,911] Trial 345 finished with value: 0.7961398811530275 and parameters: {'solver': 'sag', 'C': 0.045476802835713016, 'max_iter': 156}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:20,954] Trial 343 finished with value: 0.7961393996012752 and parameters: {'solver': 'sag', 'C': 0.04537948994449831, 'max_iter': 911}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:20,988] Trial 346 finished with value: 0.7961249530487041 and parameters: {'solver': 'sag', 'C': 0.01921803491440144, 'max_iter': 162}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:21,040] Trial 344 finished with value: 0.7961408442565323 and parameters: {'solver': 'sag', 'C': 0.044665909234534264, 'max_iter': 132}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:21,192] Trial 342 finished with value: 0.7961398811530275 and parameters: {'solver': 'sag', 'C': 0.04592826965452093, 'max_iter': 477}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:21,195] Trial 347 finished with value: 0.7961350656355038 and parameters: {'solver': 'sag', 'C': 0.04854222551586099, 'max_iter': 131}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:21,285] Trial 348 finished with value: 0.7961297685662279 and parameters: {'solver': 'sag', 'C': 0.042222682157770995, 'max_iter': 846}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:21,336] Trial 349 finished with value: 0.7959901185580415 and parameters: {'solver': 'sag', 'C': 0.003132524888083859, 'max_iter': 180}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:21,402] Trial 350 finished with value: 0.7961413258082846 and parameters: {'solver': 'sag', 'C': 0.045718212778543786, 'max_iter': 844}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:21,442] Trial 351 finished with value: 0.7961365102907609 and parameters: {'solver': 'sag', 'C': 0.04687157650295069, 'max_iter': 880}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:21,521] Trial 352 finished with value: 0.7961403627047798 and parameters: {'solver': 'sag', 'C': 0.045236104946940095, 'max_iter': 878}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:21,649] Trial 354 finished with value: 0.7959968602825745 and parameters: {'solver': 'sag', 'C': 0.0030581378961260708, 'max_iter': 496}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:21,663] Trial 353 finished with value: 0.7961403627047798 and parameters: {'solver': 'sag', 'C': 0.045240998679658216, 'max_iter': 821}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:21,725] Trial 358 finished with value: 0.7959766351089752 and parameters: {'solver': 'sag', 'C': 0.002958079208804072, 'max_iter': 847}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:21,728] Trial 355 finished with value: 0.796107617185619 and parameters: {'solver': 'sag', 'C': 0.21681146690335168, 'max_iter': 884}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:21,805] Trial 357 finished with value: 0.796135065635504 and parameters: {'solver': 'sag', 'C': 0.047905049537551564, 'max_iter': 846}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:21,879] Trial 356 finished with value: 0.7961090618408759 and parameters: {'solver': 'sag', 'C': 0.2337952671061389, 'max_iter': 467}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:21,934] Trial 360 finished with value: 0.7961109880478856 and
```

```
parameters: {'solver': 'sag', 'C': 0.2692423985981658, 'max_iter': 478}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:21,959] Trial 359 finished with value: 0.796123508393447 and parameters: {'solver': 'sag', 'C': 0.019192036167671414, 'max_iter': 823}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:22,007] Trial 361 finished with value: 0.7961307316697325 and parameters: {'solver': 'sag', 'C': 0.049609711062933506, 'max_iter': 879}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:22,141] Trial 362 finished with value: 0.7961124327031426 and parameters: {'solver': 'sag', 'C': 0.0197532848904958, 'max_iter': 486}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:22,152] Trial 363 finished with value: 0.7961196559794279 and parameters: {'solver': 'sag', 'C': 0.019028563946054476, 'max_iter': 945}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:22,282] Trial 367 finished with value: 0.7961124327031427 and parameters: {'solver': 'sag', 'C': 0.019767668842262456, 'max_iter': 849}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:22,306] Trial 365 finished with value: 0.7961032832198477 and parameters: {'solver': 'sag', 'C': 0.021593960510076716, 'max_iter': 940}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:22,311] Trial 364 finished with value: 0.7961119511513902 and parameters: {'solver': 'sag', 'C': 0.24317124288306602, 'max_iter': 898}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:22,333] Trial 366 finished with value: 0.7961206190829329 and parameters: {'solver': 'sag', 'C': 0.01954596054519228, 'max_iter': 337}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:22,363] Trial 368 finished with value: 0.796116766668914 and parameters: {'solver': 'sag', 'C': 0.019629772389294503, 'max_iter': 881}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:22,530] Trial 369 finished with value: 0.7961109880478856 and parameters: {'solver': 'sag', 'C': 0.20242681656205458, 'max_iter': 475}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:22,561] Trial 371 finished with value: 0.796115803565409 and parameters: {'solver': 'sag', 'C': 0.07100423915846428, 'max_iter': 482}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:22,610] Trial 370 finished with value: 0.7961080987373712 and parameters: {'solver': 'sag', 'C': 0.02086184551527659, 'max_iter': 820}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:22,667] Trial 374 finished with value: 0.7961080987373712 and parameters: {'solver': 'sag', 'C': 0.02057571645893995, 'max_iter': 819}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:22,761] Trial 372 finished with value: 0.7961133958066473 and parameters: {'solver': 'sag', 'C': 0.019980066431195855, 'max_iter': 480}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:22,853] Trial 375 finished with value: 0.796119655979428 and parameters: {'solver': 'sag', 'C': 0.07735021016384633, 'max_iter': 778}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:22,871] Trial 373 finished with value: 0.7961085802891237 and parameters: {'solver': 'sag', 'C': 0.1806744356470242, 'max_iter': 821}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:22,915] Trial 377 finished with value: 0.7961177297724186 and parameters: {'solver': 'sag', 'C': 0.07951249674504465, 'max_iter': 818}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:22,933] Trial 376 finished with value: 0.7961215821864375 and parameters: {'solver': 'sag', 'C': 0.07471158551722393, 'max_iter': 888}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:23,020] Trial 378 finished with value: 0.796118211324171 and parameters: {'solver': 'sag', 'C': 0.07349590540111638, 'max_iter': 827}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:23,084] Trial 379 finished with value: 0.796116766668914 and
```

```
parameters: {'solver': 'sag', 'C': 0.07171339107890122, 'max_iter': 814}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:23,136] Trial 380 finished with value: 0.7961158035654092 and parameters: {'solver': 'sag', 'C': 0.08433884776408263, 'max_iter': 807}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:23,215] Trial 381 finished with value: 0.7961201375311805 and parameters: {'solver': 'sag', 'C': 0.07801431056308156, 'max_iter': 820}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:23,290] Trial 386 finished with value: 0.7961090618408762 and parameters: {'solver': 'lbfgs', 'C': 0.06850173152985671, 'max_iter': 877}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:23,298] Trial 384 finished with value: 0.796112914254895 and parameters: {'solver': 'sag', 'C': 0.06218239401500807, 'max_iter': 885}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:23,331] Trial 382 finished with value: 0.7961119511513903 and parameters: {'solver': 'lbfgs', 'C': 0.07146142917829976, 'max_iter': 809}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:23,364] Trial 383 finished with value: 0.7961066540821141 and parameters: {'solver': 'lbfgs', 'C': 0.07774534804414081, 'max_iter': 883}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:23,489] Trial 385 finished with value: 0.7961018385645906 and parameters: {'solver': 'lbfgs', 'C': 0.08600004990567965, 'max_iter': 809}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:23,558] Trial 387 finished with value: 0.796116766668914 and parameters: {'solver': 'sag', 'C': 0.07250710282599461, 'max_iter': 821}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:23,663] Trial 388 finished with value: 0.7961172482206662 and parameters: {'solver': 'sag', 'C': 0.0848999725241612, 'max_iter': 803}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:23,726] Trial 390 finished with value: 0.796118211324171 and parameters: {'solver': 'sag', 'C': 0.0734178549297601, 'max_iter': 910}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:23,738] Trial 392 finished with value: 0.7960994308058287 and parameters: {'solver': 'lbfgs', 'C': 0.08178740291772563, 'max_iter': 906}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:23,741] Trial 389 finished with value: 0.7961095433926284 and parameters: {'solver': 'lbfgs', 'C': 0.07628356238456087, 'max_iter': 815}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:23,868] Trial 393 finished with value: 0.7961158035654092 and parameters: {'solver': 'sag', 'C': 0.06089221099622551, 'max_iter': 907}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:23,881] Trial 391 finished with value: 0.7961191744276757 and parameters: {'solver': 'lbfgs', 'C': 0.05048448326511654, 'max_iter': 904}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:23,892] Trial 395 finished with value: 0.7961023201163429 and parameters: {'solver': 'lbfgs', 'C': 0.08294930520847997, 'max_iter': 908}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:24,018] Trial 397 finished with value: 0.7961162851171616 and parameters: {'solver': 'sag', 'C': 0.0727005540991712, 'max_iter': 910}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:24,063] Trial 394 finished with value: 0.796107617185619 and parameters: {'solver': 'lbfgs', 'C': 0.07754607134278743, 'max_iter': 901}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:24,149] Trial 398 finished with value: 0.7961331394284943 and parameters: {'solver': 'sag', 'C': 0.047736504431759925, 'max_iter': 913}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:24,157] Trial 399 finished with value: 0.7961201375311806 and parameters: {'solver': 'lbfgs', 'C': 0.05067890584783823, 'max_iter': 909}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:24,192] Trial 396 finished with value: 0.7961133958066473 and
```

```
parameters: {'solver': 'lbfgs', 'C': 0.07034118407557967, 'max_iter': 907}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:24,197] Trial 400 finished with value: 0.7961177297724186 and parameters: {'solver': 'lbfgs', 'C': 0.04446122682962375, 'max_iter': 858}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:24,271] Trial 401 finished with value: 0.7961177297724187 and parameters: {'solver': 'lbfgs', 'C': 0.04940883703785058, 'max_iter': 910}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:24,330] Trial 404 finished with value: 0.7961331394284944 and parameters: {'solver': 'sag', 'C': 0.04770132664876649, 'max_iter': 855}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:24,407] Trial 402 finished with value: 0.796137954946018 and parameters: {'solver': 'sag', 'C': 0.04811399702574196, 'max_iter': 896}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:24,494] Trial 403 finished with value: 0.7961148404619044 and parameters: {'solver': 'lbfgs', 'C': 0.044862988670915094, 'max_iter': 855}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:24,527] Trial 405 finished with value: 0.7961331394284943 and parameters: {'solver': 'sag', 'C': 0.04997378156049024, 'max_iter': 854}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:24,620] Trial 407 finished with value: 0.7961331394284944 and parameters: {'solver': 'sag', 'C': 0.03246321217321463, 'max_iter': 909}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:24,664] Trial 408 finished with value: 0.7961350656355037 and parameters: {'solver': 'sag', 'C': 0.04714217905143155, 'max_iter': 848}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:24,679] Trial 406 finished with value: 0.7961408442565323 and parameters: {'solver': 'sag', 'C': 0.044647989351543634, 'max_iter': 910}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:24,765] Trial 409 finished with value: 0.796135065635504 and parameters: {'solver': 'sag', 'C': 0.052141237571281036, 'max_iter': 906}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:24,865] Trial 410 finished with value: 0.7961398811530276 and parameters: {'solver': 'sag', 'C': 0.04503794697794017, 'max_iter': 853}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:24,885] Trial 411 finished with value: 0.7961408442565323 and parameters: {'solver': 'sag', 'C': 0.04466556778166588, 'max_iter': 860}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:24,980] Trial 412 finished with value: 0.7961374733942657 and parameters: {'solver': 'sag', 'C': 0.044359066185792176, 'max_iter': 865}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:25,010] Trial 413 finished with value: 0.7961369918425133 and parameters: {'solver': 'sag', 'C': 0.043435244073194906, 'max_iter': 861}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:25,048] Trial 414 finished with value: 0.7961331394284944 and parameters: {'solver': 'sag', 'C': 0.04248211797020008, 'max_iter': 858}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:25,117] Trial 416 finished with value: 0.7961326578767419 and parameters: {'solver': 'sag', 'C': 0.04285215878550851, 'max_iter': 856}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:25,135] Trial 415 finished with value: 0.7961369918425133 and parameters: {'solver': 'sag', 'C': 0.0436484153328394, 'max_iter': 845}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:25,226] Trial 417 finished with value: 0.7961321763249897 and parameters: {'solver': 'sag', 'C': 0.042673995160585135, 'max_iter': 849}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:25,289] Trial 418 finished with value: 0.7961321763249896 and parameters: {'solver': 'sag', 'C': 0.040370597870729046, 'max_iter': 857}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:25,372] Trial 419 finished with value: 0.7961316947732373 and
```

```
parameters: {'solver': 'sag', 'C': 0.036779862819597095, 'max_iter': 855}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:25,400] Trial 422 finished with value: 0.7961307316697326 and parameters: {'solver': 'sag', 'C': 0.034007349488141624, 'max_iter': 956}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:25,450] Trial 420 finished with value: 0.7961326578767419 and parameters: {'solver': 'sag', 'C': 0.035934143322886344, 'max_iter': 950}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:25,480] Trial 423 finished with value: 0.7961316947732373 and parameters: {'solver': 'sag', 'C': 0.03293080631782604, 'max_iter': 870}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:25,543] Trial 421 finished with value: 0.7961336209802468 and parameters: {'solver': 'sag', 'C': 0.03607986480052959, 'max_iter': 1000}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:25,587] Trial 424 finished with value: 0.788589631227668 and parameters: {'solver': 'sag', 'C': 6.298120992209254e-06, 'max_iter': 961}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:25,632] Trial 425 finished with value: 0.7961239899451995 and parameters: {'solver': 'sag', 'C': 0.03336991183678574, 'max_iter': 960}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:25,704] Trial 426 finished with value: 0.7961244714969518 and parameters: {'solver': 'sag', 'C': 0.03344202559224791, 'max_iter': 936}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:25,739] Trial 428 finished with value: 0.7961316947732373 and parameters: {'solver': 'sag', 'C': 0.03211642196695708, 'max_iter': 944}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:25,788] Trial 427 finished with value: 0.7961288054627232 and parameters: {'solver': 'sag', 'C': 0.031032201905151907, 'max_iter': 949}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:25,930] Trial 429 finished with value: 0.7961263977039612 and parameters: {'solver': 'sag', 'C': 0.02984175036895986, 'max_iter': 456}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:25,982] Trial 430 finished with value: 0.7961292870144755 and parameters: {'solver': 'sag', 'C': 0.03212872581568063, 'max_iter': 783}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:26,000] Trial 432 finished with value: 0.7961288054627231 and parameters: {'solver': 'sag', 'C': 0.031114335880179794, 'max_iter': 869}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:26,023] Trial 431 finished with value: 0.7961307316697326 and parameters: {'solver': 'sag', 'C': 0.030309637620025795, 'max_iter': 950}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:26,125] Trial 435 finished with value: 0.7885101751885275 and parameters: {'solver': 'sag', 'C': 4.172524413955448e-06, 'max_iter': 453}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:26,183] Trial 436 finished with value: 0.796125916152209 and parameters: {'solver': 'sag', 'C': 0.028723932524193755, 'max_iter': 946}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:26,209] Trial 434 finished with value: 0.7961263977039613 and parameters: {'solver': 'sag', 'C': 0.02884665687734226, 'max_iter': 455}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:26,227] Trial 433 finished with value: 0.7961263977039613 and parameters: {'solver': 'sag', 'C': 0.02885461741936438, 'max_iter': 941}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:26,374] Trial 438 finished with value: 0.7961263977039613 and parameters: {'solver': 'sag', 'C': 0.024320997196715703, 'max_iter': 456}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:26,434] Trial 439 finished with value: 0.7961071356338666 and parameters: {'solver': 'sag', 'C': 0.15548512068504464, 'max_iter': 135}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:26,454] Trial 440 finished with value: 0.7961061725303619 and
```

```
parameters: {'solver': 'sag', 'C': 0.1561188745560215, 'max_iter': 132}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:26,488] Trial 437 finished with value: 0.7961080987373714 and parameters: {'solver': 'sag', 'C': 0.15796646594841252, 'max_iter': 952}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:26,549] Trial 441 finished with value: 0.7961071356338666 and parameters: {'solver': 'sag', 'C': 0.1587376260296459, 'max_iter': 872}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:26,642] Trial 443 finished with value: 0.796116766668914 and parameters: {'solver': 'sag', 'C': 0.02569315910064255, 'max_iter': 409}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:26,658] Trial 442 finished with value: 0.7961095433926284 and parameters: {'solver': 'sag', 'C': 0.15002700520326254, 'max_iter': 453}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:26,703] Trial 444 finished with value: 0.7961105064961332 and parameters: {'solver': 'sag', 'C': 0.145745296864294, 'max_iter': 875}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:26,792] Trial 445 finished with value: 0.7961124327031427 and parameters: {'solver': 'sag', 'C': 0.16941662722427728, 'max_iter': 933}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:26,851] Trial 446 finished with value: 0.7961196559794281 and parameters: {'solver': 'sag', 'C': 0.024838120612816515, 'max_iter': 881}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:26,947] Trial 449 finished with value: 0.7961109880478855 and parameters: {'solver': 'sag', 'C': 0.1452858844149825, 'max_iter': 124}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:26,955] Trial 447 finished with value: 0.7961138773583997 and parameters: {'solver': 'sag', 'C': 0.022794873591301643, 'max_iter': 532}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:26,957] Trial 450 finished with value: 0.7960994308058286 and parameters: {'solver': 'sag', 'C': 0.021311994704052428, 'max_iter': 414}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:27,037] Trial 448 finished with value: 0.7961191744276757 and parameters: {'solver': 'sag', 'C': 0.02479416512497202, 'max_iter': 119}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:27,123] Trial 451 finished with value: 0.7961080987373712 and parameters: {'solver': 'sag', 'C': 0.15455844177311645, 'max_iter': 122}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:27,142] Trial 452 finished with value: 0.7961095433926284 and parameters: {'solver': 'sag', 'C': 0.02213854836240209, 'max_iter': 724}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:27,192] Trial 453 finished with value: 0.7961191744276757 and parameters: {'solver': 'sag', 'C': 0.022936399515951094, 'max_iter': 402}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:27,267] Trial 454 finished with value: 0.796107617185619 and parameters: {'solver': 'sag', 'C': 0.16218423587423508, 'max_iter': 140}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:27,316] Trial 456 finished with value: 0.7961201375311806 and parameters: {'solver': 'sag', 'C': 0.022965562110340135, 'max_iter': 400}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:27,368] Trial 455 finished with value: 0.7961124327031426 and parameters: {'solver': 'sag', 'C': 0.13927417847614107, 'max_iter': 118}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:27,433] Trial 457 finished with value: 0.7961100249443808 and parameters: {'solver': 'sag', 'C': 0.16455188826607575, 'max_iter': 411}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:27,463] Trial 458 finished with value: 0.7961028016680952 and parameters: {'solver': 'sag', 'C': 0.02160156930737592, 'max_iter': 878}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:27,524] Trial 460 finished with value: 0.7961235083934471 and
```

```
parameters: {'solver': 'sag', 'C': 0.023054461120495886, 'max_iter': 410}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:27,561] Trial 459 finished with value: 0.7961095433926284 and parameters: {'solver': 'sag', 'C': 0.01048405945868235, 'max_iter': 415}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:27,611] Trial 461 finished with value: 0.7961105064961331 and parameters: {'solver': 'sag', 'C': 0.020793572262475635, 'max_iter': 396}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:27,714] Trial 462 finished with value: 0.7961061725303619 and parameters: {'solver': 'sag', 'C': 0.021070799978751432, 'max_iter': 886}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:27,731] Trial 463 finished with value: 0.7961061725303619 and parameters: {'solver': 'sag', 'C': 1.849348894673997, 'max_iter': 893}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:27,748] Trial 464 finished with value: 0.7961143589101521 and parameters: {'solver': 'sag', 'C': 0.020311654699318525, 'max_iter': 534}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:27,777] Trial 465 finished with value: 0.7961239899451995 and parameters: {'solver': 'sag', 'C': 0.0193560157377668, 'max_iter': 420}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:27,867] Trial 466 finished with value: 0.7961114695996379 and parameters: {'solver': 'sag', 'C': 0.010447149355159262, 'max_iter': 888}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:27,905] Trial 468 finished with value: 0.7961225452899423 and parameters: {'solver': 'sag', 'C': 0.010091412438291942, 'max_iter': 890}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:27,949] Trial 467 finished with value: 0.7961186928759234 and parameters: {'solver': 'sag', 'C': 0.010898481158163633, 'max_iter': 719}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:28,046] Trial 469 finished with value: 0.7961206190829329 and parameters: {'solver': 'sag', 'C': 0.058833413414553636, 'max_iter': 831}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:28,141] Trial 471 finished with value: 0.796118211324171 and parameters: {'solver': 'sag', 'C': 0.059944546998454896, 'max_iter': 832}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:28,187] Trial 472 finished with value: 0.7961196559794281 and parameters: {'solver': 'sag', 'C': 0.010730600469616866, 'max_iter': 695}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:28,250] Trial 470 finished with value: 0.7961071356338666 and parameters: {'solver': 'sag', 'C': 8.141687935812165, 'max_iter': 835}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:28,259] Trial 474 finished with value: 0.7961124327031426 and parameters: {'solver': 'sag', 'C': 0.06179915053313215, 'max_iter': 841}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:28,326] Trial 475 finished with value: 0.7961100249443808 and parameters: {'solver': 'sag', 'C': 0.010486044286997153, 'max_iter': 830}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:28,350] Trial 473 finished with value: 0.7961148404619044 and parameters: {'solver': 'sag', 'C': 0.05951877976921409, 'max_iter': 832}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:28,389] Trial 476 finished with value: 0.796125916152209 and parameters: {'solver': 'sag', 'C': 0.05630818717415303, 'max_iter': 881}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:28,483] Trial 477 finished with value: 0.7961177297724186 and parameters: {'solver': 'sag', 'C': 0.06372721549306991, 'max_iter': 835}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:28,510] Trial 478 finished with value: 0.7961158035654091 and parameters: {'solver': 'sag', 'C': 0.011711007161109252, 'max_iter': 894}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:28,530] Trial 480 finished with value: 0.7961162851171616 and
```

```
parameters: {'solver': 'sag', 'C': 0.06081801628932068, 'max_iter': 831}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:28,632] Trial 479 finished with value: 0.796116766668914 and parameters: {'solver': 'sag', 'C': 0.010332651707117639, 'max_iter': 886}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:28,702] Trial 481 finished with value: 0.7961182113241709 and parameters: {'solver': 'sag', 'C': 0.06022753834626345, 'max_iter': 882}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:28,767] Trial 482 finished with value: 0.7961201375311805 and parameters: {'solver': 'sag', 'C': 0.05852462243186359, 'max_iter': 889}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:28,810] Trial 484 finished with value: 0.79612206373819 and parameters: {'solver': 'sag', 'C': 0.057726378821143814, 'max_iter': 838}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:28,864] Trial 486 finished with value: 0.7961230268416948 and parameters: {'solver': 'sag', 'C': 0.05684728034877608, 'max_iter': 343}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:28,907] Trial 483 finished with value: 0.7961191744276758 and parameters: {'solver': 'sag', 'C': 0.05891396504374605, 'max_iter': 336}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:28,955] Trial 485 finished with value: 0.7961230268416948 and parameters: {'solver': 'sag', 'C': 0.05690773102015693, 'max_iter': 832}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:29,004] Trial 488 finished with value: 0.7961206190829329 and parameters: {'solver': 'sag', 'C': 0.05804460298484287, 'max_iter': 830}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:29,020] Trial 491 finished with value: 0.7961263977039612 and parameters: {'solver': 'sag', 'C': 0.05571370099488999, 'max_iter': 924}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:29,034] Trial 489 finished with value: 0.7961273608074659 and parameters: {'solver': 'sag', 'C': 0.05433153644814747, 'max_iter': 837}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:29,075] Trial 487 finished with value: 0.7961263977039612 and parameters: {'solver': 'sag', 'C': 0.05481615192104611, 'max_iter': 839}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:29,104] Trial 493 finished with value: 0.7961177297724187 and parameters: {'solver': 'sag', 'C': 0.05997042307536789, 'max_iter': 505}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:29,144] Trial 494 finished with value: 0.7961239899451995 and parameters: {'solver': 'sag', 'C': 0.05649946699130191, 'max_iter': 865}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:29,145] Trial 492 finished with value: 0.7961360287390085 and parameters: {'solver': 'sag', 'C': 0.04802627267842765, 'max_iter': 505}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:29,167] Trial 490 finished with value: 0.796119655979428 and parameters: {'solver': 'sag', 'C': 0.06031202251066914, 'max_iter': 923}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:29,266] Trial 495 finished with value: 0.7961114695996379 and parameters: {'solver': 'sag', 'C': 0.09456621261715516, 'max_iter': 874}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:29,298] Trial 497 finished with value: 0.796125916152209 and parameters: {'solver': 'sag', 'C': 0.056108986465164316, 'max_iter': 868}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:29,332] Trial 496 finished with value: 0.796114358910152 and parameters: {'solver': 'sag', 'C': 0.09190161803861627, 'max_iter': 925}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:29,335] Trial 498 finished with value: 0.7961162851171615 and parameters: {'solver': 'sag', 'C': 0.08663321274391518, 'max_iter': 926}. Best is trial 115 with value: 0.7961418073600369.  
[I 2024-12-23 09:55:29,342] Trial 499 finished with value: 0.7961148404619044 and
```

```
parameters: {'solver': 'sag', 'C': 0.08181681864920433, 'max_iter': 925}. Best is trial 115 with value: 0.7961418073600369.
```

```
Best hyperparameters: {'solver': 'saga', 'C': 0.04487960597783652, 'max_iter': 619}
```

```
In [27]: best_params = logisticStudy.best_params
logistic_model = LogisticRegression(
    solver=best_params["solver"],
    C=best_params["C"],
    random_state=42,
    class_weight='balanced',
    max_iter=best_params["max_iter"]
)

logistic_model.fit(X_train_scaled, y_train)
skf = StratifiedKFold(n_splits=5, shuffle=True, random_state=42)
logistic_score = cross_val_score(logistic_model, X_train_scaled, y_train, cv=skf)
```

MODEL EVALUATION

```
In [28]: accuracy = accuracy_score(y_test, y_pred)
precision = precision_score(y_test, y_pred)
recall = recall_score(y_test, y_pred)
f1 = f1_score(y_test, y_pred)
roc_auc = roc_auc_score(y_test, y_pred_proba)

metrics = {
    "Accuracy": accuracy * 100,
    "Precision": precision * 100,
    "Recall": recall * 100,
    "F1 Score": f1 * 100,
    "ROC AUC Score": roc_auc * 100,
    "Error Rate": (1 - accuracy) * 100,
}

for metric, value in metrics.items():
    print(f"{metric}: {value:.2f}%")

conf_matrix = confusion_matrix(y_test, y_pred)
disp = ConfusionMatrixDisplay(confusion_matrix=conf_matrix, display_labels=logis
disp.plot(cmap="Blues")
plt.title("LogisticRegression Confusion Matrix")
plt.show()
```

Accuracy: 73.50%

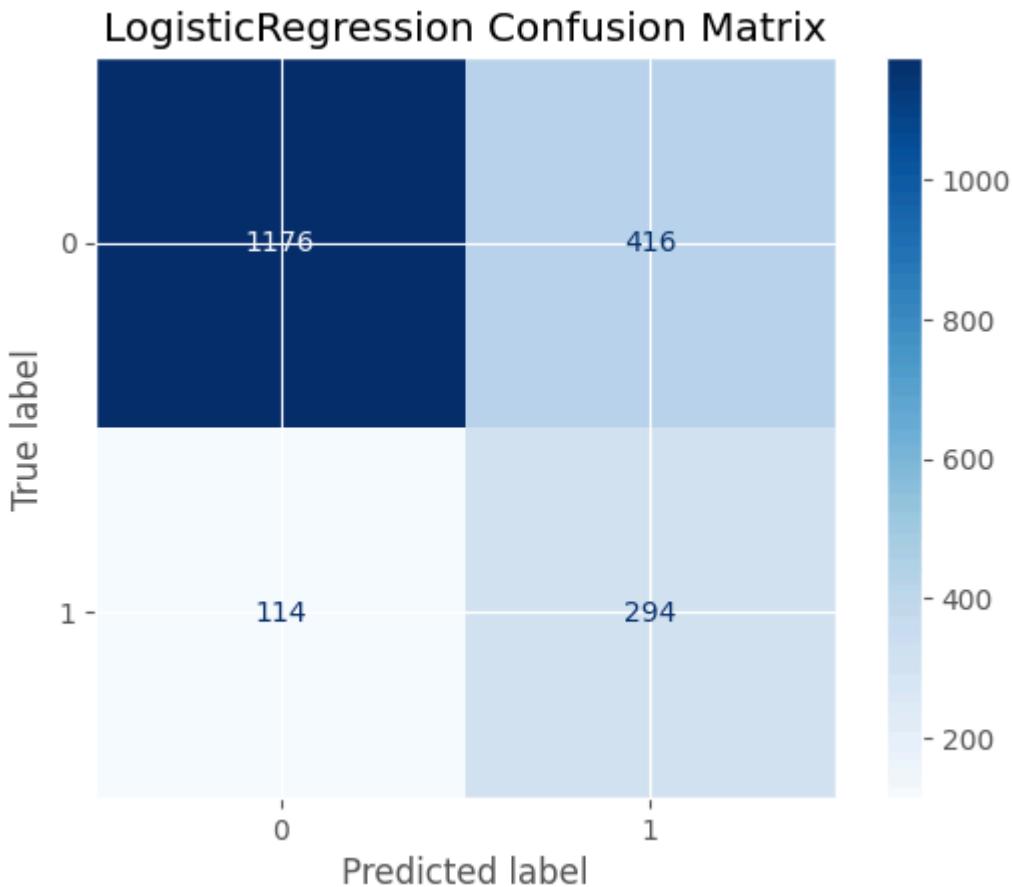
Precision: 41.41%

Recall: 72.06%

F1 Score: 52.59%

ROC AUC Score: 81.07%

Error Rate: 26.50%



Model Evaluation Summary:

Our logistic regression model shows good results in some aspects but not that good in others. We obtained a pretty solid ROC-AUC which means that our model is robust in distinguishing classes same with values for accuracy and recall, in our project we want to focus more in that we have obtained much better recall than precision(as we have 416 false positives which shows a clear imbalance), indicating a focus on minimizing false negatives.

CART (Decision Tree Classifier)

For our Decision Tree Classifier, we are using Optuna for hyperparameter tuning, evaluating the following hyperparameters:

- `max_depth`: Tree depth (3 to 50) to control model complexity and prevent overfitting by limiting how deep each tree can grow.
- `min_samples_split`: Minimum samples required to split a node (2 to 32), preventing the model from creating overly complex trees.
- `min_samples_leaf`: Minimum samples at a leaf node (1 to 32), controlling the smallest size of terminal nodes to ensure the model generalizes well.
- `max_features`: Number of features to consider at each split (`sqrt`, `log2`, or `all`), providing flexibility in feature selection and improving model robustness.

With the Decision Tree Classifier, we expect to have higher accuracy for our dataset as it can capture more complex, non-linear relationships between features. In comparison to

Logistic Regression, the Decision Tree may offer us more flexibility and better performance, though it may also be more prone to overfitting without proper tuning. We will need to be careful with it.

```
In [25]: X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_state=42)

def objective(trial):
    max_depth = trial.suggest_int("max_depth", 3, 50)
    min_samples_split = trial.suggest_int("min_samples_split", 2, 32)
    min_samples_leaf = trial.suggest_int("min_samples_leaf", 1, 32)
    max_features = trial.suggest_categorical("max_features", ["sqrt", "log2", None])
    model = DecisionTreeClassifier(
        max_depth=max_depth,
        min_samples_split=min_samples_split,
        min_samples_leaf=min_samples_leaf,
        max_features=max_features,
        random_state=42,
        class_weight="balanced",
    )

    skf = StratifiedKFold(n_splits=5, shuffle=True, random_state=42)
    score = cross_val_score(model, X_train, y_train, cv=skf, scoring="roc_auc",
                           n_jobs=-1)
    return score

treeStudy = optuna.create_study(direction="maximize", sampler=optuna.samplers.RaySampler())
treeStudy.optimize(objective, n_trials=500, n_jobs=-1)

print("Best hyperparameters:", treeStudy.best_params)
best_params = treeStudy.best_params
```

```
[I 2024-12-22 23:28:02,889] A new study created in memory with name: no-name-08b4  
0b61-c266-4018-96a6-9431653f3148  
[I 2024-12-22 23:28:03,062] Trial 1 finished with value: 0.7290014542862921 and p  
arameters: {'max_depth': 50, 'min_samples_split': 23, 'min_samples_leaf': 7, 'max  
_features': None}. Best is trial 1 with value: 0.7290014542862921.  
[I 2024-12-22 23:28:03,107] Trial 0 finished with value: 0.7313880247710223 and p  
arameters: {'max_depth': 11, 'min_samples_split': 11, 'min_samples_leaf': 5, 'max  
_features': 'log2'}. Best is trial 0 with value: 0.7313880247710223.  
[I 2024-12-22 23:28:03,138] Trial 3 finished with value: 0.7489364929548978 and p  
arameters: {'max_depth': 23, 'min_samples_split': 22, 'min_samples_leaf': 11, 'ma  
x_features': None}. Best is trial 3 with value: 0.7489364929548978.  
[I 2024-12-22 23:28:03,155] Trial 2 finished with value: 0.6888860263312498 and p  
arameters: {'max_depth': 39, 'min_samples_split': 7, 'min_samples_leaf': 3, 'max  
_features': 'sqrt'}. Best is trial 3 with value: 0.7489364929548978.  
[I 2024-12-22 23:28:03,223] Trial 6 finished with value: 0.7632108907744316 and p  
arameters: {'max_depth': 8, 'min_samples_split': 27, 'min_samples_leaf': 16, 'max  
_features': 'sqrt'}. Best is trial 6 with value: 0.7632108907744316.  
[I 2024-12-22 23:28:03,237] Trial 9 finished with value: 0.7461302501179803 and p  
arameters: {'max_depth': 39, 'min_samples_split': 25, 'min_samples_leaf': 28, 'ma  
x_features': 'sqrt'}. Best is trial 6 with value: 0.7632108907744316.  
[I 2024-12-22 23:28:03,251] Trial 8 finished with value: 0.7851051227475417 and p  
arameters: {'max_depth': 5, 'min_samples_split': 29, 'min_samples_leaf': 22, 'ma  
x_features': None}. Best is trial 8 with value: 0.7851051227475417.  
[I 2024-12-22 23:28:03,336] Trial 7 finished with value: 0.7300464215889282 and p  
arameters: {'max_depth': 37, 'min_samples_split': 20, 'min_samples_leaf': 11, 'ma  
x_features': 'log2'}. Best is trial 8 with value: 0.7851051227475417.  
[I 2024-12-22 23:28:03,360] Trial 10 finished with value: 0.6943003534589862 and p  
arameters: {'max_depth': 28, 'min_samples_split': 8, 'min_samples_leaf': 5, 'ma  
x_features': None}. Best is trial 8 with value: 0.7851051227475417.  
[I 2024-12-22 23:28:03,363] Trial 4 finished with value: 0.7496559312729338 and p  
arameters: {'max_depth': 37, 'min_samples_split': 14, 'min_samples_leaf': 32, 'ma  
x_features': 'sqrt'}. Best is trial 8 with value: 0.7851051227475417.  
[I 2024-12-22 23:28:03,434] Trial 5 finished with value: 0.7245095395402144 and p  
arameters: {'max_depth': 46, 'min_samples_split': 7, 'min_samples_leaf': 7, 'ma  
x_features': 'sqrt'}. Best is trial 8 with value: 0.7851051227475417.  
[I 2024-12-22 23:28:03,457] Trial 11 finished with value: 0.7718552262811685 and p  
arameters: {'max_depth': 28, 'min_samples_split': 18, 'min_samples_leaf': 23, 'ma  
x_features': None}. Best is trial 8 with value: 0.7851051227475417.  
[I 2024-12-22 23:28:03,509] Trial 12 finished with value: 0.7733540561104102 and p  
arameters: {'max_depth': 31, 'min_samples_split': 14, 'min_samples_leaf': 26, 'ma  
x_features': None}. Best is trial 8 with value: 0.7851051227475417.  
[I 2024-12-22 23:28:03,514] Trial 13 finished with value: 0.7550341420192428 and p  
arameters: {'max_depth': 27, 'min_samples_split': 13, 'min_samples_leaf': 29, 'ma  
x_features': 'log2'}. Best is trial 8 with value: 0.7851051227475417.  
[I 2024-12-22 23:28:03,542] Trial 14 finished with value: 0.7372764395989637 and p  
arameters: {'max_depth': 22, 'min_samples_split': 28, 'min_samples_leaf': 26, 'ma  
x_features': 'log2'}. Best is trial 8 with value: 0.7851051227475417.  
[I 2024-12-22 23:28:03,550] Trial 15 finished with value: 0.764307865666323 and p  
arameters: {'max_depth': 35, 'min_samples_split': 32, 'min_samples_leaf': 16, 'ma  
x_features': None}. Best is trial 8 with value: 0.7851051227475417.  
[I 2024-12-22 23:28:03,608] Trial 18 finished with value: 0.7420645086727472 and p  
arameters: {'max_depth': 22, 'min_samples_split': 32, 'min_samples_leaf': 23, 'ma  
x_features': 'log2'}. Best is trial 8 with value: 0.7851051227475417.  
[I 2024-12-22 23:28:03,609] Trial 16 finished with value: 0.7540486463580243 and p  
arameters: {'max_depth': 9, 'min_samples_split': 12, 'min_samples_leaf': 20, 'ma  
x_features': 'sqrt'}. Best is trial 8 with value: 0.7851051227475417.  
[I 2024-12-22 23:28:03,658] Trial 17 finished with value: 0.7497717444693781 and p  
arameters: {'max_depth': 25, 'min_samples_split': 15, 'min_samples_leaf': 12, 'ma  
x_features': None}. Best is trial 8 with value: 0.7851051227475417.  
[I 2024-12-22 23:28:03,701] Trial 19 finished with value: 0.7728917664281381 and
```

```
parameters: {'max_depth': 47, 'min_samples_split': 25, 'min_samples_leaf': 28, 'max_features': None}. Best is trial 8 with value: 0.7851051227475417.
[I 2024-12-22 23:28:03,735] Trial 21 finished with value: 0.704771937090079 and parameters: {'max_depth': 5, 'min_samples_split': 6, 'min_samples_leaf': 21, 'max_features': 'log2'}. Best is trial 8 with value: 0.7851051227475417.
[I 2024-12-22 23:28:03,751] Trial 20 finished with value: 0.7521301441765946 and parameters: {'max_depth': 36, 'min_samples_split': 10, 'min_samples_leaf': 13, 'max_features': None}. Best is trial 8 with value: 0.7851051227475417.
[I 2024-12-22 23:28:03,747] Trial 24 finished with value: 0.7511504271364045 and parameters: {'max_depth': 19, 'min_samples_split': 25, 'min_samples_leaf': 27, 'max_features': 'sqrt'}. Best is trial 8 with value: 0.7851051227475417.
[I 2024-12-22 23:28:03,746] Trial 23 finished with value: 0.7372764395989637 and parameters: {'max_depth': 19, 'min_samples_split': 8, 'min_samples_leaf': 26, 'max_features': 'log2'}. Best is trial 8 with value: 0.7851051227475417.
[I 2024-12-22 23:28:03,763] Trial 25 finished with value: 0.7550341420192428 and parameters: {'max_depth': 31, 'min_samples_split': 17, 'min_samples_leaf': 29, 'max_features': 'log2'}. Best is trial 8 with value: 0.7851051227475417.
[I 2024-12-22 23:28:03,764] Trial 22 finished with value: 0.6871478652810818 and parameters: {'max_depth': 27, 'min_samples_split': 3, 'min_samples_leaf': 3, 'max_features': 'log2'}. Best is trial 8 with value: 0.7851051227475417.
[I 2024-12-22 23:28:03,771] Trial 26 finished with value: 0.7300464215889282 and parameters: {'max_depth': 37, 'min_samples_split': 6, 'min_samples_leaf': 11, 'max_features': 'sqrt'}. Best is trial 8 with value: 0.7851051227475417.
[I 2024-12-22 23:28:03,814] Trial 29 finished with value: 0.7472785102714988 and parameters: {'max_depth': 45, 'min_samples_split': 28, 'min_samples_leaf': 13, 'max_features': 'log2'}. Best is trial 8 with value: 0.7851051227475417.
[I 2024-12-22 23:28:03,817] Trial 27 finished with value: 0.7462855505581184 and parameters: {'max_depth': 35, 'min_samples_split': 28, 'min_samples_leaf': 25, 'max_features': 'sqrt'}. Best is trial 8 with value: 0.7851051227475417.
[I 2024-12-22 23:28:03,851] Trial 28 finished with value: 0.7354532846645029 and parameters: {'max_depth': 18, 'min_samples_split': 25, 'min_samples_leaf': 8, 'max_features': None}. Best is trial 8 with value: 0.7851051227475417.
[I 2024-12-22 23:28:03,852] Trial 31 finished with value: 0.7741994202116901 and parameters: {'max_depth': 10, 'min_samples_split': 26, 'min_samples_leaf': 26, 'max_features': None}. Best is trial 8 with value: 0.7851051227475417.
[I 2024-12-22 23:28:03,853] Trial 30 finished with value: 0.6060559948377653 and parameters: {'max_depth': 3, 'min_samples_split': 18, 'min_samples_leaf': 7, 'max_features': 'log2'}. Best is trial 8 with value: 0.7851051227475417.
[I 2024-12-22 23:28:03,936] Trial 32 finished with value: 0.767985957950901 and parameters: {'max_depth': 18, 'min_samples_split': 9, 'min_samples_leaf': 21, 'max_features': None}. Best is trial 8 with value: 0.7851051227475417.
[I 2024-12-22 23:28:03,957] Trial 33 finished with value: 0.786699059047876 and parameters: {'max_depth': 6, 'min_samples_split': 15, 'min_samples_leaf': 11, 'max_features': None}. Best is trial 33 with value: 0.786699059047876.
[I 2024-12-22 23:28:03,993] Trial 35 finished with value: 0.7324479201779815 and parameters: {'max_depth': 31, 'min_samples_split': 32, 'min_samples_leaf': 2, 'max_features': 'sqrt'}. Best is trial 33 with value: 0.786699059047876.
[I 2024-12-22 23:28:04,009] Trial 34 finished with value: 0.6364325201529408 and parameters: {'max_depth': 19, 'min_samples_split': 3, 'min_samples_leaf': 1, 'max_features': 'sqrt'}. Best is trial 33 with value: 0.786699059047876.
[I 2024-12-22 23:28:04,013] Trial 37 finished with value: 0.6070296924810509 and parameters: {'max_depth': 3, 'min_samples_split': 32, 'min_samples_leaf': 15, 'max_features': 'sqrt'}. Best is trial 33 with value: 0.786699059047876.
[I 2024-12-22 23:28:04,020] Trial 38 finished with value: 0.7569658868738625 and parameters: {'max_depth': 8, 'min_samples_split': 3, 'min_samples_leaf': 28, 'max_features': 'sqrt'}. Best is trial 33 with value: 0.786699059047876.
[I 2024-12-22 23:28:04,037] Trial 39 finished with value: 0.7400771445907292 and parameters: {'max_depth': 27, 'min_samples_split': 24, 'min_samples_leaf': 14, 'max_features': 'log2'}. Best is trial 33 with value: 0.786699059047876.
[I 2024-12-22 23:28:04,043] Trial 41 finished with value: 0.7324002465544972 and
```

```
parameters: {'max_depth': 19, 'min_samples_split': 31, 'min_samples_leaf': 8, 'max_features': 'log2'}. Best is trial 33 with value: 0.786699059047876.
[I 2024-12-22 23:28:04,054] Trial 36 finished with value: 0.7327159037281736 and
parameters: {'max_depth': 43, 'min_samples_split': 11, 'min_samples_leaf': 10, 'max_features': 'sqrt'}. Best is trial 33 with value: 0.786699059047876.
[I 2024-12-22 23:28:04,093] Trial 40 finished with value: 0.767060415482852 and p
arameters: {'max_depth': 41, 'min_samples_split': 13, 'min_samples_leaf': 19, 'ma
x_features': None}. Best is trial 33 with value: 0.786699059047876.
[I 2024-12-22 23:28:04,111] Trial 43 finished with value: 0.7372764395989637 and
parameters: {'max_depth': 18, 'min_samples_split': 6, 'min_samples_leaf': 26, 'ma
x_features': 'sqrt'}. Best is trial 33 with value: 0.786699059047876.
[I 2024-12-22 23:28:04,115] Trial 42 finished with value: 0.7146731226704934 and
parameters: {'max_depth': 48, 'min_samples_split': 19, 'min_samples_leaf': 2, 'ma
x_features': 'sqrt'}. Best is trial 33 with value: 0.786699059047876.
[I 2024-12-22 23:28:04,147] Trial 44 finished with value: 0.7762178443817357 and
parameters: {'max_depth': 21, 'min_samples_split': 24, 'min_samples_leaf': 32, 'm
ax_features': None}. Best is trial 33 with value: 0.786699059047876.
[I 2024-12-22 23:28:04,181] Trial 45 finished with value: 0.7420645086727472 and
parameters: {'max_depth': 41, 'min_samples_split': 13, 'min_samples_leaf': 23, 'm
ax_features': 'sqrt'}. Best is trial 33 with value: 0.786699059047876.
[I 2024-12-22 23:28:04,240] Trial 47 finished with value: 0.7718552262811685 and
parameters: {'max_depth': 33, 'min_samples_split': 29, 'min_samples_leaf': 23, 'm
ax_features': None}. Best is trial 33 with value: 0.786699059047876.
[I 2024-12-22 23:28:04,245] Trial 46 finished with value: 0.7288220762585356 and
parameters: {'max_depth': 12, 'min_samples_split': 8, 'min_samples_leaf': 3, 'm
ax_features': 'sqrt'}. Best is trial 33 with value: 0.786699059047876.
[I 2024-12-22 23:28:04,295] Trial 49 finished with value: 0.7824845181111615 and
parameters: {'max_depth': 6, 'min_samples_split': 2, 'min_samples_leaf': 3, 'm
ax_features': None}. Best is trial 33 with value: 0.786699059047876.
[I 2024-12-22 23:28:04,341] Trial 51 finished with value: 0.7527051169689207 and
parameters: {'max_depth': 30, 'min_samples_split': 11, 'min_samples_leaf': 18, 'm
ax_features': 'log2'}. Best is trial 33 with value: 0.786699059047876.
[I 2024-12-22 23:28:04,366] Trial 50 finished with value: 0.7462855505581184 and
parameters: {'max_depth': 28, 'min_samples_split': 14, 'min_samples_leaf': 25, 'm
ax_features': 'log2'}. Best is trial 33 with value: 0.786699059047876.
[I 2024-12-22 23:28:04,369] Trial 48 finished with value: 0.7873014802900868 and
parameters: {'max_depth': 7, 'min_samples_split': 9, 'min_samples_leaf': 18, 'm
ax_features': None}. Best is trial 48 with value: 0.7873014802900868.
[I 2024-12-22 23:28:04,392] Trial 53 finished with value: 0.7342142520056629 and
parameters: {'max_depth': 14, 'min_samples_split': 27, 'min_samples_leaf': 8, 'm
ax_features': 'log2'}. Best is trial 48 with value: 0.7873014802900868.
[I 2024-12-22 23:28:04,424] Trial 55 finished with value: 0.7527051169689207 and
parameters: {'max_depth': 50, 'min_samples_split': 26, 'min_samples_leaf': 18, 'm
ax_features': 'log2'}. Best is trial 48 with value: 0.7873014802900868.
[I 2024-12-22 23:28:04,427] Trial 52 finished with value: 0.7396386917201991 and
parameters: {'max_depth': 37, 'min_samples_split': 27, 'min_samples_leaf': 11, 'm
ax_features': 'log2'}. Best is trial 48 with value: 0.7873014802900868.
[I 2024-12-22 23:28:04,481] Trial 56 finished with value: 0.7340182604424498 and
parameters: {'max_depth': 11, 'min_samples_split': 13, 'min_samples_leaf': 4, 'm
ax_features': 'sqrt'}. Best is trial 48 with value: 0.7873014802900868.
[I 2024-12-22 23:28:04,529] Trial 54 finished with value: 0.7680565052826227 and
parameters: {'max_depth': 16, 'min_samples_split': 15, 'min_samples_leaf': 21, 'm
ax_features': None}. Best is trial 48 with value: 0.7873014802900868.
[I 2024-12-22 23:28:04,537] Trial 58 finished with value: 0.7039292215234371 and
parameters: {'max_depth': 5, 'min_samples_split': 28, 'min_samples_leaf': 32, 'm
ax_features': 'log2'}. Best is trial 48 with value: 0.7873014802900868.
[I 2024-12-22 23:28:04,567] Trial 57 finished with value: 0.7392871589409714 and
parameters: {'max_depth': 50, 'min_samples_split': 29, 'min_samples_leaf': 8, 'm
ax_features': 'log2'}. Best is trial 48 with value: 0.7873014802900868.
[I 2024-12-22 23:28:04,568] Trial 59 finished with value: 0.7461302501179803 and
```

```
parameters: {'max_depth': 19, 'min_samples_split': 21, 'min_samples_leaf': 28, 'max_features': 'sqrt'}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:04,574] Trial 62 finished with value: 0.7430808236461173 and parameters: {'max_depth': 23, 'min_samples_split': 9, 'min_samples_leaf': 15, 'max_features': 'sqrt'}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:04,577] Trial 60 finished with value: 0.7457621038032958 and parameters: {'max_depth': 40, 'min_samples_split': 31, 'min_samples_leaf': 5, 'max_features': 'log2'}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:04,581] Trial 61 finished with value: 0.7472166308713197 and parameters: {'max_depth': 28, 'min_samples_split': 23, 'min_samples_leaf': 21, 'max_features': 'log2'}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:04,587] Trial 64 finished with value: 0.7400771445907292 and parameters: {'max_depth': 20, 'min_samples_split': 28, 'min_samples_leaf': 14, 'max_features': 'log2'}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:04,629] Trial 63 finished with value: 0.7690087738729281 and parameters: {'max_depth': 26, 'min_samples_split': 10, 'min_samples_leaf': 22, 'max_features': None}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:04,651] Trial 66 finished with value: 0.7045773901821228 and parameters: {'max_depth': 47, 'min_samples_split': 5, 'min_samples_leaf': 5, 'max_features': 'sqrt'}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:04,672] Trial 65 finished with value: 0.7762178443817357 and parameters: {'max_depth': 17, 'min_samples_split': 23, 'min_samples_leaf': 32, 'max_features': None}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:04,751] Trial 69 finished with value: 0.6849454883416322 and parameters: {'max_depth': 14, 'min_samples_split': 10, 'min_samples_leaf': 2, 'max_features': 'sqrt'}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:04,756] Trial 68 finished with value: 0.767060415482852 and parameters: {'max_depth': 27, 'min_samples_split': 29, 'min_samples_leaf': 19, 'max_features': None}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:04,757] Trial 67 finished with value: 0.767985957950901 and parameters: {'max_depth': 36, 'min_samples_split': 16, 'min_samples_leaf': 21, 'max_features': None}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:04,763] Trial 70 finished with value: 0.7496559312729338 and parameters: {'max_depth': 40, 'min_samples_split': 20, 'min_samples_leaf': 32, 'max_features': 'sqrt'}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:04,806] Trial 71 finished with value: 0.7492863403029923 and parameters: {'max_depth': 16, 'min_samples_split': 30, 'min_samples_leaf': 21, 'max_features': 'sqrt'}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:04,819] Trial 73 finished with value: 0.7521301441765946 and parameters: {'max_depth': 34, 'min_samples_split': 10, 'min_samples_leaf': 13, 'max_features': None}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:04,862] Trial 74 finished with value: 0.7738924309695563 and parameters: {'max_depth': 16, 'min_samples_split': 26, 'min_samples_leaf': 30, 'max_features': None}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:04,876] Trial 76 finished with value: 0.7407744315281563 and parameters: {'max_depth': 7, 'min_samples_split': 9, 'min_samples_leaf': 3, 'max_features': 'sqrt'}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:04,902] Trial 72 finished with value: 0.755422995059279 and parameters: {'max_depth': 14, 'min_samples_split': 16, 'min_samples_leaf': 27, 'max_features': 'log2'}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:04,906] Trial 78 finished with value: 0.7300464215889282 and parameters: {'max_depth': 36, 'min_samples_split': 20, 'min_samples_leaf': 11, 'max_features': 'log2'}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:04,976] Trial 79 finished with value: 0.7479093430670994 and parameters: {'max_depth': 14, 'min_samples_split': 25, 'min_samples_leaf': 23, 'max_features': 'sqrt'}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:04,980] Trial 75 finished with value: 0.767985957950901 and parameters: {'max_depth': 33, 'min_samples_split': 2, 'min_samples_leaf': 21, 'max_features': None}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:04,982] Trial 77 finished with value: 0.7733540561104102 and
```

```
parameters: {'max_depth': 41, 'min_samples_split': 3, 'min_samples_leaf': 26, 'max_features': None}. Best is trial 48 with value: 0.7873014802900868.
[I 2024-12-22 23:28:05,021] Trial 80 finished with value: 0.7484551819784072 and
parameters: {'max_depth': 6, 'min_samples_split': 27, 'min_samples_leaf': 12, 'max_features': 'log2'}. Best is trial 48 with value: 0.7873014802900868.
[I 2024-12-22 23:28:05,069] Trial 82 finished with value: 0.7559543874180158 and
parameters: {'max_depth': 15, 'min_samples_split': 14, 'min_samples_leaf': 24, 'max_features': 'log2'}. Best is trial 48 with value: 0.7873014802900868.
[I 2024-12-22 23:28:05,071] Trial 81 finished with value: 0.7461302501179803 and
parameters: {'max_depth': 28, 'min_samples_split': 15, 'min_samples_leaf': 28, 'max_features': 'log2'}. Best is trial 48 with value: 0.7873014802900868.
[I 2024-12-22 23:28:05,074] Trial 83 finished with value: 0.7461302501179803 and
parameters: {'max_depth': 50, 'min_samples_split': 14, 'min_samples_leaf': 28, 'max_features': 'log2'}. Best is trial 48 with value: 0.7873014802900868.
[I 2024-12-22 23:28:05,075] Trial 86 finished with value: 0.7433736071115563 and
parameters: {'max_depth': 46, 'min_samples_split': 20, 'min_samples_leaf': 17, 'max_features': 'sqrt'}. Best is trial 48 with value: 0.7873014802900868.
[I 2024-12-22 23:28:05,075] Trial 84 finished with value: 0.6605086631160251 and
parameters: {'max_depth': 39, 'min_samples_split': 6, 'min_samples_leaf': 2, 'max_features': 'log2'}. Best is trial 48 with value: 0.7873014802900868.
[I 2024-12-22 23:28:05,138] Trial 88 finished with value: 0.7489887413200297 and
parameters: {'max_depth': 50, 'min_samples_split': 9, 'min_samples_leaf': 20, 'max_features': 'log2'}. Best is trial 48 with value: 0.7873014802900868.
[I 2024-12-22 23:28:05,139] Trial 85 finished with value: 0.7561655478614286 and
parameters: {'max_depth': 29, 'min_samples_split': 13, 'min_samples_leaf': 14, 'max_features': None}. Best is trial 48 with value: 0.7873014802900868.
[I 2024-12-22 23:28:05,154] Trial 87 finished with value: 0.7532998333830937 and
parameters: {'max_depth': 20, 'min_samples_split': 3, 'min_samples_leaf': 30, 'max_features': 'sqrt'}. Best is trial 48 with value: 0.7873014802900868.
[I 2024-12-22 23:28:05,223] Trial 89 finished with value: 0.7644708709344993 and
parameters: {'max_depth': 38, 'min_samples_split': 6, 'min_samples_leaf': 17, 'max_features': None}. Best is trial 48 with value: 0.7873014802900868.
[I 2024-12-22 23:28:05,238] Trial 90 finished with value: 0.7520343153778737 and
parameters: {'max_depth': 47, 'min_samples_split': 10, 'min_samples_leaf': 24, 'max_features': 'sqrt'}. Best is trial 48 with value: 0.7873014802900868.
[I 2024-12-22 23:28:05,247] Trial 91 finished with value: 0.7496559312729338 and
parameters: {'max_depth': 36, 'min_samples_split': 7, 'min_samples_leaf': 32, 'max_features': 'log2'}. Best is trial 48 with value: 0.7873014802900868.
[I 2024-12-22 23:28:05,306] Trial 94 finished with value: 0.7532998333830937 and
parameters: {'max_depth': 37, 'min_samples_split': 19, 'min_samples_leaf': 30, 'max_features': 'sqrt'}. Best is trial 48 with value: 0.7873014802900868.
[I 2024-12-22 23:28:05,316] Trial 92 finished with value: 0.7182799452957209 and
parameters: {'max_depth': 33, 'min_samples_split': 18, 'min_samples_leaf': 4, 'max_features': 'sqrt'}. Best is trial 48 with value: 0.7873014802900868.
[I 2024-12-22 23:28:05,325] Trial 97 finished with value: 0.7165174658820583 and
parameters: {'max_depth': 43, 'min_samples_split': 24, 'min_samples_leaf': 5, 'max_features': 'log2'}. Best is trial 48 with value: 0.7873014802900868.
[I 2024-12-22 23:28:05,327] Trial 93 finished with value: 0.7527051169689207 and
parameters: {'max_depth': 24, 'min_samples_split': 15, 'min_samples_leaf': 18, 'max_features': 'log2'}. Best is trial 48 with value: 0.7873014802900868.
[I 2024-12-22 23:28:05,330] Trial 95 finished with value: 0.7520343153778737 and
parameters: {'max_depth': 44, 'min_samples_split': 7, 'min_samples_leaf': 24, 'max_features': 'sqrt'}. Best is trial 48 with value: 0.7873014802900868.
[I 2024-12-22 23:28:05,351] Trial 98 finished with value: 0.7462855505581184 and
parameters: {'max_depth': 37, 'min_samples_split': 32, 'min_samples_leaf': 25, 'max_features': 'log2'}. Best is trial 48 with value: 0.7873014802900868.
[I 2024-12-22 23:28:05,372] Trial 96 finished with value: 0.749224220126937 and
parameters: {'max_depth': 11, 'min_samples_split': 27, 'min_samples_leaf': 14, 'max_features': 'log2'}. Best is trial 48 with value: 0.7873014802900868.
[I 2024-12-22 23:28:05,432] Trial 103 finished with value: 0.7665658618331712 and
```

```
parameters: {'max_depth': 8, 'min_samples_split': 8, 'min_samples_leaf': 5, 'max_features': 'sqrt'}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:05,437] Trial 101 finished with value: 0.7040780210149185 and parameters: {'max_depth': 41, 'min_samples_split': 10, 'min_samples_leaf': 4, 'max_features': 'log2'}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:05,441] Trial 99 finished with value: 0.7260577284240738 and parameters: {'max_depth': 49, 'min_samples_split': 23, 'min_samples_leaf': 5, 'max_features': None}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:05,444] Trial 100 finished with value: 0.7712703816779188 and parameters: {'max_depth': 26, 'min_samples_split': 13, 'min_samples_leaf': 20, 'max_features': None}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:05,504] Trial 104 finished with value: 0.7394058614479297 and parameters: {'max_depth': 32, 'min_samples_split': 11, 'min_samples_leaf': 10, 'max_features': None}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:05,512] Trial 102 finished with value: 0.7182736851229402 and parameters: {'max_depth': 17, 'min_samples_split': 17, 'min_samples_leaf': 6, 'max_features': None}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:05,562] Trial 109 finished with value: 0.7284765628762123 and parameters: {'max_depth': 29, 'min_samples_split': 15, 'min_samples_leaf': 8, 'max_features': 'log2'}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:05,618] Trial 107 finished with value: 0.714325923857037 and parameters: {'max_depth': 31, 'min_samples_split': 4, 'min_samples_leaf': 7, 'max_features': None}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:05,638] Trial 105 finished with value: 0.7527051169689207 and parameters: {'max_depth': 48, 'min_samples_split': 18, 'min_samples_leaf': 18, 'max_features': 'log2'}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:05,644] Trial 108 finished with value: 0.7336725062842504 and parameters: {'max_depth': 6, 'min_samples_split': 16, 'min_samples_leaf': 1, 'max_features': 'log2'}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:05,655] Trial 106 finished with value: 0.7429599541562731 and parameters: {'max_depth': 12, 'min_samples_split': 5, 'min_samples_leaf': 27, 'max_features': 'sqrt'}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:05,687] Trial 110 finished with value: 0.7718552262811685 and parameters: {'max_depth': 43, 'min_samples_split': 31, 'min_samples_leaf': 23, 'max_features': None}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:05,696] Trial 111 finished with value: 0.7710645183037821 and parameters: {'max_depth': 11, 'min_samples_split': 6, 'min_samples_leaf': 23, 'max_features': None}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:05,718] Trial 112 finished with value: 0.767060415482852 and parameters: {'max_depth': 20, 'min_samples_split': 6, 'min_samples_leaf': 19, 'max_features': None}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:05,761] Trial 113 finished with value: 0.7430808236461173 and parameters: {'max_depth': 40, 'min_samples_split': 26, 'min_samples_leaf': 15, 'max_features': 'log2'}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:05,790] Trial 117 finished with value: 0.7425556914601612 and parameters: {'max_depth': 11, 'min_samples_split': 26, 'min_samples_leaf': 29, 'max_features': 'sqrt'}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:05,804] Trial 114 finished with value: 0.7570475098958885 and parameters: {'max_depth': 12, 'min_samples_split': 14, 'min_samples_leaf': 14, 'max_features': 'log2'}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:05,807] Trial 115 finished with value: 0.775424006317959 and parameters: {'max_depth': 24, 'min_samples_split': 20, 'min_samples_leaf': 31, 'max_features': None}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:05,832] Trial 116 finished with value: 0.7574370852635534 and parameters: {'max_depth': 29, 'min_samples_split': 14, 'min_samples_leaf': 19, 'max_features': 'sqrt'}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:05,846] Trial 121 finished with value: 0.7409352698134468 and parameters: {'max_depth': 37, 'min_samples_split': 26, 'min_samples_leaf': 3, 'max_features': 'log2'}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:05,883] Trial 119 finished with value: 0.7454637824927045 and
```

```
parameters: {'max_depth': 7, 'min_samples_split': 13, 'min_samples_leaf': 13, 'max_features': 'log2'}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:05,951] Trial 124 finished with value: 0.7262440889522397 and parameters: {'max_depth': 18, 'min_samples_split': 17, 'min_samples_leaf': 5, 'max_features': 'log2'}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:05,952] Trial 123 finished with value: 0.768782926101068 and parameters: {'max_depth': 48, 'min_samples_split': 12, 'min_samples_leaf': 18, 'max_features': None}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:05,993] Trial 120 finished with value: 0.7561655478614286 and parameters: {'max_depth': 31, 'min_samples_split': 5, 'min_samples_leaf': 14, 'max_features': None}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:05,997] Trial 122 finished with value: 0.7320566593791835 and parameters: {'max_depth': 36, 'min_samples_split': 19, 'min_samples_leaf': 7, 'max_features': 'log2'}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:05,998] Trial 118 finished with value: 0.7307480424921267 and parameters: {'max_depth': 47, 'min_samples_split': 30, 'min_samples_leaf': 4, 'max_features': 'sqrt'}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:06,064] Trial 126 finished with value: 0.7105370746694147 and parameters: {'max_depth': 36, 'min_samples_split': 25, 'min_samples_leaf': 1, 'max_features': 'log2'}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:06,111] Trial 125 finished with value: 0.735263071722318 and parameters: {'max_depth': 22, 'min_samples_split': 25, 'min_samples_leaf': 8, 'max_features': None}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:06,116] Trial 128 finished with value: 0.7481669732546157 and parameters: {'max_depth': 14, 'min_samples_split': 19, 'min_samples_leaf': 25, 'max_features': 'log2'}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:06,116] Trial 132 finished with value: 0.7520343153778737 and parameters: {'max_depth': 36, 'min_samples_split': 17, 'min_samples_leaf': 24, 'max_features': 'log2'}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:06,133] Trial 127 finished with value: 0.7511504271364045 and parameters: {'max_depth': 24, 'min_samples_split': 23, 'min_samples_leaf': 27, 'max_features': 'sqrt'}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:06,175] Trial 130 finished with value: 0.7372764395989637 and parameters: {'max_depth': 43, 'min_samples_split': 15, 'min_samples_leaf': 26, 'max_features': 'sqrt'}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:06,221] Trial 129 finished with value: 0.7733540561104102 and parameters: {'max_depth': 23, 'min_samples_split': 8, 'min_samples_leaf': 26, 'max_features': None}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:06,284] Trial 133 finished with value: 0.7733540561104102 and parameters: {'max_depth': 47, 'min_samples_split': 9, 'min_samples_leaf': 26, 'max_features': None}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:06,295] Trial 134 finished with value: 0.7335899201587195 and parameters: {'max_depth': 15, 'min_samples_split': 23, 'min_samples_leaf': 10, 'max_features': 'log2'}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:06,296] Trial 131 finished with value: 0.7527051169689207 and parameters: {'max_depth': 21, 'min_samples_split': 3, 'min_samples_leaf': 18, 'max_features': 'log2'}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:06,306] Trial 135 finished with value: 0.7489364929548978 and parameters: {'max_depth': 26, 'min_samples_split': 9, 'min_samples_leaf': 11, 'max_features': None}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:06,318] Trial 136 finished with value: 0.767985957950901 and parameters: {'max_depth': 44, 'min_samples_split': 25, 'min_samples_leaf': 21, 'max_features': None}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:06,409] Trial 142 finished with value: 0.6975337327002533 and parameters: {'max_depth': 28, 'min_samples_split': 11, 'min_samples_leaf': 3, 'max_features': 'sqrt'}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:06,414] Trial 137 finished with value: 0.7437720911866398 and parameters: {'max_depth': 23, 'min_samples_split': 31, 'min_samples_leaf': 7, 'max_features': None}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:06,417] Trial 138 finished with value: 0.7400771445907292 and
```

```
parameters: {'max_depth': 26, 'min_samples_split': 23, 'min_samples_leaf': 14, 'max_features': 'sqrt'}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:06,418] Trial 140 finished with value: 0.7108922190867852 and parameters: {'max_depth': 44, 'min_samples_split': 18, 'min_samples_leaf': 3, 'max_features': 'log2'}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:06,419] Trial 139 finished with value: 0.767060415482852 and parameters: {'max_depth': 46, 'min_samples_split': 32, 'min_samples_leaf': 19, 'max_features': None}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:06,479] Trial 141 finished with value: 0.7746402808409819 and parameters: {'max_depth': 28, 'min_samples_split': 2, 'min_samples_leaf': 27, 'max_features': None}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:06,475] Trial 146 finished with value: 0.7112940740241354 and parameters: {'max_depth': 37, 'min_samples_split': 5, 'min_samples_leaf': 6, 'max_features': 'log2'}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:06,603] Trial 144 finished with value: 0.7332119020331115 and parameters: {'max_depth': 48, 'min_samples_split': 18, 'min_samples_leaf': 9, 'max_features': None}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:06,648] Trial 145 finished with value: 0.7385265479481079 and parameters: {'max_depth': 24, 'min_samples_split': 29, 'min_samples_leaf': 7, 'max_features': None}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:06,652] Trial 143 finished with value: 0.7462855505581184 and parameters: {'max_depth': 18, 'min_samples_split': 22, 'min_samples_leaf': 25, 'max_features': 'sqrt'}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:06,679] Trial 147 finished with value: 0.7045516271633712 and parameters: {'max_depth': 22, 'min_samples_split': 14, 'min_samples_leaf': 2, 'max_features': 'sqrt'}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:06,731] Trial 148 finished with value: 0.7151953655459352 and parameters: {'max_depth': 29, 'min_samples_split': 23, 'min_samples_leaf': 1, 'max_features': 'sqrt'}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:06,731] Trial 154 finished with value: 0.7484253257697605 and parameters: {'max_depth': 9, 'min_samples_split': 5, 'min_samples_leaf': 16, 'max_features': 'sqrt'}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:06,732] Trial 151 finished with value: 0.7496559312729338 and parameters: {'max_depth': 36, 'min_samples_split': 10, 'min_samples_leaf': 32, 'max_features': 'sqrt'}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:06,733] Trial 150 finished with value: 0.714325923857037 and parameters: {'max_depth': 42, 'min_samples_split': 8, 'min_samples_leaf': 7, 'max_features': None}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:06,733] Trial 153 finished with value: 0.7550341420192428 and parameters: {'max_depth': 45, 'min_samples_split': 18, 'min_samples_leaf': 29, 'max_features': 'log2'}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:06,733] Trial 149 finished with value: 0.7746402808409819 and parameters: {'max_depth': 50, 'min_samples_split': 13, 'min_samples_leaf': 27, 'max_features': None}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:06,818] Trial 152 finished with value: 0.7706954088855931 and parameters: {'max_depth': 46, 'min_samples_split': 8, 'min_samples_leaf': 24, 'max_features': None}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:06,865] Trial 155 finished with value: 0.7372764395989637 and parameters: {'max_depth': 33, 'min_samples_split': 11, 'min_samples_leaf': 26, 'max_features': 'sqrt'}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:06,869] Trial 156 finished with value: 0.7306151342084735 and parameters: {'max_depth': 3, 'min_samples_split': 17, 'min_samples_leaf': 4, 'max_features': None}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:06,870] Trial 157 finished with value: 0.7300464215889282 and parameters: {'max_depth': 40, 'min_samples_split': 5, 'min_samples_leaf': 11, 'max_features': 'log2'}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:06,896] Trial 158 finished with value: 0.7461302501179803 and parameters: {'max_depth': 18, 'min_samples_split': 29, 'min_samples_leaf': 28, 'max_features': 'sqrt'}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:06,921] Trial 159 finished with value: 0.7472166308713197 and
```

```
parameters: {'max_depth': 35, 'min_samples_split': 2, 'min_samples_leaf': 21, 'max_features': 'log2'}. Best is trial 48 with value: 0.7873014802900868.
[I 2024-12-22 23:28:06,945] Trial 163 finished with value: 0.7744257495353025 and
parameters: {'max_depth': 48, 'min_samples_split': 28, 'min_samples_leaf': 29, 'max_features': None}. Best is trial 48 with value: 0.7873014802900868.
[I 2024-12-22 23:28:07,011] Trial 160 finished with value: 0.7392390037657346 and
parameters: {'max_depth': 43, 'min_samples_split': 30, 'min_samples_leaf': 8, 'max_features': 'log2'}. Best is trial 48 with value: 0.7873014802900868.
[I 2024-12-22 23:28:07,016] Trial 162 finished with value: 0.7400771445907292 and
parameters: {'max_depth': 50, 'min_samples_split': 13, 'min_samples_leaf': 14, 'max_features': 'sqrt'}. Best is trial 48 with value: 0.7873014802900868.
[I 2024-12-22 23:28:07,020] Trial 164 finished with value: 0.7372764395989637 and
parameters: {'max_depth': 41, 'min_samples_split': 2, 'min_samples_leaf': 26, 'max_features': 'log2'}. Best is trial 48 with value: 0.7873014802900868.
[I 2024-12-22 23:28:07,027] Trial 161 finished with value: 0.7400771445907292 and
parameters: {'max_depth': 28, 'min_samples_split': 25, 'min_samples_leaf': 14, 'max_features': 'sqrt'}. Best is trial 48 with value: 0.7873014802900868.
[I 2024-12-22 23:28:07,064] Trial 165 finished with value: 0.767060415482852 and
parameters: {'max_depth': 32, 'min_samples_split': 9, 'min_samples_leaf': 19, 'max_features': None}. Best is trial 48 with value: 0.7873014802900868.
[I 2024-12-22 23:28:07,075] Trial 166 finished with value: 0.7449270930646916 and
parameters: {'max_depth': 25, 'min_samples_split': 12, 'min_samples_leaf': 12, 'max_features': 'sqrt'}. Best is trial 48 with value: 0.7873014802900868.
[I 2024-12-22 23:28:07,143] Trial 168 finished with value: 0.6975337327002533 and
parameters: {'max_depth': 36, 'min_samples_split': 11, 'min_samples_leaf': 3, 'max_features': 'sqrt'}. Best is trial 48 with value: 0.7873014802900868.
[I 2024-12-22 23:28:07,156] Trial 167 finished with value: 0.7361168629792643 and
parameters: {'max_depth': 20, 'min_samples_split': 32, 'min_samples_leaf': 8, 'max_features': 'sqrt'}. Best is trial 48 with value: 0.7873014802900868.
[I 2024-12-22 23:28:07,157] Trial 172 finished with value: 0.7417110496865098 and
parameters: {'max_depth': 23, 'min_samples_split': 27, 'min_samples_leaf': 9, 'max_features': 'log2'}. Best is trial 48 with value: 0.7873014802900868.
[I 2024-12-22 23:28:07,202] Trial 169 finished with value: 0.7462855505581184 and
parameters: {'max_depth': 18, 'min_samples_split': 4, 'min_samples_leaf': 25, 'max_features': 'sqrt'}. Best is trial 48 with value: 0.7873014802900868.
[I 2024-12-22 23:28:07,210] Trial 171 finished with value: 0.669787202280629 and
parameters: {'max_depth': 49, 'min_samples_split': 4, 'min_samples_leaf': 3, 'max_features': None}. Best is trial 48 with value: 0.7873014802900868.
[I 2024-12-22 23:28:07,289] Trial 175 finished with value: 0.6066995887548035 and
parameters: {'max_depth': 3, 'min_samples_split': 4, 'min_samples_leaf': 13, 'max_features': 'log2'}. Best is trial 48 with value: 0.7873014802900868.
[I 2024-12-22 23:28:07,292] Trial 174 finished with value: 0.7429772900193584 and
parameters: {'max_depth': 18, 'min_samples_split': 10, 'min_samples_leaf': 12, 'max_features': 'sqrt'}. Best is trial 48 with value: 0.7873014802900868.
[I 2024-12-22 23:28:07,299] Trial 170 finished with value: 0.7374098294343693 and
parameters: {'max_depth': 10, 'min_samples_split': 6, 'min_samples_leaf': 7, 'max_features': None}. Best is trial 48 with value: 0.7873014802900868.
[I 2024-12-22 23:28:07,334] Trial 173 finished with value: 0.7345183519372827 and
parameters: {'max_depth': 47, 'min_samples_split': 20, 'min_samples_leaf': 9, 'max_features': None}. Best is trial 48 with value: 0.7873014802900868.
[I 2024-12-22 23:28:07,340] Trial 176 finished with value: 0.704771937090079 and
parameters: {'max_depth': 5, 'min_samples_split': 27, 'min_samples_leaf': 21, 'max_features': 'log2'}. Best is trial 48 with value: 0.7873014802900868.
[I 2024-12-22 23:28:07,376] Trial 177 finished with value: 0.7327159037281736 and
parameters: {'max_depth': 40, 'min_samples_split': 8, 'min_samples_leaf': 10, 'max_features': 'sqrt'}. Best is trial 48 with value: 0.7873014802900868.
[I 2024-12-22 23:28:07,382] Trial 178 finished with value: 0.7461302501179803 and
parameters: {'max_depth': 31, 'min_samples_split': 24, 'min_samples_leaf': 28, 'max_features': 'sqrt'}. Best is trial 48 with value: 0.7873014802900868.
[I 2024-12-22 23:28:07,400] Trial 181 finished with value: 0.7499884427579431 and
```

```
parameters: {'max_depth': 11, 'min_samples_split': 30, 'min_samples_leaf': 24, 'max_features': 'sqrt'}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:07,429] Trial 179 finished with value: 0.7602702949986035 and parameters: {'max_depth': 28, 'min_samples_split': 30, 'min_samples_leaf': 14, 'max_features': None}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:07,451] Trial 180 finished with value: 0.7134880238079185 and parameters: {'max_depth': 11, 'min_samples_split': 6, 'min_samples_leaf': 2, 'max_features': 'sqrt'}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:07,537] Trial 183 finished with value: 0.7744257495353025 and parameters: {'max_depth': 41, 'min_samples_split': 6, 'min_samples_leaf': 29, 'max_features': None}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:07,541] Trial 182 finished with value: 0.7547331721740136 and parameters: {'max_depth': 10, 'min_samples_split': 16, 'min_samples_leaf': 17, 'max_features': 'log2'}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:07,581] Trial 185 finished with value: 0.7489706831293159 and parameters: {'max_depth': 21, 'min_samples_split': 22, 'min_samples_leaf': 22, 'max_features': 'log2'}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:07,612] Trial 184 finished with value: 0.613543643035317 and parameters: {'max_depth': 3, 'min_samples_split': 30, 'min_samples_leaf': 20, 'max_features': 'log2'}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:07,658] Trial 189 finished with value: 0.6975337327002533 and parameters: {'max_depth': 27, 'min_samples_split': 11, 'min_samples_leaf': 3, 'max_features': 'sqrt'}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:07,664] Trial 191 finished with value: 0.6066995887548035 and parameters: {'max_depth': 3, 'min_samples_split': 22, 'min_samples_leaf': 14, 'max_features': 'sqrt'}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:07,670] Trial 190 finished with value: 0.7496559312729338 and parameters: {'max_depth': 48, 'min_samples_split': 19, 'min_samples_leaf': 32, 'max_features': 'log2'}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:07,675] Trial 188 finished with value: 0.7532998333830937 and parameters: {'max_depth': 21, 'min_samples_split': 21, 'min_samples_leaf': 30, 'max_features': 'sqrt'}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:07,680] Trial 187 finished with value: 0.7496559312729338 and parameters: {'max_depth': 19, 'min_samples_split': 30, 'min_samples_leaf': 32, 'max_features': 'log2'}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:07,681] Trial 186 finished with value: 0.7489887413200297 and parameters: {'max_depth': 21, 'min_samples_split': 9, 'min_samples_leaf': 20, 'max_features': 'sqrt'}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:07,694] Trial 192 finished with value: 0.7746402808409819 and parameters: {'max_depth': 37, 'min_samples_split': 23, 'min_samples_leaf': 27, 'max_features': None}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:07,732] Trial 194 finished with value: 0.7662995637141125 and parameters: {'max_depth': 8, 'min_samples_split': 5, 'min_samples_leaf': 19, 'max_features': 'log2'}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:07,771] Trial 197 finished with value: 0.7574370852635534 and parameters: {'max_depth': 25, 'min_samples_split': 5, 'min_samples_leaf': 19, 'max_features': 'sqrt'}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:07,774] Trial 193 finished with value: 0.7208184453583226 and parameters: {'max_depth': 14, 'min_samples_split': 25, 'min_samples_leaf': 3, 'max_features': None}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:07,792] Trial 196 finished with value: 0.769461432520153 and parameters: {'max_depth': 41, 'min_samples_split': 9, 'min_samples_leaf': 25, 'max_features': None}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:07,808] Trial 195 finished with value: 0.7489706831293159 and parameters: {'max_depth': 41, 'min_samples_split': 20, 'min_samples_leaf': 22, 'max_features': 'log2'}. Best is trial 48 with value: 0.7873014802900868.  
[I 2024-12-22 23:28:07,870] Trial 198 finished with value: 0.7912562240563994 and parameters: {'max_depth': 6, 'min_samples_split': 21, 'min_samples_leaf': 30, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:07,874] Trial 199 finished with value: 0.7133806377671409 and
```

```
parameters: {'max_depth': 16, 'min_samples_split': 14, 'min_samples_leaf': 4, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:07,881] Trial 200 finished with value: 0.7176936560372144 and parameters: {'max_depth': 43, 'min_samples_split': 21, 'min_samples_leaf': 3, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:07,950] Trial 204 finished with value: 0.775424006317959 and parameters: {'max_depth': 49, 'min_samples_split': 2, 'min_samples_leaf': 31, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:07,966] Trial 201 finished with value: 0.7300464215889282 and parameters: {'max_depth': 23, 'min_samples_split': 11, 'min_samples_leaf': 11, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:07,977] Trial 203 finished with value: 0.7462855505581184 and parameters: {'max_depth': 50, 'min_samples_split': 26, 'min_samples_leaf': 25, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:08,048] Trial 208 finished with value: 0.7267015631169882 and parameters: {'max_depth': 47, 'min_samples_split': 15, 'min_samples_leaf': 7, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:08,053] Trial 202 finished with value: 0.7237096820795331 and parameters: {'max_depth': 22, 'min_samples_split': 24, 'min_samples_leaf': 4, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:08,056] Trial 206 finished with value: 0.7706954088855931 and parameters: {'max_depth': 30, 'min_samples_split': 4, 'min_samples_leaf': 24, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:08,056] Trial 205 finished with value: 0.7627408962641216 and parameters: {'max_depth': 27, 'min_samples_split': 29, 'min_samples_leaf': 15, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:08,090] Trial 207 finished with value: 0.7310921112191927 and parameters: {'max_depth': 26, 'min_samples_split': 23, 'min_samples_leaf': 6, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:08,117] Trial 211 finished with value: 0.7446658512390327 and parameters: {'max_depth': 7, 'min_samples_split': 5, 'min_samples_leaf': 32, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:08,120] Trial 212 finished with value: 0.7406258728125512 and parameters: {'max_depth': 26, 'min_samples_split': 31, 'min_samples_leaf': 7, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:08,169] Trial 213 finished with value: 0.7400771445907292 and parameters: {'max_depth': 30, 'min_samples_split': 12, 'min_samples_leaf': 14, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:08,191] Trial 209 finished with value: 0.7718552262811685 and parameters: {'max_depth': 34, 'min_samples_split': 27, 'min_samples_leaf': 23, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:08,253] Trial 210 finished with value: 0.7574370852635534 and parameters: {'max_depth': 20, 'min_samples_split': 13, 'min_samples_leaf': 19, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:08,275] Trial 214 finished with value: 0.7654159162485191 and parameters: {'max_depth': 13, 'min_samples_split': 5, 'min_samples_leaf': 16, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:08,292] Trial 215 finished with value: 0.7641638816923655 and parameters: {'max_depth': 8, 'min_samples_split': 3, 'min_samples_leaf': 9, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:08,295] Trial 218 finished with value: 0.7433736071115563 and parameters: {'max_depth': 30, 'min_samples_split': 12, 'min_samples_leaf': 17, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:08,304] Trial 217 finished with value: 0.7529916402615789 and parameters: {'max_depth': 41, 'min_samples_split': 8, 'min_samples_leaf': 31, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:08,319] Trial 216 finished with value: 0.7574370852635534 and parameters: {'max_depth': 17, 'min_samples_split': 18, 'min_samples_leaf': 19, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:08,347] Trial 220 finished with value: 0.7754728838208242 and
```

```
parameters: {'max_depth': 9, 'min_samples_split': 7, 'min_samples_leaf': 22, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:08,351] Trial 221 finished with value: 0.7527051169689207 and parameters: {'max_depth': 27, 'min_samples_split': 21, 'min_samples_leaf': 18, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:08,357] Trial 219 finished with value: 0.7446658512390327 and parameters: {'max_depth': 7, 'min_samples_split': 25, 'min_samples_leaf': 32, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:08,440] Trial 222 finished with value: 0.7744257495353025 and parameters: {'max_depth': 35, 'min_samples_split': 20, 'min_samples_leaf': 29, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:08,445] Trial 223 finished with value: 0.7811896254490469 and parameters: {'max_depth': 7, 'min_samples_split': 13, 'min_samples_leaf': 9, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:08,474] Trial 224 finished with value: 0.7394472748986334 and parameters: {'max_depth': 38, 'min_samples_split': 32, 'min_samples_leaf': 3, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:08,511] Trial 226 finished with value: 0.7744257495353025 and parameters: {'max_depth': 45, 'min_samples_split': 3, 'min_samples_leaf': 29, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:08,516] Trial 228 finished with value: 0.7520343153778737 and parameters: {'max_depth': 47, 'min_samples_split': 24, 'min_samples_leaf': 24, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:08,522] Trial 225 finished with value: 0.7383382612129326 and parameters: {'max_depth': 15, 'min_samples_split': 22, 'min_samples_leaf': 9, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:08,524] Trial 227 finished with value: 0.7112940740241354 and parameters: {'max_depth': 50, 'min_samples_split': 4, 'min_samples_leaf': 6, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:08,586] Trial 229 finished with value: 0.7835085379125696 and parameters: {'max_depth': 7, 'min_samples_split': 7, 'min_samples_leaf': 10, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:08,605] Trial 230 finished with value: 0.7496559312729338 and parameters: {'max_depth': 50, 'min_samples_split': 4, 'min_samples_leaf': 32, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:08,605] Trial 231 finished with value: 0.7327159037281736 and parameters: {'max_depth': 21, 'min_samples_split': 3, 'min_samples_leaf': 10, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:08,612] Trial 233 finished with value: 0.613543643035317 and parameters: {'max_depth': 3, 'min_samples_split': 27, 'min_samples_leaf': 19, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:08,623] Trial 232 finished with value: 0.7324455124192196 and parameters: {'max_depth': 16, 'min_samples_split': 7, 'min_samples_leaf': 13, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:08,649] Trial 235 finished with value: 0.7224891891631594 and parameters: {'max_depth': 27, 'min_samples_split': 17, 'min_samples_leaf': 8, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:08,661] Trial 234 finished with value: 0.7741955677976712 and parameters: {'max_depth': 12, 'min_samples_split': 9, 'min_samples_leaf': 30, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:08,755] Trial 236 finished with value: 0.7489706831293159 and parameters: {'max_depth': 32, 'min_samples_split': 12, 'min_samples_leaf': 22, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:08,759] Trial 238 finished with value: 0.6173919638643566 and parameters: {'max_depth': 3, 'min_samples_split': 32, 'min_samples_leaf': 29, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:08,778] Trial 237 finished with value: 0.7532998333830937 and parameters: {'max_depth': 21, 'min_samples_split': 31, 'min_samples_leaf': 30, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:08,796] Trial 240 finished with value: 0.7245095395402144 and
```

```
parameters: {'max_depth': 24, 'min_samples_split': 14, 'min_samples_leaf': 7, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:08,801] Trial 239 finished with value: 0.7409778871435313 and parameters: {'max_depth': 23, 'min_samples_split': 31, 'min_samples_leaf': 9, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:08,806] Trial 241 finished with value: 0.7065698105575408 and parameters: {'max_depth': 5, 'min_samples_split': 10, 'min_samples_leaf': 2, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:08,879] Trial 243 finished with value: 0.7489887413200297 and parameters: {'max_depth': 20, 'min_samples_split': 11, 'min_samples_leaf': 20, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:08,926] Trial 244 finished with value: 0.7462855505581184 and parameters: {'max_depth': 29, 'min_samples_split': 32, 'min_samples_leaf': 25, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:08,930] Trial 242 finished with value: 0.7013447332684845 and parameters: {'max_depth': 36, 'min_samples_split': 12, 'min_samples_leaf': 5, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:08,953] Trial 250 finished with value: 0.7284765628762123 and parameters: {'max_depth': 39, 'min_samples_split': 13, 'min_samples_leaf': 8, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:08,945] Trial 247 finished with value: 0.7520343153778737 and parameters: {'max_depth': 30, 'min_samples_split': 32, 'min_samples_leaf': 24, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:08,945] Trial 246 finished with value: 0.764307865666323 and parameters: {'max_depth': 40, 'min_samples_split': 29, 'min_samples_leaf': 16, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:08,946] Trial 249 finished with value: 0.7383016632797527 and parameters: {'max_depth': 7, 'min_samples_split': 15, 'min_samples_leaf': 6, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:08,931] Trial 245 finished with value: 0.746597355317776 and parameters: {'max_depth': 23, 'min_samples_split': 31, 'min_samples_leaf': 12, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:09,014] Trial 251 finished with value: 0.7112940740241354 and parameters: {'max_depth': 25, 'min_samples_split': 7, 'min_samples_leaf': 6, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:09,044] Trial 248 finished with value: 0.7409952230066166 and parameters: {'max_depth': 40, 'min_samples_split': 21, 'min_samples_leaf': 10, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:09,057] Trial 252 finished with value: 0.7430808236461173 and parameters: {'max_depth': 31, 'min_samples_split': 3, 'min_samples_leaf': 15, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:09,067] Trial 253 finished with value: 0.744079561980526 and parameters: {'max_depth': 23, 'min_samples_split': 28, 'min_samples_leaf': 12, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:09,077] Trial 254 finished with value: 0.7361635734992439 and parameters: {'max_depth': 49, 'min_samples_split': 31, 'min_samples_leaf': 4, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:09,113] Trial 256 finished with value: 0.7327159037281736 and parameters: {'max_depth': 26, 'min_samples_split': 15, 'min_samples_leaf': 10, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:09,156] Trial 257 finished with value: 0.7565043195192187 and parameters: {'max_depth': 11, 'min_samples_split': 31, 'min_samples_leaf': 16, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:09,163] Trial 258 finished with value: 0.7520343153778737 and parameters: {'max_depth': 31, 'min_samples_split': 32, 'min_samples_leaf': 24, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:09,164] Trial 255 finished with value: 0.7372764395989637 and parameters: {'max_depth': 40, 'min_samples_split': 8, 'min_samples_leaf': 26, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:09,212] Trial 259 finished with value: 0.775424006317959 and
```

```
parameters: {'max_depth': 32, 'min_samples_split': 24, 'min_samples_leaf': 31, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:09,270] Trial 261 finished with value: 0.7402283518409724 and parameters: {'max_depth': 14, 'min_samples_split': 12, 'min_samples_leaf': 20, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:09,279] Trial 262 finished with value: 0.7550341420192428 and parameters: {'max_depth': 27, 'min_samples_split': 27, 'min_samples_leaf': 29, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:09,290] Trial 260 finished with value: 0.7254189500245591 and parameters: {'max_depth': 16, 'min_samples_split': 9, 'min_samples_leaf': 8, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:09,311] Trial 266 finished with value: 0.7757955234949101 and parameters: {'max_depth': 12, 'min_samples_split': 23, 'min_samples_leaf': 32, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:09,410] Trial 263 finished with value: 0.7207134670763067 and parameters: {'max_depth': 19, 'min_samples_split': 5, 'min_samples_leaf': 9, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:09,417] Trial 269 finished with value: 0.7116171952499736 and parameters: {'max_depth': 12, 'min_samples_split': 6, 'min_samples_leaf': 3, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:09,443] Trial 264 finished with value: 0.755422995059279 and parameters: {'max_depth': 14, 'min_samples_split': 9, 'min_samples_leaf': 27, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:09,426] Trial 267 finished with value: 0.7463096281457368 and parameters: {'max_depth': 17, 'min_samples_split': 7, 'min_samples_leaf': 16, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:09,423] Trial 268 finished with value: 0.7029454112933516 and parameters: {'max_depth': 16, 'min_samples_split': 4, 'min_samples_leaf': 5, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:09,447] Trial 271 finished with value: 0.764307865666323 and parameters: {'max_depth': 20, 'min_samples_split': 22, 'min_samples_leaf': 16, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:09,454] Trial 265 finished with value: 0.7706954088855931 and parameters: {'max_depth': 38, 'min_samples_split': 10, 'min_samples_leaf': 24, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:09,539] Trial 272 finished with value: 0.7284765628762123 and parameters: {'max_depth': 37, 'min_samples_split': 11, 'min_samples_leaf': 8, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:09,555] Trial 270 finished with value: 0.7627408962641216 and parameters: {'max_depth': 22, 'min_samples_split': 10, 'min_samples_leaf': 15, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:09,587] Trial 274 finished with value: 0.7390372335814931 and parameters: {'max_depth': 49, 'min_samples_split': 25, 'min_samples_leaf': 13, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:09,620] Trial 275 finished with value: 0.6051653648717628 and parameters: {'max_depth': 3, 'min_samples_split': 24, 'min_samples_leaf': 6, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:09,602] Trial 273 finished with value: 0.7401108532133949 and parameters: {'max_depth': 16, 'min_samples_split': 5, 'min_samples_leaf': 11, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:09,655] Trial 276 finished with value: 0.7573051400834048 and parameters: {'max_depth': 17, 'min_samples_split': 30, 'min_samples_leaf': 13, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:09,670] Trial 277 finished with value: 0.6239280657992314 and parameters: {'max_depth': 40, 'min_samples_split': 3, 'min_samples_leaf': 1, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:09,762] Trial 281 finished with value: 0.7294418333638315 and parameters: {'max_depth': 24, 'min_samples_split': 28, 'min_samples_leaf': 6, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:09,765] Trial 279 finished with value: 0.7862199150542708 and
```

```
parameters: {'max_depth': 7, 'min_samples_split': 16, 'min_samples_leaf': 22, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:09,781] Trial 280 finished with value: 0.7520343153778737 and
parameters: {'max_depth': 16, 'min_samples_split': 5, 'min_samples_leaf': 24, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:09,782] Trial 278 finished with value: 0.7357525690785989 and
parameters: {'max_depth': 18, 'min_samples_split': 29, 'min_samples_leaf': 13, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:09,783] Trial 282 finished with value: 0.7489706831293159 and
parameters: {'max_depth': 19, 'min_samples_split': 14, 'min_samples_leaf': 22, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:09,855] Trial 284 finished with value: 0.7728917664281381 and
parameters: {'max_depth': 27, 'min_samples_split': 14, 'min_samples_leaf': 28, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:09,856] Trial 285 finished with value: 0.7400771445907292 and
parameters: {'max_depth': 30, 'min_samples_split': 15, 'min_samples_leaf': 14, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:09,860] Trial 283 finished with value: 0.7717138908418488 and
parameters: {'max_depth': 15, 'min_samples_split': 26, 'min_samples_leaf': 23, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:09,888] Trial 286 finished with value: 0.6897877319875567 and
parameters: {'max_depth': 13, 'min_samples_split': 11, 'min_samples_leaf': 3, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:09,934] Trial 287 finished with value: 0.7717906983463514 and
parameters: {'max_depth': 13, 'min_samples_split': 2, 'min_samples_leaf': 23, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:09,949] Trial 288 finished with value: 0.7410323024915487 and
parameters: {'max_depth': 17, 'min_samples_split': 10, 'min_samples_leaf': 12, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:10,000] Trial 289 finished with value: 0.769461432520153 and
parameters: {'max_depth': 29, 'min_samples_split': 14, 'min_samples_leaf': 25, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:10,016] Trial 292 finished with value: 0.7489706831293159 and
parameters: {'max_depth': 30, 'min_samples_split': 29, 'min_samples_leaf': 22, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:10,036] Trial 290 finished with value: 0.7324455124192196 and
parameters: {'max_depth': 16, 'min_samples_split': 21, 'min_samples_leaf': 13, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:10,052] Trial 296 finished with value: 0.6173919638643566 and
parameters: {'max_depth': 3, 'min_samples_split': 23, 'min_samples_leaf': 27, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:10,058] Trial 291 finished with value: 0.7746402808409819 and
parameters: {'max_depth': 43, 'min_samples_split': 14, 'min_samples_leaf': 27, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:10,135] Trial 293 finished with value: 0.7646377286166944 and
parameters: {'max_depth': 8, 'min_samples_split': 21, 'min_samples_leaf': 4, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:10,180] Trial 297 finished with value: 0.7729541273800695 and
parameters: {'max_depth': 13, 'min_samples_split': 5, 'min_samples_leaf': 28, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:10,181] Trial 298 finished with value: 0.7751952692355848 and
parameters: {'max_depth': 14, 'min_samples_split': 9, 'min_samples_leaf': 31, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:10,202] Trial 299 finished with value: 0.7527051169689207 and
parameters: {'max_depth': 21, 'min_samples_split': 4, 'min_samples_leaf': 18, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:10,206] Trial 295 finished with value: 0.7040031397174256 and
parameters: {'max_depth': 5, 'min_samples_split': 19, 'min_samples_leaf': 30, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:10,218] Trial 294 finished with value: 0.7491303175352255 and
```

```
parameters: {'max_depth': 13, 'min_samples_split': 32, 'min_samples_leaf': 8, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:10,270] Trial 300 finished with value: 0.7497717444693781 and
parameters: {'max_depth': 39, 'min_samples_split': 18, 'min_samples_leaf': 12, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:10,304] Trial 301 finished with value: 0.7489706831293159 and
parameters: {'max_depth': 34, 'min_samples_split': 4, 'min_samples_leaf': 22, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:10,341] Trial 302 finished with value: 0.7644708709344993 and
parameters: {'max_depth': 24, 'min_samples_split': 26, 'min_samples_leaf': 17, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:10,360] Trial 304 finished with value: 0.7550341420192428 and
parameters: {'max_depth': 33, 'min_samples_split': 32, 'min_samples_leaf': 29, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:10,363] Trial 303 finished with value: 0.7762178443817357 and
parameters: {'max_depth': 47, 'min_samples_split': 3, 'min_samples_leaf': 32, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:10,415] Trial 305 finished with value: 0.7738924309695563 and
parameters: {'max_depth': 25, 'min_samples_split': 23, 'min_samples_leaf': 30, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:10,415] Trial 307 finished with value: 0.7420483766890429 and
parameters: {'max_depth': 29, 'min_samples_split': 30, 'min_samples_leaf': 10, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:10,496] Trial 306 finished with value: 0.7709496682108427 and
parameters: {'max_depth': 8, 'min_samples_split': 27, 'min_samples_leaf': 9, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:10,504] Trial 310 finished with value: 0.7390596257379781 and
parameters: {'max_depth': 31, 'min_samples_split': 27, 'min_samples_leaf': 8, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:10,507] Trial 313 finished with value: 0.7027905924049658 and
parameters: {'max_depth': 5, 'min_samples_split': 9, 'min_samples_leaf': 16, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:10,507] Trial 311 finished with value: 0.7400771445907292 and
parameters: {'max_depth': 26, 'min_samples_split': 28, 'min_samples_leaf': 14, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:10,511] Trial 308 finished with value: 0.7733540561104102 and
parameters: {'max_depth': 50, 'min_samples_split': 26, 'min_samples_leaf': 26, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:10,607] Trial 314 finished with value: 0.7461302501179803 and
parameters: {'max_depth': 39, 'min_samples_split': 4, 'min_samples_leaf': 28, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:10,616] Trial 309 finished with value: 0.7489364929548978 and
parameters: {'max_depth': 37, 'min_samples_split': 4, 'min_samples_leaf': 11, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:10,662] Trial 312 finished with value: 0.7532998333830937 and
parameters: {'max_depth': 36, 'min_samples_split': 16, 'min_samples_leaf': 30, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:10,711] Trial 315 finished with value: 0.7489706831293159 and
parameters: {'max_depth': 30, 'min_samples_split': 3, 'min_samples_leaf': 22, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:10,744] Trial 316 finished with value: 0.7527051169689207 and
parameters: {'max_depth': 32, 'min_samples_split': 9, 'min_samples_leaf': 18, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:10,744] Trial 317 finished with value: 0.7364038678236751 and
parameters: {'max_depth': 49, 'min_samples_split': 26, 'min_samples_leaf': 8, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:10,754] Trial 318 finished with value: 0.7496559312729338 and
parameters: {'max_depth': 15, 'min_samples_split': 6, 'min_samples_leaf': 32, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:10,765] Trial 323 finished with value: 0.6557280580944034 and
```

```
parameters: {'max_depth': 37, 'min_samples_split': 2, 'min_samples_leaf': 2, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:10,767] Trial 321 finished with value: 0.7470242509462491 and  
parameters: {'max_depth': 11, 'min_samples_split': 22, 'min_samples_leaf': 6, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:10,772] Trial 320 finished with value: 0.7462855505581184 and  
parameters: {'max_depth': 48, 'min_samples_split': 24, 'min_samples_leaf': 25, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:10,820] Trial 319 finished with value: 0.768782926101068 and  
parameters: {'max_depth': 48, 'min_samples_split': 11, 'min_samples_leaf': 18, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:10,820] Trial 322 finished with value: 0.7809604068149203 and  
parameters: {'max_depth': 8, 'min_samples_split': 10, 'min_samples_leaf': 21, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:10,828] Trial 325 finished with value: 0.7390372335814931 and  
parameters: {'max_depth': 30, 'min_samples_split': 15, 'min_samples_leaf': 13, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:10,849] Trial 324 finished with value: 0.7489887413200297 and  
parameters: {'max_depth': 20, 'min_samples_split': 32, 'min_samples_leaf': 20, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:10,883] Trial 326 finished with value: 0.7005186312372991 and  
parameters: {'max_depth': 18, 'min_samples_split': 13, 'min_samples_leaf': 2, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:10,945] Trial 327 finished with value: 0.7498201404204912 and  
parameters: {'max_depth': 17, 'min_samples_split': 28, 'min_samples_leaf': 11, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:10,948] Trial 328 finished with value: 0.750640463830648 and  
parameters: {'max_depth': 11, 'min_samples_split': 3, 'min_samples_leaf': 25, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:10,980] Trial 329 finished with value: 0.7307143338694609 and  
parameters: {'max_depth': 3, 'min_samples_split': 10, 'min_samples_leaf': 32, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:11,067] Trial 330 finished with value: 0.7497717444693781 and  
parameters: {'max_depth': 39, 'min_samples_split': 4, 'min_samples_leaf': 12, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:11,072] Trial 331 finished with value: 0.7489887413200297 and  
parameters: {'max_depth': 49, 'min_samples_split': 5, 'min_samples_leaf': 20, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:11,106] Trial 333 finished with value: 0.7245095395402144 and  
parameters: {'max_depth': 26, 'min_samples_split': 4, 'min_samples_leaf': 7, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:11,120] Trial 332 finished with value: 0.7346377767718697 and  
parameters: {'max_depth': 17, 'min_samples_split': 15, 'min_samples_leaf': 9, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:11,121] Trial 337 finished with value: 0.7462855505581184 and  
parameters: {'max_depth': 50, 'min_samples_split': 4, 'min_samples_leaf': 25, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:11,177] Trial 338 finished with value: 0.7159070990359334 and  
parameters: {'max_depth': 29, 'min_samples_split': 20, 'min_samples_leaf': 6, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:11,199] Trial 335 finished with value: 0.6797196887249473 and  
parameters: {'max_depth': 4, 'min_samples_split': 21, 'min_samples_leaf': 8, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:11,206] Trial 341 finished with value: 0.7556534175727865 and  
parameters: {'max_depth': 11, 'min_samples_split': 10, 'min_samples_leaf': 32, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:11,212] Trial 336 finished with value: 0.7738924309695563 and  
parameters: {'max_depth': 25, 'min_samples_split': 9, 'min_samples_leaf': 30, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:11,235] Trial 334 finished with value: 0.7474576475233794 and
```

```
parameters: {'max_depth': 43, 'min_samples_split': 5, 'min_samples_leaf': 16, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:11,236] Trial 339 finished with value: 0.775424006317959 and
parameters: {'max_depth': 23, 'min_samples_split': 21, 'min_samples_leaf': 31, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:11,250] Trial 340 finished with value: 0.7341071067407614 and
parameters: {'max_depth': 15, 'min_samples_split': 6, 'min_samples_leaf': 9, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:11,263] Trial 345 finished with value: 0.7474576475233794 and
parameters: {'max_depth': 33, 'min_samples_split': 6, 'min_samples_leaf': 16, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:11,286] Trial 342 finished with value: 0.7627408962641216 and
parameters: {'max_depth': 25, 'min_samples_split': 29, 'min_samples_leaf': 15, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:11,326] Trial 344 finished with value: 0.6943003534589862 and
parameters: {'max_depth': 34, 'min_samples_split': 3, 'min_samples_leaf': 5, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:11,347] Trial 346 finished with value: 0.7300464215889282 and
parameters: {'max_depth': 43, 'min_samples_split': 21, 'min_samples_leaf': 11, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:11,404] Trial 343 finished with value: 0.7527831283528041 and
parameters: {'max_depth': 20, 'min_samples_split': 32, 'min_samples_leaf': 10, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:11,444] Trial 347 finished with value: 0.7323388487060705 and
parameters: {'max_depth': 31, 'min_samples_split': 21, 'min_samples_leaf': 10, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:11,445] Trial 348 finished with value: 0.7520343153778737 and
parameters: {'max_depth': 16, 'min_samples_split': 10, 'min_samples_leaf': 24, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:11,450] Trial 349 finished with value: 0.7112940740241354 and
parameters: {'max_depth': 20, 'min_samples_split': 4, 'min_samples_leaf': 6, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:11,471] Trial 350 finished with value: 0.7307143338694609 and
parameters: {'max_depth': 3, 'min_samples_split': 12, 'min_samples_leaf': 28, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:11,536] Trial 351 finished with value: 0.7507690381485299 and
parameters: {'max_depth': 27, 'min_samples_split': 28, 'min_samples_leaf': 11, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:11,548] Trial 355 finished with value: 0.7245095395402144 and
parameters: {'max_depth': 38, 'min_samples_split': 2, 'min_samples_leaf': 7, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:11,623] Trial 352 finished with value: 0.7639955793549132 and
parameters: {'max_depth': 11, 'min_samples_split': 19, 'min_samples_leaf': 16, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:11,627] Trial 354 finished with value: 0.7755882154655162 and
parameters: {'max_depth': 13, 'min_samples_split': 2, 'min_samples_leaf': 31, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:11,641] Trial 356 finished with value: 0.767985957950901 and
parameters: {'max_depth': 50, 'min_samples_split': 13, 'min_samples_leaf': 21, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:11,677] Trial 357 finished with value: 0.7504420645086727 and
parameters: {'max_depth': 9, 'min_samples_split': 6, 'min_samples_leaf': 23, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:11,689] Trial 353 finished with value: 0.7670382641022431 and
parameters: {'max_depth': 4, 'min_samples_split': 10, 'min_samples_leaf': 17, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:11,712] Trial 358 finished with value: 0.7450193102252698 and
parameters: {'max_depth': 11, 'min_samples_split': 15, 'min_samples_leaf': 22, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:11,715] Trial 361 finished with value: 0.7420645086727472 and
```

```
parameters: {'max_depth': 40, 'min_samples_split': 13, 'min_samples_leaf': 23, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:11,729] Trial 359 finished with value: 0.7762178443817357 and parameters: {'max_depth': 17, 'min_samples_split': 16, 'min_samples_leaf': 32, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:11,791] Trial 364 finished with value: 0.7827173483834309 and parameters: {'max_depth': 6, 'min_samples_split': 2, 'min_samples_leaf': 6, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:11,794] Trial 360 finished with value: 0.727579431961553 and parameters: {'max_depth': 29, 'min_samples_split': 24, 'min_samples_leaf': 5, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:11,795] Trial 363 finished with value: 0.732766466662172 and parameters: {'max_depth': 12, 'min_samples_split': 22, 'min_samples_leaf': 2, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:11,842] Trial 367 finished with value: 0.6782119501882867 and parameters: {'max_depth': 4, 'min_samples_split': 24, 'min_samples_leaf': 11, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:11,906] Trial 366 finished with value: 0.7751952692355848 and parameters: {'max_depth': 14, 'min_samples_split': 9, 'min_samples_leaf': 31, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:11,912] Trial 369 finished with value: 0.7314602575338771 and parameters: {'max_depth': 14, 'min_samples_split': 19, 'min_samples_leaf': 13, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:11,913] Trial 365 finished with value: 0.6763842205121784 and parameters: {'max_depth': 4, 'min_samples_split': 24, 'min_samples_leaf': 28, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:11,927] Trial 368 finished with value: 0.7504461576985678 and parameters: {'max_depth': 16, 'min_samples_split': 19, 'min_samples_leaf': 31, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:11,928] Trial 370 finished with value: 0.7300464215889282 and parameters: {'max_depth': 35, 'min_samples_split': 8, 'min_samples_leaf': 11, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:11,937] Trial 362 finished with value: 0.7496559312729338 and parameters: {'max_depth': 26, 'min_samples_split': 13, 'min_samples_leaf': 32, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:11,957] Trial 372 finished with value: 0.746126156928085 and parameters: {'max_depth': 7, 'min_samples_split': 11, 'min_samples_leaf': 16, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:11,997] Trial 371 finished with value: 0.7733540561104102 and parameters: {'max_depth': 34, 'min_samples_split': 19, 'min_samples_leaf': 26, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:12,048] Trial 376 finished with value: 0.7529916402615789 and parameters: {'max_depth': 37, 'min_samples_split': 25, 'min_samples_leaf': 31, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:12,093] Trial 374 finished with value: 0.7375730754784215 and parameters: {'max_depth': 17, 'min_samples_split': 22, 'min_samples_leaf': 8, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:12,120] Trial 377 finished with value: 0.7316393947857577 and parameters: {'max_depth': 13, 'min_samples_split': 3, 'min_samples_leaf': 5, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:12,109] Trial 378 finished with value: 0.764672641118741 and parameters: {'max_depth': 8, 'min_samples_split': 7, 'min_samples_leaf': 14, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:12,117] Trial 375 finished with value: 0.7489706831293159 and parameters: {'max_depth': 47, 'min_samples_split': 14, 'min_samples_leaf': 22, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:12,097] Trial 373 finished with value: 0.7502374050139169 and parameters: {'max_depth': 11, 'min_samples_split': 15, 'min_samples_leaf': 11, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:12,189] Trial 381 finished with value: 0.729238859300209 and
```

```
parameters: {'max_depth': 36, 'min_samples_split': 26, 'min_samples_leaf': 5, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:12,215] Trial 382 finished with value: 0.7132405062072021 and
parameters: {'max_depth': 5, 'min_samples_split': 27, 'min_samples_leaf': 12, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:12,240] Trial 384 finished with value: 0.7362504935905461 and
parameters: {'max_depth': 7, 'min_samples_split': 14, 'min_samples_leaf': 21, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:12,244] Trial 380 finished with value: 0.7690087738729281 and
parameters: {'max_depth': 41, 'min_samples_split': 10, 'min_samples_leaf': 22, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:12,266] Trial 383 finished with value: 0.7756833219366084 and
parameters: {'max_depth': 7, 'min_samples_split': 11, 'min_samples_leaf': 5, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:12,296] Trial 379 finished with value: 0.7561655478614286 and
parameters: {'max_depth': 45, 'min_samples_split': 16, 'min_samples_leaf': 14, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:12,313] Trial 386 finished with value: 0.7417669096897843 and
parameters: {'max_depth': 11, 'min_samples_split': 24, 'min_samples_leaf': 28, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:12,315] Trial 385 finished with value: 0.7842344771792624 and
parameters: {'max_depth': 5, 'min_samples_split': 27, 'min_samples_leaf': 15, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:12,357] Trial 388 finished with value: 0.7128978821353931 and
parameters: {'max_depth': 42, 'min_samples_split': 26, 'min_samples_leaf': 1, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:12,361] Trial 387 finished with value: 0.7474576475233794 and
parameters: {'max_depth': 46, 'min_samples_split': 15, 'min_samples_leaf': 16, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:12,372] Trial 389 finished with value: 0.7813690034768037 and
parameters: {'max_depth': 5, 'min_samples_split': 13, 'min_samples_leaf': 9, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:12,414] Trial 390 finished with value: 0.764196145659774 and
parameters: {'max_depth': 12, 'min_samples_split': 23, 'min_samples_leaf': 16, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:12,446] Trial 391 finished with value: 0.7762178443817357 and
parameters: {'max_depth': 19, 'min_samples_split': 9, 'min_samples_leaf': 32, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:12,455] Trial 393 finished with value: 0.7363239302327821 and
parameters: {'max_depth': 20, 'min_samples_split': 22, 'min_samples_leaf': 9, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:12,475] Trial 392 finished with value: 0.7461302501179803 and
parameters: {'max_depth': 50, 'min_samples_split': 23, 'min_samples_leaf': 28, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:12,523] Trial 394 finished with value: 0.6997329795533127 and
parameters: {'max_depth': 32, 'min_samples_split': 8, 'min_samples_leaf': 4, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:12,532] Trial 395 finished with value: 0.735401036299371 and
parameters: {'max_depth': 40, 'min_samples_split': 29, 'min_samples_leaf': 12, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:12,586] Trial 397 finished with value: 0.7210281611464783 and
parameters: {'max_depth': 26, 'min_samples_split': 23, 'min_samples_leaf': 4, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:12,586] Trial 398 finished with value: 0.7372764395989637 and
parameters: {'max_depth': 23, 'min_samples_split': 22, 'min_samples_leaf': 26, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:12,598] Trial 396 finished with value: 0.744739769433021 and
parameters: {'max_depth': 12, 'min_samples_split': 19, 'min_samples_leaf': 31, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:12,669] Trial 399 finished with value: 0.7004940720979282 and
```

```
parameters: {'max_depth': 23, 'min_samples_split': 14, 'min_samples_leaf': 4, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:12,676] Trial 400 finished with value: 0.7527051169689207 and parameters: {'max_depth': 21, 'min_samples_split': 8, 'min_samples_leaf': 18, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:12,690] Trial 403 finished with value: 0.7390372335814931 and parameters: {'max_depth': 49, 'min_samples_split': 8, 'min_samples_leaf': 13, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:12,724] Trial 402 finished with value: 0.7372764395989637 and parameters: {'max_depth': 47, 'min_samples_split': 31, 'min_samples_leaf': 26, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:12,725] Trial 406 finished with value: 0.7574370852635534 and parameters: {'max_depth': 35, 'min_samples_split': 29, 'min_samples_leaf': 19, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:12,741] Trial 401 finished with value: 0.7400966474367 and parameters: {'max_depth': 25, 'min_samples_split': 27, 'min_samples_leaf': 9, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:12,756] Trial 404 finished with value: 0.7152107752020109 and parameters: {'max_depth': 13, 'min_samples_split': 5, 'min_samples_leaf': 6, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:12,801] Trial 405 finished with value: 0.767060415482852 and parameters: {'max_depth': 19, 'min_samples_split': 9, 'min_samples_leaf': 19, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:12,816] Trial 409 finished with value: 0.767060415482852 and parameters: {'max_depth': 39, 'min_samples_split': 7, 'min_samples_leaf': 19, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:12,841] Trial 408 finished with value: 0.7497717444693781 and parameters: {'max_depth': 32, 'min_samples_split': 15, 'min_samples_leaf': 12, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:12,878] Trial 411 finished with value: 0.7475599772707573 and parameters: {'max_depth': 16, 'min_samples_split': 16, 'min_samples_leaf': 22, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:12,895] Trial 410 finished with value: 0.7744257495353025 and parameters: {'max_depth': 28, 'min_samples_split': 11, 'min_samples_leaf': 29, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:12,899] Trial 407 finished with value: 0.6844393774498945 and parameters: {'max_depth': 50, 'min_samples_split': 7, 'min_samples_leaf': 2, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:12,945] Trial 414 finished with value: 0.6172537585114273 and parameters: {'max_depth': 3, 'min_samples_split': 17, 'min_samples_leaf': 30, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:12,964] Trial 412 finished with value: 0.7712703816779188 and parameters: {'max_depth': 30, 'min_samples_split': 21, 'min_samples_leaf': 20, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:12,954] Trial 413 finished with value: 0.7284765628762123 and parameters: {'max_depth': 37, 'min_samples_split': 15, 'min_samples_leaf': 8, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:12,968] Trial 417 finished with value: 0.7738924309695563 and parameters: {'max_depth': 36, 'min_samples_split': 13, 'min_samples_leaf': 30, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:13,038] Trial 415 finished with value: 0.7013447332684845 and parameters: {'max_depth': 45, 'min_samples_split': 12, 'min_samples_leaf': 5, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:13,041] Trial 416 finished with value: 0.7284765628762123 and parameters: {'max_depth': 49, 'min_samples_split': 6, 'min_samples_leaf': 8, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:13,119] Trial 419 finished with value: 0.7561655478614286 and parameters: {'max_depth': 33, 'min_samples_split': 10, 'min_samples_leaf': 14, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:13,129] Trial 418 finished with value: 0.7690087738729281 and
```

```
parameters: {'max_depth': 22, 'min_samples_split': 12, 'min_samples_leaf': 22, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:13,174] Trial 420 finished with value: 0.7866085273184309 and parameters: {'max_depth': 7, 'min_samples_split': 28, 'min_samples_leaf': 17, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:13,184] Trial 421 finished with value: 0.7407826179079466 and parameters: {'max_depth': 7, 'min_samples_split': 13, 'min_samples_leaf': 19, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:13,184] Trial 422 finished with value: 0.7307143338694609 and parameters: {'max_depth': 3, 'min_samples_split': 18, 'min_samples_leaf': 13, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:13,256] Trial 425 finished with value: 0.7644708709344993 and parameters: {'max_depth': 39, 'min_samples_split': 3, 'min_samples_leaf': 17, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:13,268] Trial 424 finished with value: 0.7314092130481263 and parameters: {'max_depth': 28, 'min_samples_split': 32, 'min_samples_leaf': 7, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:13,272] Trial 427 finished with value: 0.7313774306324701 and parameters: {'max_depth': 6, 'min_samples_split': 9, 'min_samples_leaf': 29, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:13,297] Trial 426 finished with value: 0.6392377998863539 and parameters: {'max_depth': 25, 'min_samples_split': 4, 'min_samples_leaf': 2, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:13,316] Trial 423 finished with value: 0.7462855505581184 and parameters: {'max_depth': 46, 'min_samples_split': 26, 'min_samples_leaf': 25, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:13,370] Trial 428 finished with value: 0.7644708709344993 and parameters: {'max_depth': 18, 'min_samples_split': 23, 'min_samples_leaf': 17, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:13,372] Trial 431 finished with value: 0.7247479076576359 and parameters: {'max_depth': 21, 'min_samples_split': 16, 'min_samples_leaf': 5, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:13,386] Trial 429 finished with value: 0.7529916402615789 and parameters: {'max_depth': 45, 'min_samples_split': 29, 'min_samples_leaf': 31, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:13,417] Trial 432 finished with value: 0.7449270930646916 and parameters: {'max_depth': 32, 'min_samples_split': 18, 'min_samples_leaf': 12, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:13,482] Trial 430 finished with value: 0.7393100326492089 and parameters: {'max_depth': 44, 'min_samples_split': 32, 'min_samples_leaf': 4, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:13,487] Trial 435 finished with value: 0.7429599541562731 and parameters: {'max_depth': 12, 'min_samples_split': 7, 'min_samples_leaf': 27, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:13,515] Trial 433 finished with value: 0.7532998333830937 and parameters: {'max_depth': 21, 'min_samples_split': 17, 'min_samples_leaf': 30, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:13,524] Trial 434 finished with value: 0.7496559312729338 and parameters: {'max_depth': 18, 'min_samples_split': 18, 'min_samples_leaf': 32, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:13,559] Trial 436 finished with value: 0.766990831254635 and parameters: {'max_depth': 13, 'min_samples_split': 19, 'min_samples_leaf': 17, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:13,569] Trial 438 finished with value: 0.775424006317959 and parameters: {'max_depth': 30, 'min_samples_split': 5, 'min_samples_leaf': 31, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:13,570] Trial 437 finished with value: 0.613543643035317 and parameters: {'max_depth': 3, 'min_samples_split': 9, 'min_samples_leaf': 21, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:13,642] Trial 443 finished with value: 0.7509113366913541 and
```

```
parameters: {'max_depth': 13, 'min_samples_split': 11, 'min_samples_leaf': 30, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:13,650] Trial 439 finished with value: 0.767060415482852 and parameters: {'max_depth': 32, 'min_samples_split': 3, 'min_samples_leaf': 19, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:13,665] Trial 444 finished with value: 0.7159745162812647 and parameters: {'max_depth': 18, 'min_samples_split': 9, 'min_samples_leaf': 6, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:13,692] Trial 440 finished with value: 0.7151785112346024 and parameters: {'max_depth': 37, 'min_samples_split': 22, 'min_samples_leaf': 3, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:13,700] Trial 441 finished with value: 0.7365175140372335 and parameters: {'max_depth': 18, 'min_samples_split': 32, 'min_samples_leaf': 3, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:13,730] Trial 445 finished with value: 0.7332119020331115 and parameters: {'max_depth': 26, 'min_samples_split': 18, 'min_samples_leaf': 9, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:13,769] Trial 446 finished with value: 0.739420548776377 and parameters: {'max_depth': 12, 'min_samples_split': 27, 'min_samples_leaf': 2, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:13,783] Trial 442 finished with value: 0.775424006317959 and parameters: {'max_depth': 27, 'min_samples_split': 19, 'min_samples_leaf': 31, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:13,851] Trial 447 finished with value: 0.7521301441765946 and parameters: {'max_depth': 34, 'min_samples_split': 22, 'min_samples_leaf': 13, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:13,860] Trial 449 finished with value: 0.7461302501179803 and parameters: {'max_depth': 31, 'min_samples_split': 25, 'min_samples_leaf': 28, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:13,868] Trial 448 finished with value: 0.7529916402615789 and parameters: {'max_depth': 24, 'min_samples_split': 30, 'min_samples_leaf': 31, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:13,908] Trial 451 finished with value: 0.7574370852635534 and parameters: {'max_depth': 32, 'min_samples_split': 9, 'min_samples_leaf': 19, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:13,926] Trial 453 finished with value: 0.7489887413200297 and parameters: {'max_depth': 21, 'min_samples_split': 2, 'min_samples_leaf': 20, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:13,931] Trial 450 finished with value: 0.7666046267492368 and parameters: {'max_depth': 15, 'min_samples_split': 13, 'min_samples_leaf': 19, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:13,932] Trial 452 finished with value: 0.7496559312729338 and parameters: {'max_depth': 28, 'min_samples_split': 22, 'min_samples_leaf': 32, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:13,982] Trial 457 finished with value: 0.7718552262811685 and parameters: {'max_depth': 40, 'min_samples_split': 9, 'min_samples_leaf': 23, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:14,057] Trial 454 finished with value: 0.6784363533048896 and parameters: {'max_depth': 22, 'min_samples_split': 2, 'min_samples_leaf': 4, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:14,071] Trial 456 finished with value: 0.7266156061291907 and parameters: {'max_depth': 45, 'min_samples_split': 28, 'min_samples_leaf': 4, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:14,086] Trial 462 finished with value: 0.7402283518409724 and parameters: {'max_depth': 14, 'min_samples_split': 9, 'min_samples_leaf': 20, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:14,087] Trial 455 finished with value: 0.7527051169689207 and parameters: {'max_depth': 19, 'min_samples_split': 14, 'min_samples_leaf': 18, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:14,087] Trial 458 finished with value: 0.7462855505581184 and
```

```
parameters: {'max_depth': 37, 'min_samples_split': 7, 'min_samples_leaf': 25, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:14,098] Trial 463 finished with value: 0.7565098573643712 and
parameters: {'max_depth': 10, 'min_samples_split': 27, 'min_samples_leaf': 14, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:14,165] Trial 460 finished with value: 0.7521301441765946 and
parameters: {'max_depth': 50, 'min_samples_split': 18, 'min_samples_leaf': 13, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:14,238] Trial 461 finished with value: 0.7300464215889282 and
parameters: {'max_depth': 26, 'min_samples_split': 18, 'min_samples_leaf': 11, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:14,272] Trial 464 finished with value: 0.7528406737872118 and
parameters: {'max_depth': 13, 'min_samples_split': 29, 'min_samples_leaf': 26, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:14,282] Trial 465 finished with value: 0.7496559312729338 and
parameters: {'max_depth': 46, 'min_samples_split': 7, 'min_samples_leaf': 32, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:14,286] Trial 466 finished with value: 0.7189541177490344 and
parameters: {'max_depth': 36, 'min_samples_split': 10, 'min_samples_leaf': 9, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:14,287] Trial 459 finished with value: 0.7550341420192428 and
parameters: {'max_depth': 16, 'min_samples_split': 5, 'min_samples_leaf': 29, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:14,293] Trial 469 finished with value: 0.6780583351792818 and
parameters: {'max_depth': 4, 'min_samples_split': 29, 'min_samples_leaf': 20, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:14,296] Trial 467 finished with value: 0.7529916402615789 and
parameters: {'max_depth': 38, 'min_samples_split': 7, 'min_samples_leaf': 31, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:14,376] Trial 468 finished with value: 0.7260767497182923 and
parameters: {'max_depth': 14, 'min_samples_split': 10, 'min_samples_leaf': 8, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:14,399] Trial 471 finished with value: 0.7489887413200297 and
parameters: {'max_depth': 50, 'min_samples_split': 23, 'min_samples_leaf': 20, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:14,408] Trial 470 finished with value: 0.7690087738729281 and
parameters: {'max_depth': 24, 'min_samples_split': 10, 'min_samples_leaf': 22, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:14,423] Trial 472 finished with value: 0.7489364929548978 and
parameters: {'max_depth': 29, 'min_samples_split': 19, 'min_samples_leaf': 11, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:14,424] Trial 473 finished with value: 0.7481380801494737 and
parameters: {'max_depth': 9, 'min_samples_split': 11, 'min_samples_leaf': 13, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:14,503] Trial 474 finished with value: 0.6881027824060252 and
parameters: {'max_depth': 22, 'min_samples_split': 10, 'min_samples_leaf': 4, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:14,571] Trial 475 finished with value: 0.7702783850680432 and
parameters: {'max_depth': 11, 'min_samples_split': 8, 'min_samples_leaf': 25, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:14,586] Trial 476 finished with value: 0.7400771445907292 and
parameters: {'max_depth': 31, 'min_samples_split': 19, 'min_samples_leaf': 14, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:14,625] Trial 479 finished with value: 0.7484703508586069 and
parameters: {'max_depth': 13, 'min_samples_split': 21, 'min_samples_leaf': 29, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:14,626] Trial 481 finished with value: 0.7574370852635534 and
parameters: {'max_depth': 46, 'min_samples_split': 7, 'min_samples_leaf': 19, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.
[I 2024-12-22 23:28:14,626] Trial 478 finished with value: 0.7211851470177499 and
```

```
parameters: {'max_depth': 35, 'min_samples_split': 22, 'min_samples_leaf': 1, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:14,652] Trial 482 finished with value: 0.7712703816779188 and parameters: {'max_depth': 23, 'min_samples_split': 30, 'min_samples_leaf': 20, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:14,653] Trial 480 finished with value: 0.7220247324980016 and parameters: {'max_depth': 31, 'min_samples_split': 20, 'min_samples_leaf': 3, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:14,659] Trial 477 finished with value: 0.769461432520153 and parameters: {'max_depth': 39, 'min_samples_split': 25, 'min_samples_leaf': 25, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:14,685] Trial 484 finished with value: 0.7561655478614286 and parameters: {'max_depth': 30, 'min_samples_split': 2, 'min_samples_leaf': 14, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:14,710] Trial 485 finished with value: 0.7420645086727472 and parameters: {'max_depth': 37, 'min_samples_split': 5, 'min_samples_leaf': 23, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:14,736] Trial 483 finished with value: 0.7762178443817357 and parameters: {'max_depth': 17, 'min_samples_split': 2, 'min_samples_leaf': 32, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:14,817] Trial 489 finished with value: 0.7449270930646916 and parameters: {'max_depth': 37, 'min_samples_split': 13, 'min_samples_leaf': 12, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:14,820] Trial 488 finished with value: 0.7025500573046586 and parameters: {'max_depth': 30, 'min_samples_split': 11, 'min_samples_leaf': 4, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:14,821] Trial 487 finished with value: 0.7361341988423497 and parameters: {'max_depth': 44, 'min_samples_split': 26, 'min_samples_leaf': 7, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:14,822] Trial 486 finished with value: 0.7527831283528041 and parameters: {'max_depth': 29, 'min_samples_split': 32, 'min_samples_leaf': 10, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:14,869] Trial 490 finished with value: 0.7842344771792624 and parameters: {'max_depth': 5, 'min_samples_split': 15, 'min_samples_leaf': 15, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:14,882] Trial 491 finished with value: 0.7538223170344117 and parameters: {'max_depth': 13, 'min_samples_split': 3, 'min_samples_leaf': 13, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:14,908] Trial 493 finished with value: 0.7489887413200297 and parameters: {'max_depth': 36, 'min_samples_split': 28, 'min_samples_leaf': 20, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:14,920] Trial 492 finished with value: 0.767985957950901 and parameters: {'max_depth': 45, 'min_samples_split': 20, 'min_samples_leaf': 21, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:14,933] Trial 494 finished with value: 0.7472166308713197 and parameters: {'max_depth': 46, 'min_samples_split': 17, 'min_samples_leaf': 21, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:14,970] Trial 497 finished with value: 0.7277759050765186 and parameters: {'max_depth': 13, 'min_samples_split': 8, 'min_samples_leaf': 9, 'max_features': 'sqrt'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:14,978] Trial 496 finished with value: 0.7520343153778737 and parameters: {'max_depth': 38, 'min_samples_split': 7, 'min_samples_leaf': 24, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:14,999] Trial 498 finished with value: 0.742170690834144 and parameters: {'max_depth': 12, 'min_samples_split': 11, 'min_samples_leaf': 18, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:15,001] Trial 495 finished with value: 0.7706954088855931 and parameters: {'max_depth': 34, 'min_samples_split': 14, 'min_samples_leaf': 24, 'max_features': None}. Best is trial 198 with value: 0.7912562240563994.  
[I 2024-12-22 23:28:15,012] Trial 499 finished with value: 0.7574370852635534 and
```

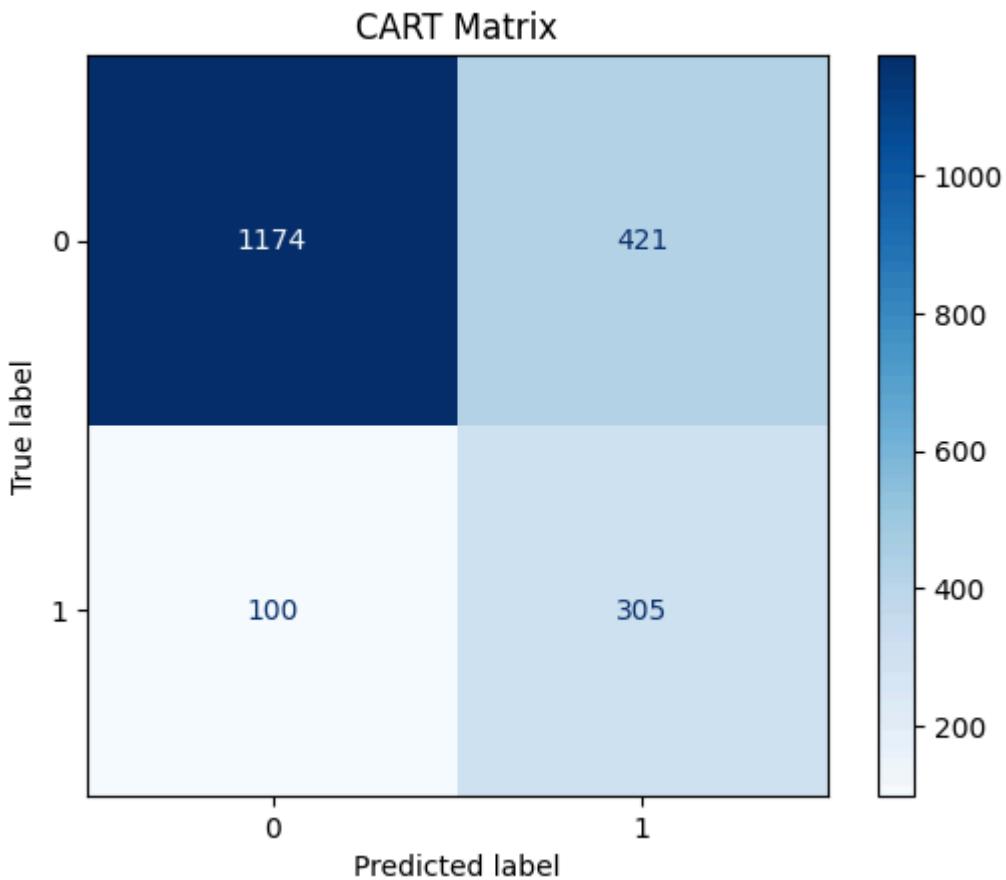
```
parameters: {'max_depth': 17, 'min_samples_split': 12, 'min_samples_leaf': 19, 'max_features': 'log2'}. Best is trial 198 with value: 0.7912562240563994.  
Best hyperparameters: {'max_depth': 6, 'min_samples_split': 21, 'min_samples_leaf': 30, 'max_features': None}
```

```
In [26]: X_train,X_test, y_train, y_test = train_test_split(X, y, test_size = 0.2, random_state=42)  
decision_tree = DecisionTreeClassifier(**best_params, class_weight='balanced', random_state=42)  
  
decision_tree.fit(X_train, y_train)  
skf = StratifiedKFold(n_splits=5, shuffle=True, random_state=42)  
score = cross_val_score(decision_tree, X_train, y_train, cv=skf, scoring="roc_auc")  
  
decision_tree.fit(X_train, y_train)  
y_pred = decision_tree.predict(X_test)  
y_pred_proba = decision_tree.predict_proba(X_test)[:, 1]
```

MODEL EVALUATION

```
In [31]: accuracy = accuracy_score(y_test, y_pred)  
precision = precision_score(y_test, y_pred)  
recall = recall_score(y_test, y_pred)  
f1 = f1_score(y_test, y_pred)  
roc_auc = roc_auc_score(y_test, y_pred_proba)  
  
metrics = {  
    "Accuracy": accuracy * 100,  
    "Precision": precision * 100,  
    "Recall": recall * 100,  
    "F1 Score": f1 * 100,  
    "ROC AUC Score": roc_auc * 100,  
    "Error Rate": (1 - accuracy) * 100,  
}  
  
for metric, value in metrics.items():  
    print(f"{metric}: {value:.2f}%")  
  
conf_matrix = confusion_matrix(y_test, y_pred)  
disp = ConfusionMatrixDisplay(confusion_matrix=conf_matrix, display_labels=decisions)  
disp.plot(cmap="Blues")  
plt.title("CART Matrix")  
plt.show()
```

```
Accuracy: 73.95%  
Precision: 42.01%  
Recall: 75.31%  
F1 Score: 53.93%  
ROC AUC Score: 79.96%  
Error Rate: 26.05%
```



Model Evaluation Summary: We were right with our hypothesis about the Decision Tree Classifier as with this hyperparameters: {'max_depth': 6, 'min_samples_split': 21, 'min_samples_leaf': 30, 'max_features': None} we achieved a solid performance with an accuracy of 73.95%, demonstrating its ability to capture important patterns in the data. However, again we obtained a relatively low precision (42.01%) indicates that it struggles with false positives as we can see in the confusion matrix.

RANDOM FOREST

For our Random Forest model, we are using Optuna for hyperparameter tuning, evaluating the following hyperparameters:

- n_estimators: The number of trees (100 to 1000) to balance model complexity and performance, ensuring sufficient trees to reduce variance without overfitting.
- max_depth: Tree depth (3 to 50) to control model complexity and prevent overfitting by limiting how deep each tree can grow.
- min_samples_split: Minimum samples required to split a node (2 to 32), preventing the model from creating overly complex trees.
- min_samples_leaf: Minimum samples at a leaf node (1 to 32), controlling the smallest size of terminal nodes to ensure the model generalizes well.
- max_features: Number of features to consider at each split (sqrt, log2, or all), providing flexibility in feature selection and improving model robustness.

We are expecting Random Forest to have better results than the previous 2 algorithms, at least better results than the decision tree as The Random Forest Classifier combines

multiple decision trees to make more robust and accurate predictions. As this model benefits from averaging the predictions of several individual trees, reducing overfitting and improving generalization in addition it handles a higher degree of feature interactions and noise in the data, which may explain its better results.

```
In [20]: X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_
```

```
In [21]: def objective(trial):
    n_estimators = trial.suggest_int("n_estimators", 100, 1000)
    max_depth = trial.suggest_int("max_depth", 3, 50)
    min_samples_split = trial.suggest_int("min_samples_split", 2, 32)
    min_samples_leaf = trial.suggest_int("min_samples_leaf", 1, 32)
    max_features = trial.suggest_categorical("max_features", ["sqrt", "log2", "No"]
    model = RandomForestClassifier(
        n_estimators=n_estimators,
        max_depth=max_depth,
        min_samples_split=min_samples_split,
        min_samples_leaf=min_samples_leaf,
        max_features=max_features,
        random_state=42,
        class_weight="balanced",
    )

    skf = StratifiedKFold(n_splits=5, shuffle=True, random_state=42)
    score = cross_val_score(model, X_train, y_train, cv=skf, scoring="roc_auc",
                           return score

study = optuna.create_study(direction="maximize", sampler=optuna.samplers.Random
study.optimize(objective, n_trials=50, n_jobs=-1)

print("Best hyperparameters:", study.best_params)

best_params = study.best_params
best_model = RandomForestClassifier(**best_params, class_weight='balanced', rand
best_model.fit(X_train, y_train)

y_pred = best_model.predict(X_test)
y_pred_proba = best_model.predict_proba(X_test)[:, 1]
```

```
[I 2024-12-22 20:47:42,975] A new study created in memory with name: no-name-75c82842-4f21-497c-8f58-e63c3a6fcc47
[I 2024-12-22 20:47:51,951] Trial 3 finished with value: 0.8087690574105999 and parameters: {'n_estimators': 822, 'max_depth': 47, 'min_samples_split': 29, 'min_samples_leaf': 21, 'max_features': 'sqrt'}. Best is trial 3 with value: 0.8087690574105999.
[I 2024-12-22 20:47:55,995] Trial 1 finished with value: 0.8148072348335276 and parameters: {'n_estimators': 530, 'max_depth': 7, 'min_samples_split': 26, 'min_samples_leaf': 19, 'max_features': None}. Best is trial 1 with value: 0.8148072348335276.
[I 2024-12-22 20:48:06,111] Trial 2 finished with value: 0.8094234862420665 and parameters: {'n_estimators': 454, 'max_depth': 36, 'min_samples_split': 23, 'min_samples_leaf': 14, 'max_features': 'sqrt'}. Best is trial 1 with value: 0.8148072348335276.
[I 2024-12-22 20:48:08,669] Trial 13 finished with value: 0.8083245851431652 and parameters: {'n_estimators': 166, 'max_depth': 34, 'min_samples_split': 19, 'min_samples_leaf': 11, 'max_features': 'sqrt'}. Best is trial 1 with value: 0.8148072348335276.
[I 2024-12-22 20:48:11,819] Trial 12 finished with value: 0.8094239677938188 and parameters: {'n_estimators': 226, 'max_depth': 7, 'min_samples_split': 15, 'min_samples_leaf': 2, 'max_features': 'sqrt'}. Best is trial 1 with value: 0.8148072348335276.
[I 2024-12-22 20:48:12,024] Trial 10 finished with value: 0.8137126677003976 and parameters: {'n_estimators': 639, 'max_depth': 34, 'min_samples_split': 8, 'min_samples_leaf': 25, 'max_features': None}. Best is trial 1 with value: 0.8148072348335276.
[I 2024-12-22 20:48:12,049] Trial 6 finished with value: 0.809744681260895 and parameters: {'n_estimators': 506, 'max_depth': 42, 'min_samples_split': 26, 'min_samples_leaf': 13, 'max_features': 'sqrt'}. Best is trial 1 with value: 0.8148072348335276.
[I 2024-12-22 20:48:12,860] Trial 5 finished with value: 0.815250262445705 and parameters: {'n_estimators': 441, 'max_depth': 7, 'min_samples_split': 5, 'min_samples_leaf': 13, 'max_features': None}. Best is trial 5 with value: 0.815250262445705.
[I 2024-12-22 20:48:14,540] Trial 11 finished with value: 0.8072141268022074 and parameters: {'n_estimators': 384, 'max_depth': 32, 'min_samples_split': 32, 'min_samples_leaf': 32, 'max_features': 'sqrt'}. Best is trial 5 with value: 0.815250262445705.
[I 2024-12-22 20:48:14,543] Trial 0 finished with value: 0.8138388342595178 and parameters: {'n_estimators': 432, 'max_depth': 39, 'min_samples_split': 17, 'min_samples_leaf': 23, 'max_features': None}. Best is trial 5 with value: 0.815250262445705.
[I 2024-12-22 20:48:16,342] Trial 8 finished with value: 0.8075391742350551 and parameters: {'n_estimators': 490, 'max_depth': 44, 'min_samples_split': 25, 'min_samples_leaf': 31, 'max_features': 'log2'}. Best is trial 5 with value: 0.815250262445705.
[I 2024-12-22 20:48:17,364] Trial 14 finished with value: 0.8070354711020794 and parameters: {'n_estimators': 213, 'max_depth': 6, 'min_samples_split': 21, 'min_samples_leaf': 1, 'max_features': 'log2'}. Best is trial 5 with value: 0.815250262445705.
[I 2024-12-22 20:48:17,898] Trial 16 finished with value: 0.8097779083318084 and parameters: {'n_estimators': 232, 'max_depth': 42, 'min_samples_split': 7, 'min_samples_leaf': 9, 'max_features': 'log2'}. Best is trial 5 with value: 0.815250262445705.
[I 2024-12-22 20:48:18,518] Trial 15 finished with value: 0.8068804114378171 and parameters: {'n_estimators': 138, 'max_depth': 30, 'min_samples_split': 18, 'min_samples_leaf': 22, 'max_features': 'log2'}. Best is trial 5 with value: 0.815250262445705.
[I 2024-12-22 20:48:20,781] Trial 19 finished with value: 0.8125603143569838 and parameters: {'n_estimators': 193, 'max_depth': 24, 'min_samples_split': 22, 'min_
```

```
samples_leaf': 20, 'max_features': None}. Best is trial 5 with value: 0.815250262  
445705.  
[I 2024-12-22 20:48:21,456] Trial 20 finished with value: 0.8091668191580549 and  
parameters: {'n_estimators': 182, 'max_depth': 21, 'min_samples_split': 10, 'min_  
samples_leaf': 18, 'max_features': 'sqrt'}. Best is trial 5 with value: 0.8152502  
62445705.  
[I 2024-12-22 20:48:22,086] Trial 21 finished with value: 0.7956703681944698 and  
parameters: {'n_estimators': 352, 'max_depth': 3, 'min_samples_split': 11, 'min_s  
amples_leaf': 7, 'max_features': 'log2'}. Best is trial 5 with value: 0.815250262  
445705.  
[I 2024-12-22 20:48:23,492] Trial 22 finished with value: 0.808308212383585 and p  
arameters: {'n_estimators': 182, 'max_depth': 22, 'min_samples_split': 24, 'min_s  
amples_leaf': 14, 'max_features': 'sqrt'}. Best is trial 5 with value: 0.815250262  
445705.  
[I 2024-12-22 20:48:26,189] Trial 9 finished with value: 0.8138946942627923 and p  
arameters: {'n_estimators': 396, 'max_depth': 44, 'min_samples_split': 17, 'min_s  
amples_leaf': 28, 'max_features': None}. Best is trial 5 with value: 0.8152502624  
45705.  
[I 2024-12-22 20:48:28,196] Trial 7 finished with value: 0.8123566179657328 and p  
arameters: {'n_estimators': 433, 'max_depth': 43, 'min_samples_split': 9, 'min_sa  
mple_leaf': 12, 'max_features': None}. Best is trial 5 with value: 0.81525026244  
5705.  
[I 2024-12-22 20:48:29,979] Trial 23 finished with value: 0.8102888347410697 and  
parameters: {'n_estimators': 757, 'max_depth': 11, 'min_samples_split': 31, 'min_  
samples_leaf': 13, 'max_features': 'log2'}. Best is trial 5 with value: 0.8152502  
62445705.  
[I 2024-12-22 20:48:30,869] Trial 24 finished with value: 0.8097981335054077 and  
parameters: {'n_estimators': 520, 'max_depth': 11, 'min_samples_split': 12, 'min_  
samples_leaf': 16, 'max_features': 'log2'}. Best is trial 5 with value: 0.8152502  
62445705.  
[I 2024-12-22 20:48:32,785] Trial 26 finished with value: 0.8091966753667018 and  
parameters: {'n_estimators': 305, 'max_depth': 33, 'min_samples_split': 17, 'min_  
samples_leaf': 13, 'max_features': 'sqrt'}. Best is trial 5 with value: 0.8152502  
62445705.  
[I 2024-12-22 20:48:33,031] Trial 4 finished with value: 0.8135272702757363 and p  
arameters: {'n_estimators': 533, 'max_depth': 29, 'min_samples_split': 32, 'min_s  
amples_leaf': 31, 'max_features': None}. Best is trial 5 with value: 0.8152502624  
45705.  
[I 2024-12-22 20:48:33,491] Trial 25 finished with value: 0.8072155714574645 and  
parameters: {'n_estimators': 562, 'max_depth': 32, 'min_samples_split': 17, 'min_  
samples_leaf': 32, 'max_features': 'sqrt'}. Best is trial 5 with value: 0.8152502  
62445705.  
[I 2024-12-22 20:48:36,737] Trial 18 finished with value: 0.8097210852250292 and  
parameters: {'n_estimators': 523, 'max_depth': 15, 'min_samples_split': 22, 'min_  
samples_leaf': 4, 'max_features': None}. Best is trial 5 with value: 0.8152502624  
45705.  
[I 2024-12-22 20:48:37,033] Trial 27 finished with value: 0.809933449547823 and p  
arameters: {'n_estimators': 495, 'max_depth': 18, 'min_samples_split': 24, 'min_s  
amples_leaf': 15, 'max_features': 'sqrt'}. Best is trial 5 with value: 0.81525026  
2445705.  
[I 2024-12-22 20:48:40,192] Trial 31 finished with value: 0.7924750315416397 and  
parameters: {'n_estimators': 149, 'max_depth': 3, 'min_samples_split': 27, 'min_s  
amples_leaf': 24, 'max_features': 'log2'}. Best is trial 5 with value: 0.81525026  
2445705.  
[I 2024-12-22 20:48:41,062] Trial 28 finished with value: 0.8106572218316301 and  
parameters: {'n_estimators': 866, 'max_depth': 35, 'min_samples_split': 32, 'min_  
samples_leaf': 11, 'max_features': 'log2'}. Best is trial 5 with value: 0.8152502  
62445705.  
[I 2024-12-22 20:48:41,695] Trial 32 finished with value: 0.8074452716433435 and  
parameters: {'n_estimators': 126, 'max_depth': 20, 'min_samples_split': 25, 'min_
```

```
samples_leaf': 26, 'max_features': 'sqrt'}. Best is trial 5 with value: 0.8152502  
62445705.  
[I 2024-12-22 20:48:42,135] Trial 30 finished with value: 0.797294401479327 and p  
arameters: {'n_estimators': 117, 'max_depth': 50, 'min_samples_split': 3, 'min_sa  
mple_leaf': 1, 'max_features': None}. Best is trial 5 with value: 0.815250262445  
705.  
[I 2024-12-22 20:48:44,322] Trial 29 finished with value: 0.8128718783407652 and  
parameters: {'n_estimators': 275, 'max_depth': 31, 'min_samples_split': 8, 'min_s  
amples_leaf': 14, 'max_features': None}. Best is trial 5 with value: 0.8152502624  
45705.  
[I 2024-12-22 20:48:46,608] Trial 36 finished with value: 0.8069685354085004 and  
parameters: {'n_estimators': 137, 'max_depth': 13, 'min_samples_split': 20, 'min_  
samples_leaf': 23, 'max_features': 'log2'}. Best is trial 5 with value: 0.8152502  
62445705.  
[I 2024-12-22 20:48:47,256] Trial 33 finished with value: 0.8063776714083464 and  
parameters: {'n_estimators': 957, 'max_depth': 6, 'min_samples_split': 26, 'min_s  
amples_leaf': 15, 'max_features': 'log2'}. Best is trial 5 with value: 0.8152502  
62445705.  
[I 2024-12-22 20:48:48,632] Trial 35 finished with value: 0.8098597721297107 and  
parameters: {'n_estimators': 699, 'max_depth': 16, 'min_samples_split': 23, 'min_  
samples_leaf': 13, 'max_features': 'sqrt'}. Best is trial 5 with value: 0.8152502  
62445705.  
[I 2024-12-22 20:48:51,632] Trial 17 finished with value: 0.8067335381533454 and  
parameters: {'n_estimators': 867, 'max_depth': 32, 'min_samples_split': 23, 'min_  
samples_leaf': 1, 'max_features': None}. Best is trial 5 with value: 0.8152502624  
45705.  
[I 2024-12-22 20:48:54,381] Trial 38 finished with value: 0.8098881836831004 and  
parameters: {'n_estimators': 763, 'max_depth': 30, 'min_samples_split': 8, 'min_s  
amples_leaf': 16, 'max_features': 'log2'}. Best is trial 5 with value: 0.8152502  
62445705.  
[I 2024-12-22 20:48:57,091] Trial 37 finished with value: 0.8128126474752243 and  
parameters: {'n_estimators': 311, 'max_depth': 37, 'min_samples_split': 24, 'min_  
samples_leaf': 16, 'max_features': None}. Best is trial 5 with value: 0.815250262  
445705.  
[I 2024-12-22 20:49:01,766] Trial 40 finished with value: 0.8083207327291465 and  
parameters: {'n_estimators': 975, 'max_depth': 32, 'min_samples_split': 27, 'min_  
samples_leaf': 27, 'max_features': 'sqrt'}. Best is trial 5 with value: 0.8152502  
62445705.  
[I 2024-12-22 20:49:07,185] Trial 42 finished with value: 0.807457791988905 and p  
arameters: {'n_estimators': 714, 'max_depth': 19, 'min_samples_split': 25, 'min_s  
amples_leaf': 32, 'max_features': 'log2'}. Best is trial 5 with value: 0.8152502  
62445705.  
[I 2024-12-22 20:49:10,591] Trial 34 finished with value: 0.8118071674162822 and  
parameters: {'n_estimators': 767, 'max_depth': 48, 'min_samples_split': 11, 'min_  
samples_leaf': 11, 'max_features': None}. Best is trial 5 with value: 0.815250262  
445705.  
[I 2024-12-22 20:49:19,867] Trial 39 finished with value: 0.8134829675145188 and  
parameters: {'n_estimators': 918, 'max_depth': 48, 'min_samples_split': 13, 'min_  
samples_leaf': 26, 'max_features': None}. Best is trial 5 with value: 0.815250262  
445705.  
[I 2024-12-22 20:49:20,143] Trial 44 finished with value: 0.8103827373327812 and  
parameters: {'n_estimators': 953, 'max_depth': 26, 'min_samples_split': 19, 'min_  
samples_leaf': 10, 'max_features': 'log2'}. Best is trial 5 with value: 0.8152502  
62445705.  
[I 2024-12-22 20:49:22,818] Trial 45 finished with value: 0.8100365016228295 and  
parameters: {'n_estimators': 554, 'max_depth': 38, 'min_samples_split': 10, 'min_  
samples_leaf': 16, 'max_features': 'sqrt'}. Best is trial 5 with value: 0.8152502  
62445705.  
[I 2024-12-22 20:49:24,777] Trial 46 finished with value: 0.8102642756016989 and  
parameters: {'n_estimators': 517, 'max_depth': 26, 'min_samples_split': 10, 'min_
```

```

samples_leaf': 11, 'max_features': 'log2'}. Best is trial 5 with value: 0.8152502
62445705.
[I 2024-12-22 20:49:25,182] Trial 43 finished with value: 0.8138407604665273 and
parameters: {'n_estimators': 555, 'max_depth': 20, 'min_samples_split': 19, 'min_
samples_leaf': 27, 'max_features': None}. Best is trial 5 with value: 0.815250262
445705.
[I 2024-12-22 20:49:27,354] Trial 48 finished with value: 0.8090839922566477 and
parameters: {'n_estimators': 328, 'max_depth': 37, 'min_samples_split': 18, 'min_
samples_leaf': 13, 'max_features': 'log2'}. Best is trial 5 with value: 0.8152502
62445705.
[I 2024-12-22 20:49:29,096] Trial 49 finished with value: 0.8084926467047413 and
parameters: {'n_estimators': 518, 'max_depth': 21, 'min_samples_split': 25, 'min_
samples_leaf': 26, 'max_features': 'log2'}. Best is trial 5 with value: 0.8152502
62445705.
[I 2024-12-22 20:49:31,250] Trial 41 finished with value: 0.8092351995068909 and
parameters: {'n_estimators': 924, 'max_depth': 10, 'min_samples_split': 3, 'min_s
amples_leaf': 4, 'max_features': None}. Best is trial 5 with value: 0.81525026244
5705.
[I 2024-12-22 20:49:41,421] Trial 47 finished with value: 0.8132816788820294 and
parameters: {'n_estimators': 954, 'max_depth': 40, 'min_samples_split': 20, 'min_
samples_leaf': 32, 'max_features': None}. Best is trial 5 with value: 0.815250262
445705.

Best hyperparameters: {'n_estimators': 441, 'max_depth': 7, 'min_samples_split':
5, 'min_samples_leaf': 13, 'max_features': None}

```

MODEL EVALUATION

```

In [19]: accuracy = accuracy_score(y_test, y_pred)
precision = precision_score(y_test, y_pred)
recall = recall_score(y_test, y_pred)
f1 = f1_score(y_test, y_pred)
roc_auc = roc_auc_score(y_test, y_pred_proba)

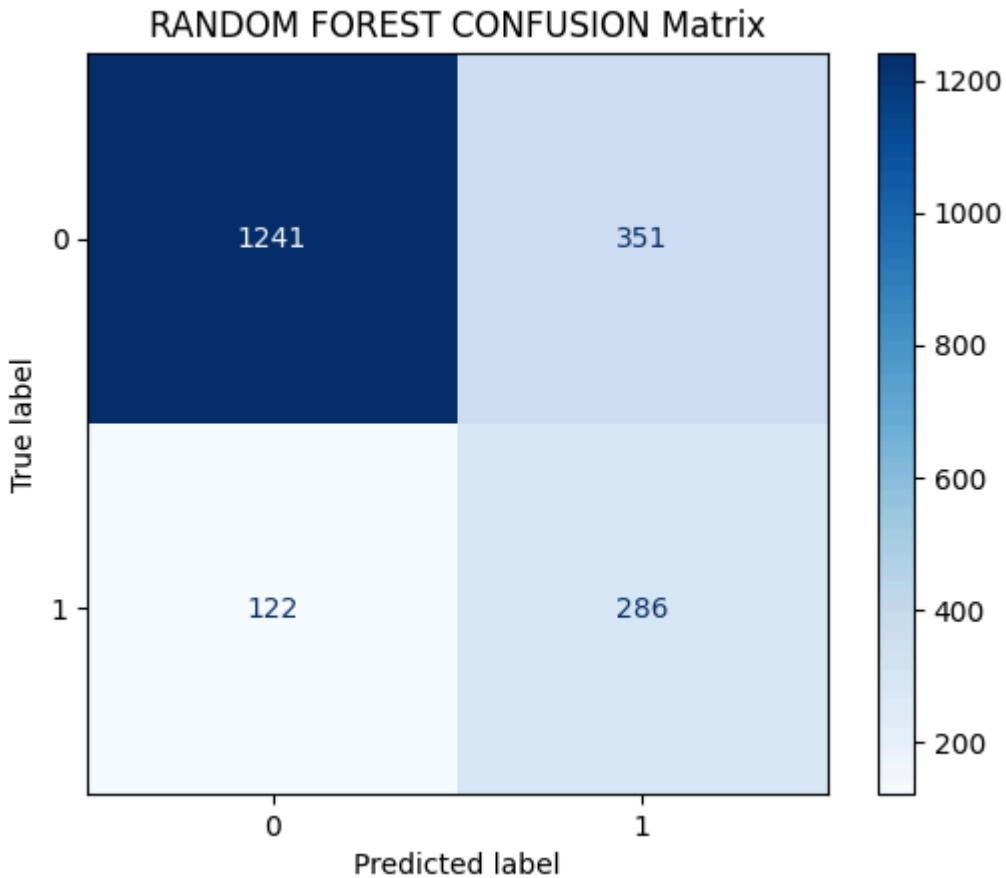
metrics = {
    "Accuracy": accuracy * 100,
    "Precision": precision * 100,
    "Recall": recall * 100,
    "F1 Score": f1 * 100,
    "ROC AUC Score": roc_auc * 100,
    "Error Rate": (1 - accuracy) * 100,
}

for metric, value in metrics.items():
    print(f"{metric}: {value:.2f}%")

conf_matrix = confusion_matrix(y_test, y_pred)
disp = ConfusionMatrixDisplay(confusion_matrix=conf_matrix, display_labels=best_
disp.plot(cmap="Blues")
plt.title("RANDOM FOREST CONFUSION Matrix")
plt.show()

```

Accuracy: 76.35%
 Precision: 44.90%
 Recall: 70.10%
 F1 Score: 54.74%
 ROC AUC Score: 82.36%
 Error Rate: 23.65%



Model Evaluation Summary:

Our predictions were right even if we find just a little improvement. For our Random Forest model trained with the hyperparameters: {'n_estimators': 441, 'max_depth': 7, 'min_samples_split': 5, 'min_samples_leaf': 13, 'max_features': None}, we observe similar trends as in logistic regression, with a slightly lower recall of 0.7 and precision of 0.45. However, compared to other model, we have seen an improvement in accuracy and also in the number of true negatives (TN), which have increased 60, and a reduction in false positives (FP). This improvement suggests that randomForest is becoming more conservative in predicting churners, thereby reducing the number of incorrect predictions.

SUPPORT VECTOR MACHINES (SVM)

For our Support Vector Classifier (SVC) model, we are using Optuna for hyperparameter tuning. The following hyperparameters are being evaluated:

- C: Regularization parameter (ranging from 1e-3 to 1e2).
- kernel: Specifies the type of kernel function used linear kernel. Because it is generally speaking the simpler, more efficient, and has the strongest performance with linearly separable data.
- gamma: Defines how much influence a single training example has. Choices are "scale" (1 / (n_features * X.var())) and "auto" (1 / n_features). Higher gamma = model

will be more sensitive to the training data, leading to overfitting. Lower gamma = may underfit the model.

With the Support Vector Machine (SVM), we expect to achieve good performance in our data. We think it can struggle if it doesn't find the optimal kernel which is hard to determine. If it does we expect to have a balance between accuracy and recall, but precision may be lower.

```
In [22]: X_train, X_test, y_train, y_test = train_test_split(  
    X, y, test_size=0.2, random_state=42, stratify=y  
)  
scaler = MinMaxScaler()  
X_train_scaled = scaler.fit_transform(X_train)  
X_test_scaled = scaler.transform(X_test)  
  
def objective(trial):  
    C = trial.suggest_float("C", 1e-3, 1e2, log=True)  
    gamma = trial.suggest_categorical("gamma", ["scale", "auto"])  
  
    model = SVC(  
        C=C,  
        kernel="linear",  
        gamma=gamma,  
        probability=True,  
        random_state=42,  
        class_weight="balanced"  
)  
    skf = StratifiedKFold(n_splits=5, shuffle=True, random_state=42)  
    score = cross_val_score(model, X_train_scaled, y_train, cv=skf, scoring="roc_auc")  
    return score  
  
study = optuna.create_study(direction="maximize")  
study.optimize(objective, n_trials=8, n_jobs=-1)  
  
print("Best hyperparameters:", study.best_params)  
  
best_params = study.best_params  
best_model = SVC(**best_params, class_weight='balanced', random_state=42, probability=True)  
best_model.fit(X_train_scaled, y_train)  
  
y_pred = best_model.predict(X_test_scaled)  
y_pred_proba = best_model.predict_proba(X_test_scaled)[:, 1]
```

```
[I 2024-12-22 20:50:15,633] A new study created in memory with name: no-name-5158  
5a73-67af-4cd9-aa2f-d97895fe47cb
```

```
[I 2024-12-22 20:50:26,944] Trial 4 finished with value: 0.7851860234419392 and parameters: {'C': 0.9522355408880301, 'gamma': 'auto'}. Best is trial 4 with value: 0.7851860234419392.
[I 2024-12-22 20:50:36,177] Trial 2 finished with value: 0.785790852442912 and parameters: {'C': 0.0048910134239100005, 'gamma': 'auto'}. Best is trial 2 with value: 0.785790852442912.
[I 2024-12-22 20:50:36,861] Trial 1 finished with value: 0.7873472277065616 and parameters: {'C': 0.0029981411170046618, 'gamma': 'scale'}. Best is trial 1 with value: 0.7873472277065616.
[I 2024-12-22 20:50:38,072] Trial 0 finished with value: 0.7851561672332925 and parameters: {'C': 3.5606470028014963, 'gamma': 'auto'}. Best is trial 1 with value: 0.7873472277065616.
[I 2024-12-22 20:50:45,685] Trial 6 finished with value: 0.7825317101828935 and parameters: {'C': 1.0760675264145052, 'gamma': 'auto'}. Best is trial 1 with value: 0.7873472277065616.
[I 2024-12-22 20:50:57,108] Trial 5 finished with value: 0.7815657173676455 and parameters: {'C': 17.844499239767007, 'gamma': 'auto'}. Best is trial 1 with value: 0.7873472277065616.
[I 2024-12-22 20:51:24,801] Trial 7 finished with value: 0.784312488563146 and parameters: {'C': 21.90418000102365, 'gamma': 'auto'}. Best is trial 1 with value: 0.7873472277065616.
[I 2024-12-22 20:57:09,228] Trial 3 finished with value: 0.7867486588783696 and parameters: {'C': 66.36130125276703, 'gamma': 'auto'}. Best is trial 1 with value: 0.7873472277065616.
```

Best hyperparameters: {'C': 0.0029981411170046618, 'gamma': 'scale'}

MODEL EVALUATION

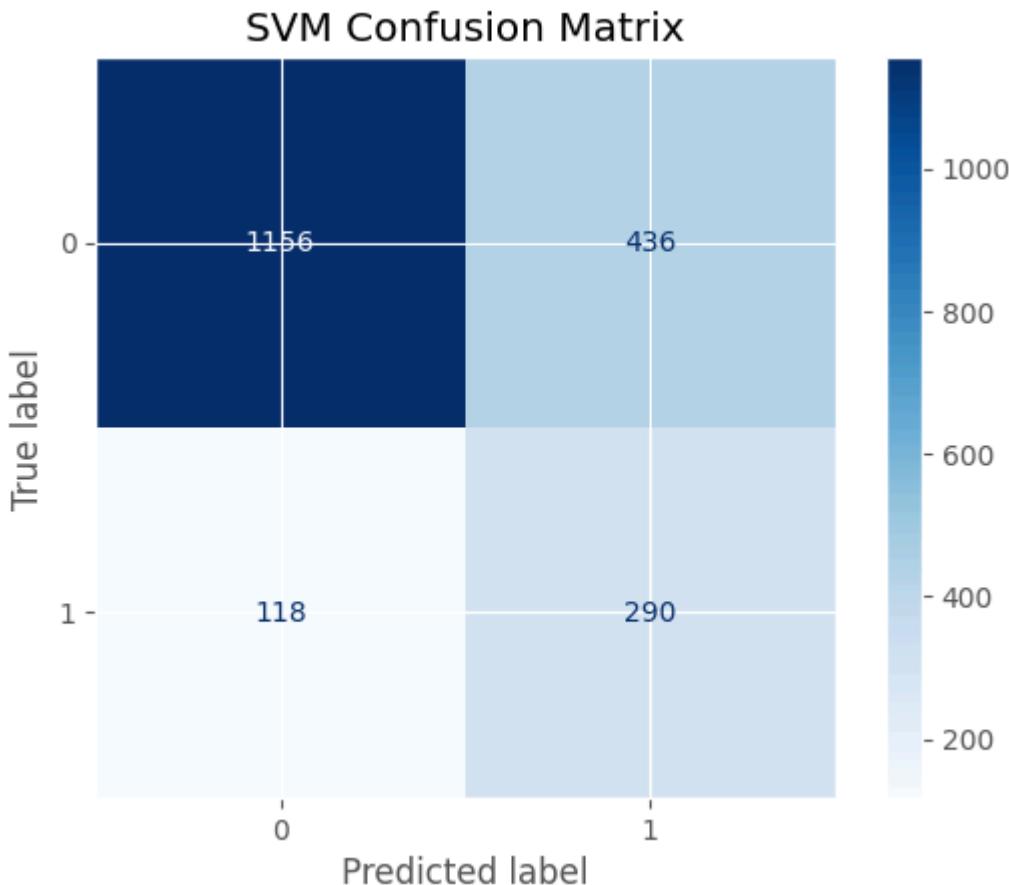
```
In [23]: accuracy = accuracy_score(y_test, y_pred)
precision = precision_score(y_test, y_pred)
recall = recall_score(y_test, y_pred)
f1 = f1_score(y_test, y_pred)
roc_auc = roc_auc_score(y_test, y_pred_proba)

metrics = {
    "Accuracy": accuracy * 100,
    "Precision": precision * 100,
    "Recall": recall * 100,
    "F1 Score": f1 * 100,
    "ROC AUC Score": roc_auc * 100,
    "Error Rate": (1 - accuracy) * 100,
}

for metric, value in metrics.items():
    print(f"{metric}: {value:.2f}%")

conf_matrix = confusion_matrix(y_test, y_pred)
disp = ConfusionMatrixDisplay(confusion_matrix=conf_matrix, display_labels=best_
disp.plot(cmap="Blues")
plt.title("SVM Confusion Matrix")
plt.show()
```

Accuracy: 72.30%
Precision: 39.94%
Recall: 71.08%
F1 Score: 51.15%
ROC AUC Score: 78.56%
Error Rate: 27.70%



Model Evaluation Summary:

Using the hyperparameters {'C': 0.0029981411170046618, 'gamma': 'scale'}. As we expected the SVM model delivered an accuracy of 72.30% which is pretty decent, showing its capability to classify data reasonably well. However, we are still in the same line with low precision (39.94%) suggests a higher rate of false positives, and while recall is relatively good (71.08%) as we mentioned before. The results stick similar to the Linear Regression and the Decision Tree, so we will take it into account later for a deeper evaluation

NAIVE BAYES

With the Naive Bayes model, we can expect relatively high accuracy, as our data follows more or less a simple distribution. However, since Naive Bayes assumes independence between features, it may struggle with some correlations. We anticipate to have moderate precision and recall.

We havent found relevant hyperparameter to tune for naive bayes, then we eill apply as for the previous models StratifiedKFold and cross_val_score to look for avoiding overfitting.

```
In [24]: scaler = StandardScaler()
xStandard = scaler.fit_transform(X)

X_train,X_test, y_train, y_test = train_test_split(xStandard, y, test_size = 0.2
model = GaussianNB()
```

```

model.fit(X_train, y_train)

skf = StratifiedKFold(n_splits=5, shuffle=True, random_state=42)
score = cross_val_score(model, X_train, y_train, cv=skf, scoring="accuracy", n_j

model.fit(X_train, y_train)
y_pred = model.predict(X_test)
y_pred_proba = model.predict_proba(X_test)[:, 1]

```

MODEL EVALUATION

```

In [25]: accuracy = accuracy_score(y_test, y_pred)
precision = precision_score(y_test, y_pred)
recall = recall_score(y_test, y_pred)
f1 = f1_score(y_test, y_pred)
roc_auc = roc_auc_score(y_test, y_pred_proba)

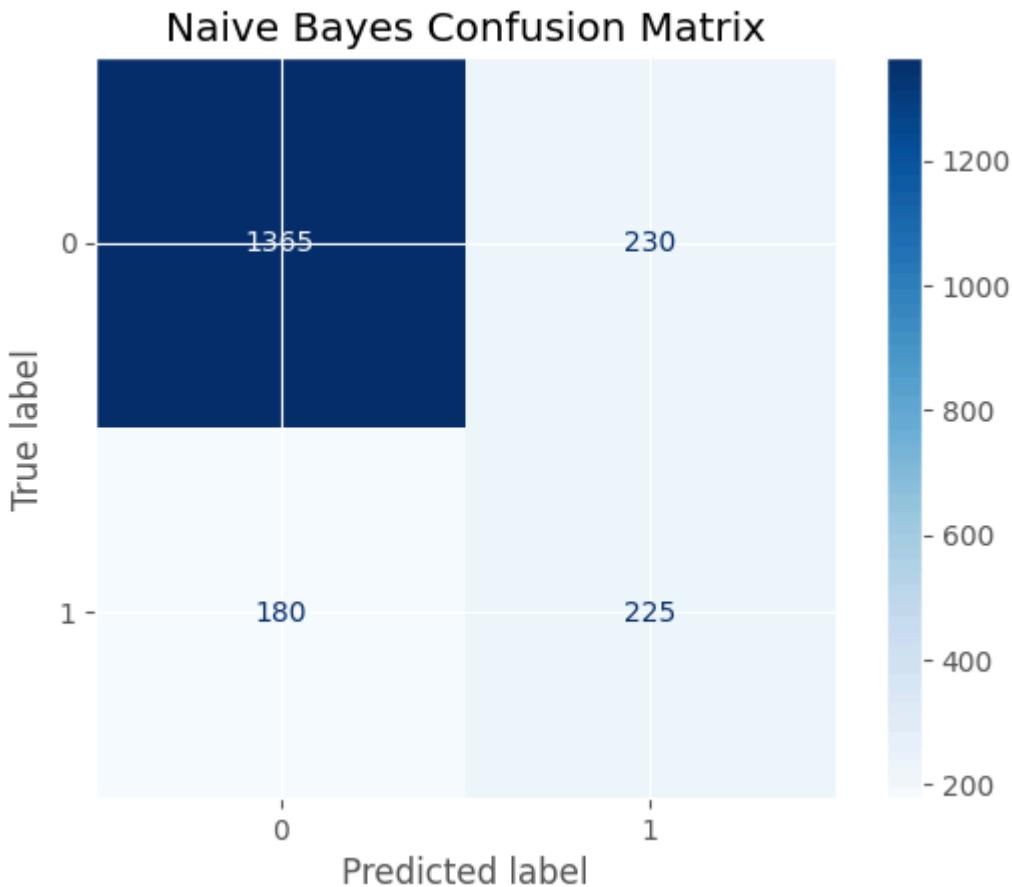
metrics = {
    "Accuracy": accuracy * 100,
    "Precision": precision * 100,
    "Recall": recall * 100,
    "F1 Score": f1 * 100,
    "ROC AUC Score": roc_auc * 100,
    "Error Rate": (1 - accuracy) * 100,
}

for metric, value in metrics.items():
    print(f"{metric}: {value:.2f}%")

conf_matrix = confusion_matrix(y_test, y_pred)
disp = ConfusionMatrixDisplay(confusion_matrix=conf_matrix, display_labels=best_
disp.plot(cmap="Blues")
plt.title("Naive Bayes Confusion Matrix")
plt.show()

```

Accuracy: 79.50%
 Precision: 49.45%
 Recall: 55.56%
 F1 Score: 52.33%
 ROC AUC Score: 78.40%
 Error Rate: 20.50%



Model Evaluation Summary:

The Naive Bayes model achieved an accuracy of 79.50%, indicating good overall performance as it also shows the confusion matrix with the number of TN. However, its precision (49.45%) and recall (55.56%) suggested that we have lost some information for the TP which number has reduced but also the number of false positives has decreased a lot which seems to be positive.

4. REGRESSION

For this section, we have decided to choose 'Balance' as the target variable for regression. The main reason for this is that using a binary variable doesn't make much sense for regression, so we have decided to get insight in this variable. We know that we have prepared our data to predict the 'Exited' variable and not 'Balance', so before starting, we don't expect the regression models to perform well.

Predicting a customer's balance can provide valuable insights into their financial behavior and potential risk of churn. By understanding patterns in balance fluctuations, the business can identify customers who may require targeted offers or interventions to improve retention.

For Regression we are going to apply all metrics we have studied:

- R-squared (R^2) gives us the proportion of the variance in the dependent variable that is predictable from the independent variables. However, it can be overly optimistic

with complex models, as it always increases when additional predictors are added, even if they don't improve the model.

- Adjusted R-squared (Adj R²) adjusts the R-squared value for the number of predictors in the model. It is particularly useful for comparing models with different numbers of predictors, as it penalizes the addition of non-significant predictors.
- Mean Absolute Error (MAE) measures the average magnitude of errors in a set of predictions, without considering their direction. It's a straightforward metric that provides the average distance between the predicted values and actual values in the dataset.
- Mean Squared Error (MSE) is the average of the squares of the errors. It gives higher weight to larger errors, which makes it useful when you want to penalize bigger discrepancies more severely.
- Root Mean Squared Error (RMSE) is the square root of the Mean Squared Error, providing an error metric in the same units as the response variable. It's widely used because it's more interpretable in the context of the data.

Each of these metrics gives us a different perspective on how well our regression model is performing and could be interesting in our project as they help us understand both the accuracy and the reliability of our predictions, ensuring we are capturing the true relationship between variables without overfitting.

```
In [6]: from sklearn.metrics import mean_absolute_percentage_error, mean_squared_error, import numpy as np import optuna from sklearn.preprocessing import StandardScaler, PolynomialFeatures from sklearn.tree import DecisionTreeRegressor from sklearn.linear_model import Ridge from sklearn.model_selection import train_test_split, cross_val_score from sklearn.preprocessing import StandardScaler from sklearn.neighbors import KNeighborsRegressor from sklearn.linear_model import HuberRegressor, TweedieRegressor, QuantileRegre from sklearn.ensemble import RandomForestRegressor from sklearn.svm import LinearSVR, NuSVR, SVR
```

LINEAR REGRESSION

This model is used to get the relationship between a dependent variable and one independent variables (in our case but we could select multiple variables). We consider it simple and appropriate to start with regression models, that is why we will start with linear regression.

To approach this model, first we have chosen the Ridge and Optuna libraries, Ridge is a regularized linear regression variant and we will use it because it produces us the alpha hyperparameter. Also, Optuna is a nice tool for hyperparameter tuning, we think that the model is fast enough to make 500 trials, and get the best possible hyperparameters:

- alpha: given by Ridge, 'alpha' selects the regularization strength, if its 0, it would perform the same as an standard linear regression. We have selected a value between 0.00001 and 300.

As said before, We dont expect a good performance of this model, because our data is not prepared to use balance as our target variable-

```
In [42]: X = dfFeature.drop(['Balance'], axis=1)
y = dfFeature['Balance']

X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_
scaler = StandardScaler()
X_train_scaled = scaler.fit_transform(X_train)
X_test_scaled = scaler.transform(X_test)

def objective(trial):
    alpha = trial.suggest_float('alpha', 1e-5, 300)

    model = Ridge(alpha=alpha, random_state=42)

    score = cross_val_score(model, X_train_scaled, y_train, cv=5, scoring='neg_r
    return score.mean()

study = optuna.create_study(direction='maximize')
study.optimize(objective, n_trials=500, n_jobs=-1)

print(f"Best Hyperparameters: {study.best_params}")
```

```
[I 2024-12-22 21:03:13,251] A new study created in memory with name: no-name-d359f795-a241-4e24-8423-1d7ed6c627ad
[I 2024-12-22 21:03:13,453] Trial 5 finished with value: -2817837048.453691 and parameters: {'alpha': 92.14650099917353}. Best is trial 5 with value: -2817837048.453691.
[I 2024-12-22 21:03:13,458] Trial 6 finished with value: -2817855428.653196 and parameters: {'alpha': 174.2761672068311}. Best is trial 5 with value: -2817837048.453691.
[I 2024-12-22 21:03:13,460] Trial 1 finished with value: -2818111357.759326 and parameters: {'alpha': 38.53235859600475}. Best is trial 5 with value: -2817837048.453691.
[I 2024-12-22 21:03:13,466] Trial 10 finished with value: -2818391511.2437487 and parameters: {'alpha': 292.6050612748044}. Best is trial 5 with value: -2817837048.453691.
[I 2024-12-22 21:03:13,467] Trial 8 finished with value: -2818093740.4805083 and parameters: {'alpha': 240.8227185472273}. Best is trial 5 with value: -2817837048.453691.
[I 2024-12-22 21:03:13,470] Trial 4 finished with value: -2817865253.7431602 and parameters: {'alpha': 81.49639803302901}. Best is trial 5 with value: -2817837048.453691.
[I 2024-12-22 21:03:13,477] Trial 2 finished with value: -2818215128.51133 and parameters: {'alpha': 29.06357814265802}. Best is trial 5 with value: -2817837048.453691.
[I 2024-12-22 21:03:13,506] Trial 0 finished with value: -2818082603.7733727 and parameters: {'alpha': 41.68386376519025}. Best is trial 5 with value: -2817837048.453691.
[I 2024-12-22 21:03:13,507] Trial 13 finished with value: -2818099047.6326475 and parameters: {'alpha': 241.9141923890545}. Best is trial 5 with value: -2817837048.453691.
[I 2024-12-22 21:03:13,514] Trial 3 finished with value: -2818265081.6449814 and parameters: {'alpha': 272.52593287476805}. Best is trial 5 with value: -2817837048.453691.
[I 2024-12-22 21:03:13,520] Trial 18 finished with value: -2818066552.1380534 and parameters: {'alpha': 43.56808626715166}. Best is trial 5 with value: -2817837048.453691.
[I 2024-12-22 21:03:13,526] Trial 11 finished with value: -2818363154.2229347 and parameters: {'alpha': 288.28329233553137}. Best is trial 5 with value: -2817837048.453691.
[I 2024-12-22 21:03:13,526] Trial 12 finished with value: -2817801732.340587 and parameters: {'alpha': 134.23043329308138}. Best is trial 12 with value: -2817801732.340587.
[I 2024-12-22 21:03:13,527] Trial 9 finished with value: -2817822926.4132557 and parameters: {'alpha': 156.85440280812608}. Best is trial 12 with value: -2817801732.340587.
[I 2024-12-22 21:03:13,527] Trial 7 finished with value: -2818270897.3324165 and parameters: {'alpha': 24.924449423513135}. Best is trial 12 with value: -2817801732.340587.
[I 2024-12-22 21:03:13,534] Trial 14 finished with value: -2817811852.672091 and parameters: {'alpha': 148.15725770979654}. Best is trial 12 with value: -2817801732.340587.
[I 2024-12-22 21:03:13,540] Trial 15 finished with value: -2817876617.2514896 and parameters: {'alpha': 78.00661891346866}. Best is trial 12 with value: -2817801732.340587.
[I 2024-12-22 21:03:13,557] Trial 19 finished with value: -2817847738.7751536 and parameters: {'alpha': 87.6832722732928}. Best is trial 12 with value: -2817801732.340587.
[I 2024-12-22 21:03:13,560] Trial 16 finished with value: -2817804926.447226 and parameters: {'alpha': 140.25597422943818}. Best is trial 12 with value: -2817801732.340587.
[I 2024-12-22 21:03:13,562] Trial 17 finished with value: -2817903213.146634 and
```

```
parameters: {'alpha': 70.94374641144287}. Best is trial 12 with value: -281780173  
2.340587.  
[I 2024-12-22 21:03:13,745] Trial 21 finished with value: -2818229600.866347 and  
parameters: {'alpha': 266.4632780279271}. Best is trial 12 with value: -281780173  
2.340587.  
[I 2024-12-22 21:03:13,747] Trial 20 finished with value: -2817943262.350737 and  
parameters: {'alpha': 204.78814242067565}. Best is trial 12 with value: -28178017  
32.340587.  
[I 2024-12-22 21:03:13,768] Trial 22 finished with value: -2817801728.401326 and  
parameters: {'alpha': 134.21995142696218}. Best is trial 22 with value: -28178017  
28.401326.  
[I 2024-12-22 21:03:13,787] Trial 23 finished with value: -2817832374.371665 and  
parameters: {'alpha': 162.72603737374033}. Best is trial 22 with value: -28178017  
28.401326.  
[I 2024-12-22 21:03:13,787] Trial 25 finished with value: -2817903036.391412 and  
parameters: {'alpha': 192.39954818302195}. Best is trial 22 with value: -28178017  
28.401326.  
[I 2024-12-22 21:03:13,808] Trial 24 finished with value: -2817800443.8328133 and  
parameters: {'alpha': 128.58410426804707}. Best is trial 24 with value: -28178004  
43.8328133.  
[I 2024-12-22 21:03:13,856] Trial 27 finished with value: -2817800463.6028495 and  
parameters: {'alpha': 128.81741726072607}. Best is trial 24 with value: -28178004  
43.8328133.  
[I 2024-12-22 21:03:13,870] Trial 28 finished with value: -2817800422.612389 and  
parameters: {'alpha': 125.98138667233374}. Best is trial 28 with value: -28178004  
22.612389.  
[I 2024-12-22 21:03:13,871] Trial 26 finished with value: -2817802078.3904448 and  
parameters: {'alpha': 119.30881059275212}. Best is trial 28 with value: -28178004  
22.612389.  
[I 2024-12-22 21:03:13,880] Trial 29 finished with value: -2817800391.5789056 and  
parameters: {'alpha': 127.5547875004027}. Best is trial 29 with value: -281780039  
1.5789056.  
[I 2024-12-22 21:03:13,895] Trial 32 finished with value: -2817801361.5715575 and  
parameters: {'alpha': 121.17885806356244}. Best is trial 29 with value: -28178003  
91.5789056.  
[I 2024-12-22 21:03:13,902] Trial 31 finished with value: -2817800572.8505816 and  
parameters: {'alpha': 124.5190386590005}. Best is trial 29 with value: -281780039  
1.5789056.  
[I 2024-12-22 21:03:13,977] Trial 33 finished with value: -2817801899.6759925 and  
parameters: {'alpha': 119.7295432573654}. Best is trial 29 with value: -281780039  
1.5789056.  
[I 2024-12-22 21:03:13,979] Trial 34 finished with value: -2817800511.702292 and  
parameters: {'alpha': 129.28237797743395}. Best is trial 29 with value: -28178003  
91.5789056.  
[I 2024-12-22 21:03:13,988] Trial 35 finished with value: -2817800709.4061956 and  
parameters: {'alpha': 123.69557318251312}. Best is trial 29 with value: -28178003  
91.5789056.  
[I 2024-12-22 21:03:13,992] Trial 30 finished with value: -2817800393.7431974 and  
parameters: {'alpha': 127.6403182652613}. Best is trial 29 with value: -281780039  
1.5789056.  
[I 2024-12-22 21:03:14,027] Trial 36 finished with value: -2817800421.3190155 and  
parameters: {'alpha': 126.00223811893746}. Best is trial 29 with value: -28178003  
91.5789056.  
[I 2024-12-22 21:03:14,048] Trial 38 finished with value: -2817800456.185 and par  
ameters: {'alpha': 128.73383937620588}. Best is trial 29 with value: -2817800391.  
5789056.  
[I 2024-12-22 21:03:14,077] Trial 37 finished with value: -2817801002.795644 and  
parameters: {'alpha': 122.39199241365348}. Best is trial 29 with value: -28178003  
91.5789056.  
[I 2024-12-22 21:03:14,079] Trial 40 finished with value: -2817800995.0546846 and
```

```
parameters: {'alpha': 122.42168235632931}. Best is trial 29 with value: -28178003  
91.5789056.  
[I 2024-12-22 21:03:14,109] Trial 39 finished with value: -2817800477.192826 and  
parameters: {'alpha': 128.96071706452938}. Best is trial 29 with value: -28178003  
91.5789056.  
[I 2024-12-22 21:03:14,154] Trial 41 finished with value: -2817800411.707547 and  
parameters: {'alpha': 128.09163920670275}. Best is trial 29 with value: -28178003  
91.5789056.  
[I 2024-12-22 21:03:14,155] Trial 43 finished with value: -2817800389.0448747 and  
parameters: {'alpha': 127.42463626812722}. Best is trial 43 with value: -28178003  
89.0448747.  
[I 2024-12-22 21:03:14,156] Trial 42 finished with value: -2817810484.498559 and  
parameters: {'alpha': 108.30148156986206}. Best is trial 43 with value: -28178003  
89.0448747.  
[I 2024-12-22 21:03:14,160] Trial 46 finished with value: -2817805803.2834334 and  
parameters: {'alpha': 113.24525370610885}. Best is trial 43 with value: -28178003  
89.0448747.  
[I 2024-12-22 21:03:14,181] Trial 47 finished with value: -2817809760.3257875 and  
parameters: {'alpha': 108.9719551530977}. Best is trial 43 with value: -28178003  
89.0448747.  
[I 2024-12-22 21:03:14,186] Trial 45 finished with value: -2817802796.8403177 and  
parameters: {'alpha': 117.81235702365429}. Best is trial 43 with value: -28178003  
89.0448747.  
[I 2024-12-22 21:03:14,190] Trial 44 finished with value: -2817801012.0030966 and  
parameters: {'alpha': 122.35692251113858}. Best is trial 43 with value: -28178003  
89.0448747.  
[I 2024-12-22 21:03:14,201] Trial 48 finished with value: -2817810923.391896 and  
parameters: {'alpha': 107.9074450364313}. Best is trial 43 with value: -28178003  
89.0448747.  
[I 2024-12-22 21:03:14,226] Trial 51 finished with value: -2817807521.3604074 and  
parameters: {'alpha': 111.2381611235464}. Best is trial 43 with value: -28178003  
89.0448747.  
[I 2024-12-22 21:03:14,262] Trial 50 finished with value: -2817817212.517064 and  
parameters: {'alpha': 103.01273017342017}. Best is trial 43 with value: -28178003  
89.0448747.  
[I 2024-12-22 21:03:14,271] Trial 49 finished with value: -2817813527.088956 and  
parameters: {'alpha': 105.73082423081003}. Best is trial 43 with value: -28178003  
89.0448747.  
[I 2024-12-22 21:03:14,280] Trial 54 finished with value: -2817821359.0809374 and  
parameters: {'alpha': 100.3154548217532}. Best is trial 43 with value: -28178003  
89.0448747.  
[I 2024-12-22 21:03:14,281] Trial 52 finished with value: -2817816006.778277 and  
parameters: {'alpha': 103.86324052355857}. Best is trial 43 with value: -28178003  
89.0448747.  
[I 2024-12-22 21:03:14,296] Trial 55 finished with value: -2817822554.417012 and  
parameters: {'alpha': 99.59296656451343}. Best is trial 43 with value: -28178003  
89.0448747.  
[I 2024-12-22 21:03:14,327] Trial 57 finished with value: -2817826019.0199313 and  
parameters: {'alpha': 97.61205441106496}. Best is trial 43 with value: -28178003  
89.0448747.  
[I 2024-12-22 21:03:14,329] Trial 53 finished with value: -2817818351.8611693 and  
parameters: {'alpha': 102.23875560351229}. Best is trial 43 with value: -28178003  
89.0448747.  
[I 2024-12-22 21:03:14,334] Trial 56 finished with value: -2817825720.3975835 and  
parameters: {'alpha': 97.77675497251334}. Best is trial 43 with value: -28178003  
89.0448747.  
[I 2024-12-22 21:03:14,379] Trial 58 finished with value: -2817819599.1636577 and  
parameters: {'alpha': 101.42130152249132}. Best is trial 43 with value: -28178003  
89.0448747.  
[I 2024-12-22 21:03:14,383] Trial 59 finished with value: -2817830263.7178164 and
```

```
parameters: {'alpha': 95.37715397344823}. Best is trial 43 with value: -281780038  
9.0448747.  
[I 2024-12-22 21:03:14,426] Trial 60 finished with value: -2817864204.956696 and  
parameters: {'alpha': 178.04746305868855}. Best is trial 43 with value: -28178003  
89.0448747.  
[I 2024-12-22 21:03:14,439] Trial 61 finished with value: -2817952565.4206476 and  
parameters: {'alpha': 60.51614928102269}. Best is trial 43 with value: -28178003  
89.0448747.  
[I 2024-12-22 21:03:14,505] Trial 62 finished with value: -2817859808.6658607 and  
parameters: {'alpha': 176.19079420592243}. Best is trial 43 with value: -28178003  
89.0448747.  
[I 2024-12-22 21:03:14,509] Trial 66 finished with value: -2817849893.6096134 and  
parameters: {'alpha': 171.75172494129762}. Best is trial 43 with value: -28178003  
89.0448747.  
[I 2024-12-22 21:03:14,526] Trial 65 finished with value: -2817854318.913427 and  
parameters: {'alpha': 173.779893729781}. Best is trial 43 with value: -28178003  
89.0448747.  
[I 2024-12-22 21:03:14,535] Trial 64 finished with value: -2817928356.009887 and  
parameters: {'alpha': 65.2875546883339}. Best is trial 43 with value: -28178003  
89.0448747.  
[I 2024-12-22 21:03:14,541] Trial 67 finished with value: -2817940270.2932725 and  
parameters: {'alpha': 62.86763941577401}. Best is trial 43 with value: -28178003  
89.0448747.  
[I 2024-12-22 21:03:14,545] Trial 63 finished with value: -2817853656.51213 and p  
arameters: {'alpha': 173.48139502680598}. Best is trial 43 with value: -28178003  
89.0448747.  
[I 2024-12-22 21:03:14,579] Trial 69 finished with value: -2817850050.608376 and  
parameters: {'alpha': 171.82509544559548}. Best is trial 43 with value: -28178003  
89.0448747.  
[I 2024-12-22 21:03:14,589] Trial 70 finished with value: -2817959573.5928345 and  
parameters: {'alpha': 59.23549444658039}. Best is trial 43 with value: -28178003  
89.0448747.  
[I 2024-12-22 21:03:14,592] Trial 68 finished with value: -2817848018.100122 and  
parameters: {'alpha': 170.86666916029512}. Best is trial 43 with value: -28178003  
89.0448747.  
[I 2024-12-22 21:03:14,618] Trial 71 finished with value: -2817938329.7188044 and  
parameters: {'alpha': 63.25184271996318}. Best is trial 43 with value: -28178003  
89.0448747.  
[I 2024-12-22 21:03:14,642] Trial 74 finished with value: -2817932486.80636 and p  
arameters: {'alpha': 64.43167297045125}. Best is trial 43 with value: -28178003  
89.0448747.  
[I 2024-12-22 21:03:14,656] Trial 72 finished with value: -2817849524.818611 and  
parameters: {'alpha': 171.5789478761266}. Best is trial 43 with value: -28178003  
89.0448747.  
[I 2024-12-22 21:03:14,671] Trial 75 finished with value: -2817824767.0449224 and  
parameters: {'alpha': 158.07859246276598}. Best is trial 43 with value: -28178003  
89.0448747.  
[I 2024-12-22 21:03:14,686] Trial 76 finished with value: -2817941719.994238 and  
parameters: {'alpha': 62.58303042959605}. Best is trial 43 with value: -28178003  
89.0448747.  
[I 2024-12-22 21:03:14,696] Trial 77 finished with value: -2817941923.462571 and  
parameters: {'alpha': 62.54324785597504}. Best is trial 43 with value: -28178003  
89.0448747.  
[I 2024-12-22 21:03:14,700] Trial 73 finished with value: -2817955289.0308914 and  
parameters: {'alpha': 60.013538336957254}. Best is trial 43 with value: -28178003  
89.0448747.  
[I 2024-12-22 21:03:14,722] Trial 80 finished with value: -2817814866.2705083 and  
parameters: {'alpha': 150.8203818292822}. Best is trial 43 with value: -28178003  
89.0448747.  
[I 2024-12-22 21:03:14,724] Trial 79 finished with value: -2817808946.237212 and
```

```
parameters: {'alpha': 145.24561201816417}. Best is trial 43 with value: -28178003  
89.0448747.  
[I 2024-12-22 21:03:14,727] Trial 81 finished with value: -2817809088.673436 and  
parameters: {'alpha': 145.39850871106256}. Best is trial 43 with value: -28178003  
89.0448747.  
[I 2024-12-22 21:03:14,751] Trial 78 finished with value: -2817810485.88253 and p  
arameters: {'alpha': 146.83871191752155}. Best is trial 43 with value: -281780038  
9.0448747.  
[I 2024-12-22 21:03:14,811] Trial 82 finished with value: -2817814414.7452455 and  
parameters: {'alpha': 150.439585271244}. Best is trial 43 with value: -281780038  
9.0448747.  
[I 2024-12-22 21:03:14,814] Trial 84 finished with value: -2817809395.6648026 and  
parameters: {'alpha': 145.7239917543122}. Best is trial 43 with value: -281780038  
9.0448747.  
[I 2024-12-22 21:03:14,836] Trial 83 finished with value: -2817810257.21701 and p  
arameters: {'alpha': 146.60990922165533}. Best is trial 43 with value: -281780038  
9.0448747.  
[I 2024-12-22 21:03:14,842] Trial 85 finished with value: -2817810046.9447765 and  
parameters: {'alpha': 146.39724630122672}. Best is trial 43 with value: -28178003  
89.0448747.  
[I 2024-12-22 21:03:14,893] Trial 86 finished with value: -2817809446.972573 and  
parameters: {'alpha': 145.77786502461132}. Best is trial 43 with value: -28178003  
89.0448747.  
[I 2024-12-22 21:03:14,896] Trial 89 finished with value: -2817811540.3096642 and  
parameters: {'alpha': 147.86289568285}. Best is trial 43 with value: -2817800389.  
0448747.  
[I 2024-12-22 21:03:14,899] Trial 88 finished with value: -2817808919.0751634 and  
parameters: {'alpha': 145.21631611389734}. Best is trial 43 with value: -28178003  
89.0448747.  
[I 2024-12-22 21:03:14,911] Trial 90 finished with value: -2817809351.8626246 and  
parameters: {'alpha': 145.67788213701405}. Best is trial 43 with value: -28178003  
89.0448747.  
[I 2024-12-22 21:03:14,917] Trial 87 finished with value: -2817809725.412137 and  
parameters: {'alpha': 146.0676957079536}. Best is trial 43 with value: -281780038  
9.0448747.  
[I 2024-12-22 21:03:14,960] Trial 91 finished with value: -2817806577.9964924 and  
parameters: {'alpha': 142.49420859444632}. Best is trial 43 with value: -28178003  
89.0448747.  
[I 2024-12-22 21:03:14,973] Trial 92 finished with value: -2817807785.2929745 and  
parameters: {'alpha': 143.95042627992427}. Best is trial 43 with value: -28178003  
89.0448747.  
[I 2024-12-22 21:03:14,990] Trial 93 finished with value: -2817807466.816907 and  
parameters: {'alpha': 143.57822457730623}. Best is trial 43 with value: -28178003  
89.0448747.  
[I 2024-12-22 21:03:14,991] Trial 94 finished with value: -2818885467.966929 and  
parameters: {'alpha': 0.33813506754199807}. Best is trial 43 with value: -2817800  
389.0448747.  
[I 2024-12-22 21:03:14,998] Trial 97 finished with value: -2817802257.460994 and  
parameters: {'alpha': 135.51370539283204}. Best is trial 43 with value: -28178003  
89.0448747.  
[I 2024-12-22 21:03:15,002] Trial 96 finished with value: -2817803048.793343 and  
parameters: {'alpha': 137.14849758455628}. Best is trial 43 with value: -28178003  
89.0448747.  
[I 2024-12-22 21:03:15,014] Trial 95 finished with value: -2817802108.6245723 and  
parameters: {'alpha': 135.17029842069448}. Best is trial 43 with value: -28178003  
89.0448747.  
[I 2024-12-22 21:03:15,051] Trial 98 finished with value: -2817803080.8907547 and  
parameters: {'alpha': 137.20937001914118}. Best is trial 43 with value: -28178003  
89.0448747.  
[I 2024-12-22 21:03:15,079] Trial 100 finished with value: -2817803514.5937986 an
```

```
d parameters: {'alpha': 137.99953036867367}. Best is trial 43 with value: -281780  
0389.0448747.  
[I 2024-12-22 21:03:15,080] Trial 99 finished with value: -2817851342.637394 and  
parameters: {'alpha': 86.31211961309371}. Best is trial 43 with value: -281780038  
9.0448747.  
[I 2024-12-22 21:03:15,088] Trial 101 finished with value: -2817801367.331687 and  
parameters: {'alpha': 133.1844527557789}. Best is trial 43 with value: -281780038  
9.0448747.  
[I 2024-12-22 21:03:15,094] Trial 102 finished with value: -2817802105.5561914 an  
d parameters: {'alpha': 135.16306845365784}. Best is trial 43 with value: -281780  
0389.0448747.  
[I 2024-12-22 21:03:15,101] Trial 104 finished with value: -2817801458.0163455 an  
d parameters: {'alpha': 133.46012763904173}. Best is trial 43 with value: -281780  
0389.0448747.  
[I 2024-12-22 21:03:15,129] Trial 103 finished with value: -2817801407.26037 and  
parameters: {'alpha': 133.30731848433024}. Best is trial 43 with value: -28178003  
89.0448747.  
[I 2024-12-22 21:03:15,164] Trial 105 finished with value: -2817801684.818834 and  
parameters: {'alpha': 134.1029569013897}. Best is trial 43 with value: -281780038  
9.0448747.  
[I 2024-12-22 21:03:15,166] Trial 107 finished with value: -2817801785.0303025 an  
d parameters: {'alpha': 134.36920810457414}. Best is trial 43 with value: -281780  
0389.0448747.  
[I 2024-12-22 21:03:15,197] Trial 106 finished with value: -2817801241.7156496 an  
d parameters: {'alpha': 132.78087686276345}. Best is trial 43 with value: -281780  
0389.0448747.  
[I 2024-12-22 21:03:15,214] Trial 108 finished with value: -2817800951.5882974 an  
d parameters: {'alpha': 131.71775035447834}. Best is trial 43 with value: -281780  
0389.0448747.  
[I 2024-12-22 21:03:15,228] Trial 110 finished with value: -2817801079.063508 and  
parameters: {'alpha': 132.21186334843807}. Best is trial 43 with value: -28178003  
89.0448747.  
[I 2024-12-22 21:03:15,230] Trial 109 finished with value: -2817801631.1901674 an  
d parameters: {'alpha': 133.95630610990142}. Best is trial 43 with value: -281780  
0389.0448747.  
[I 2024-12-22 21:03:15,253] Trial 111 finished with value: -2817801219.9901137 an  
d parameters: {'alpha': 132.70817447601908}. Best is trial 43 with value: -281780  
0389.0448747.  
[I 2024-12-22 21:03:15,301] Trial 113 finished with value: -2817856541.224163 and  
parameters: {'alpha': 84.43074483756952}. Best is trial 43 with value: -281780038  
9.0448747.  
[I 2024-12-22 21:03:15,345] Trial 115 finished with value: -2817800451.0484033 an  
d parameters: {'alpha': 128.6733294046833}. Best is trial 43 with value: -2817800  
389.0448747.  
[I 2024-12-22 21:03:15,347] Trial 114 finished with value: -2817852073.8626657 an  
d parameters: {'alpha': 86.04088297961141}. Best is trial 43 with value: -2817800  
389.0448747.  
[I 2024-12-22 21:03:15,358] Trial 112 finished with value: -2817800467.9634714 an  
d parameters: {'alpha': 128.86468064253552}. Best is trial 43 with value: -281780  
0389.0448747.  
[I 2024-12-22 21:03:15,358] Trial 116 finished with value: -2817852041.5232224 an  
d parameters: {'alpha': 86.0528311522719}. Best is trial 43 with value: -28178003  
89.0448747.  
[I 2024-12-22 21:03:15,367] Trial 117 finished with value: -2817800473.1769304 an  
d parameters: {'alpha': 125.34876131048375}. Best is trial 43 with value: -281780  
0389.0448747.  
[I 2024-12-22 21:03:15,395] Trial 118 finished with value: -2817800503.949786 and  
parameters: {'alpha': 129.2144163767823}. Best is trial 43 with value: -281780038  
9.0448747.  
[I 2024-12-22 21:03:15,399] Trial 120 finished with value: -2817800387.1933694 an
```

```
d parameters: {'alpha': 126.99530148820197}. Best is trial 120 with value: -2817800387.1933694.
[I 2024-12-22 21:03:15,404] Trial 119 finished with value: -2817800524.9303427 and parameters: {'alpha': 129.39366692372332}. Best is trial 120 with value: -2817800387.1933694.
[I 2024-12-22 21:03:15,427] Trial 121 finished with value: -2817800417.087779 and parameters: {'alpha': 128.19012142396642}. Best is trial 120 with value: -2817800387.1933694.
[I 2024-12-22 21:03:15,479] Trial 124 finished with value: -2817804265.943879 and parameters: {'alpha': 115.34674163666352}. Best is trial 120 with value: -2817800387.1933694.
[I 2024-12-22 21:03:15,484] Trial 122 finished with value: -2817804577.3226852 and parameters: {'alpha': 114.89034368124842}. Best is trial 120 with value: -2817800387.1933694.
[I 2024-12-22 21:03:15,499] Trial 123 finished with value: -2817804110.0366316 and parameters: {'alpha': 115.58237332813891}. Best is trial 120 with value: -2817800387.1933694.
[I 2024-12-22 21:03:15,510] Trial 128 finished with value: -2817804547.792394 and parameters: {'alpha': 114.93285814360891}. Best is trial 120 with value: -2817800387.1933694.
[I 2024-12-22 21:03:15,531] Trial 125 finished with value: -2817805155.9601803 and parameters: {'alpha': 114.08659164713647}. Best is trial 120 with value: -2817800387.1933694.
[I 2024-12-22 21:03:15,537] Trial 126 finished with value: -2817805024.499316 and parameters: {'alpha': 114.26455772302207}. Best is trial 120 with value: -2817800387.1933694.
[I 2024-12-22 21:03:15,551] Trial 127 finished with value: -2817804330.1422014 and parameters: {'alpha': 115.2511379373638}. Best is trial 120 with value: -2817800387.1933694.
[I 2024-12-22 21:03:15,556] Trial 129 finished with value: -2817804554.358712 and parameters: {'alpha': 114.92339123487068}. Best is trial 120 with value: -2817800387.1933694.
[I 2024-12-22 21:03:15,566] Trial 130 finished with value: -2817801935.8269506 and parameters: {'alpha': 119.64247178784643}. Best is trial 120 with value: -2817800387.1933694.
[I 2024-12-22 21:03:15,593] Trial 132 finished with value: -2817803078.5001507 and parameters: {'alpha': 117.28957127279985}. Best is trial 120 with value: -2817800387.1933694.
[I 2024-12-22 21:03:15,602] Trial 131 finished with value: -2817803997.7234907 and parameters: {'alpha': 115.75528848066766}. Best is trial 120 with value: -2817800387.1933694.
[I 2024-12-22 21:03:15,629] Trial 133 finished with value: -2817805257.5785627 and parameters: {'alpha': 113.95076003582761}. Best is trial 120 with value: -2817800387.1933694.
[I 2024-12-22 21:03:15,673] Trial 135 finished with value: -2817804412.8662004 and parameters: {'alpha': 115.12912309852614}. Best is trial 120 with value: -2817800387.1933694.
[I 2024-12-22 21:03:15,690] Trial 134 finished with value: -2817805889.71839 and parameters: {'alpha': 113.13695367318371}. Best is trial 120 with value: -2817800387.1933694.
[I 2024-12-22 21:03:15,707] Trial 138 finished with value: -2817803568.753496 and parameters: {'alpha': 116.44266715459615}. Best is trial 120 with value: -2817800387.1933694.
[I 2024-12-22 21:03:15,723] Trial 136 finished with value: -2817802803.916295 and parameters: {'alpha': 117.79885092203662}. Best is trial 120 with value: -2817800387.1933694.
[I 2024-12-22 21:03:15,742] Trial 137 finished with value: -2817804397.554633 and parameters: {'alpha': 115.15160876966642}. Best is trial 120 with value: -2817800387.1933694.
[I 2024-12-22 21:03:15,774] Trial 141 finished with value: -2817804036.231386 and
```

```
parameters: {'alpha': 115.6956940978602}. Best is trial 120 with value: -28178003  
87.1933694.  
[I 2024-12-22 21:03:15,778] Trial 143 finished with value: -2817821832.947255 and  
parameters: {'alpha': 156.10457530626644}. Best is trial 120 with value: -2817800  
387.1933694.  
[I 2024-12-22 21:03:15,784] Trial 140 finished with value: -2817804947.9481325 an  
d parameters: {'alpha': 114.36939477937158}. Best is trial 120 with value: -2817800  
387.1933694.  
[I 2024-12-22 21:03:15,786] Trial 142 finished with value: -2817830855.0728564 an  
d parameters: {'alpha': 161.8436324583222}. Best is trial 120 with value: -2817800  
387.1933694.  
[I 2024-12-22 21:03:15,803] Trial 139 finished with value: -2817802917.572547 and  
parameters: {'alpha': 117.58462665483529}. Best is trial 120 with value: -2817800  
387.1933694.  
[I 2024-12-22 21:03:15,805] Trial 145 finished with value: -2817830296.238599 and  
parameters: {'alpha': 161.51385362454093}. Best is trial 120 with value: -2817800  
387.1933694.  
[I 2024-12-22 21:03:15,838] Trial 144 finished with value: -2817820480.75025 and  
parameters: {'alpha': 155.1517053616607}. Best is trial 120 with value: -28178003  
87.1933694.  
[I 2024-12-22 21:03:15,877] Trial 146 finished with value: -2817821863.3444343 an  
d parameters: {'alpha': 156.12566201856333}. Best is trial 120 with value: -2817800  
387.1933694.  
[I 2024-12-22 21:03:15,883] Trial 149 finished with value: -2817821343.246021 and  
parameters: {'alpha': 155.76288589594728}. Best is trial 120 with value: -2817800  
387.1933694.  
[I 2024-12-22 21:03:15,895] Trial 151 finished with value: -2817800593.6768775 an  
d parameters: {'alpha': 124.3773046173727}. Best is trial 120 with value: -2817800  
387.1933694.  
[I 2024-12-22 21:03:15,900] Trial 148 finished with value: -2817800624.74616 and  
parameters: {'alpha': 124.1786032049373}. Best is trial 120 with value: -28178003  
87.1933694.  
[I 2024-12-22 21:03:15,917] Trial 147 finished with value: -2817800484.75944 and  
parameters: {'alpha': 125.23345901176405}. Best is trial 120 with value: -2817800  
387.1933694.  
[I 2024-12-22 21:03:15,923] Trial 150 finished with value: -2817800508.886674 and  
parameters: {'alpha': 125.01347311778973}. Best is trial 120 with value: -2817800  
387.1933694.  
[I 2024-12-22 21:03:15,936] Trial 152 finished with value: -2817800530.3588705 an  
d parameters: {'alpha': 124.83548325557227}. Best is trial 120 with value: -2817800  
387.1933694.  
[I 2024-12-22 21:03:15,956] Trial 156 finished with value: -2817800550.353816 and  
parameters: {'alpha': 124.6814324324073}. Best is trial 120 with value: -28178003  
87.1933694.  
[I 2024-12-22 21:03:15,958] Trial 153 finished with value: -2817800622.9799824 an  
d parameters: {'alpha': 124.18953503381263}. Best is trial 120 with value: -2817800  
387.1933694.  
[I 2024-12-22 21:03:15,968] Trial 155 finished with value: -2817812244.27537 and  
parameters: {'alpha': 106.77139464145385}. Best is trial 120 with value: -2817800  
387.1933694.  
[I 2024-12-22 21:03:15,997] Trial 154 finished with value: -2817800457.573223 and  
parameters: {'alpha': 125.51716043557008}. Best is trial 120 with value: -2817800  
387.1933694.  
[I 2024-12-22 21:03:16,001] Trial 157 finished with value: -2817800388.785252 and  
parameters: {'alpha': 127.40787970895042}. Best is trial 120 with value: -2817800  
387.1933694.  
[I 2024-12-22 21:03:16,017] Trial 158 finished with value: -2817819020.256225 and  
parameters: {'alpha': 154.0875400444134}. Best is trial 120 with value: -28178003  
87.1933694.  
[I 2024-12-22 21:03:16,057] Trial 161 finished with value: -2817800584.4752207 an
```

```
d parameters: {'alpha': 124.43899727847743}. Best is trial 120 with value: -2817800387.1933694.
[I 2024-12-22 21:03:16,070] Trial 160 finished with value: -2817800390.1234846 and parameters: {'alpha': 126.77521715574484}. Best is trial 120 with value: -2817800387.1933694.
[I 2024-12-22 21:03:16,081] Trial 159 finished with value: -2817800530.512513 and parameters: {'alpha': 124.8342597735523}. Best is trial 120 with value: -2817800387.1933694.
[I 2024-12-22 21:03:16,097] Trial 164 finished with value: -2817800534.703168 and parameters: {'alpha': 124.80113865350478}. Best is trial 120 with value: -2817800387.1933694.
[I 2024-12-22 21:03:16,108] Trial 162 finished with value: -2817800422.760551 and parameters: {'alpha': 125.97902224438032}. Best is trial 120 with value: -2817800387.1933694.
[I 2024-12-22 21:03:16,109] Trial 163 finished with value: -2817800545.959824 and parameters: {'alpha': 124.71443640499434}. Best is trial 120 with value: -2817800387.1933694.
[I 2024-12-22 21:03:16,124] Trial 165 finished with value: -2817800426.432514 and parameters: {'alpha': 125.92190671996943}. Best is trial 120 with value: -2817800387.1933694.
[I 2024-12-22 21:03:16,182] Trial 167 finished with value: -2817800386.7356157 and parameters: {'alpha': 127.16765321512139}. Best is trial 167 with value: -2817800386.7356157.
[I 2024-12-22 21:03:16,188] Trial 166 finished with value: -2817812936.4128966 and parameters: {'alpha': 106.20290732405013}. Best is trial 167 with value: -2817800386.7356157.
[I 2024-12-22 21:03:16,218] Trial 168 finished with value: -2817800387.3767505 and parameters: {'alpha': 126.97226307833763}. Best is trial 167 with value: -2817800386.7356157.
[I 2024-12-22 21:03:16,245] Trial 170 finished with value: -2817800387.4192805 and parameters: {'alpha': 126.96738463303056}. Best is trial 167 with value: -2817800386.7356157.
[I 2024-12-22 21:03:16,250] Trial 169 finished with value: -2817805403.0432773 and parameters: {'alpha': 140.93756069112553}. Best is trial 167 with value: -2817800386.7356157.
[I 2024-12-22 21:03:16,254] Trial 172 finished with value: -2817812631.254247 and parameters: {'alpha': 106.45143907098596}. Best is trial 167 with value: -2817800386.7356157.
[I 2024-12-22 21:03:16,313] Trial 171 finished with value: -2817800475.4803805 and parameters: {'alpha': 128.94328024329639}. Best is trial 167 with value: -2817800386.7356157.
[I 2024-12-22 21:03:16,319] Trial 175 finished with value: -2817804355.7992353 and parameters: {'alpha': 139.392226489467}. Best is trial 167 with value: -2817800386.7356157.
[I 2024-12-22 21:03:16,329] Trial 173 finished with value: -2817832832.636815 and parameters: {'alpha': 94.10975060631816}. Best is trial 167 with value: -2817800386.7356157.
[I 2024-12-22 21:03:16,338] Trial 174 finished with value: -2817805399.3544283 and parameters: {'alpha': 140.93240926713136}. Best is trial 167 with value: -2817800386.7356157.
[I 2024-12-22 21:03:16,354] Trial 178 finished with value: -2817804675.700949 and parameters: {'alpha': 139.88336741954814}. Best is trial 167 with value: -2817800386.7356157.
[I 2024-12-22 21:03:16,361] Trial 176 finished with value: -2817804280.6186256 and parameters: {'alpha': 139.27403139607358}. Best is trial 167 with value: -2817800386.7356157.
[I 2024-12-22 21:03:16,363] Trial 180 finished with value: -2817804893.689273 and parameters: {'alpha': 140.20787550327225}. Best is trial 167 with value: -2817800386.7356157.
[I 2024-12-22 21:03:16,388] Trial 179 finished with value: -2818017813.848932 and
```

```
parameters: {'alpha': 224.08847871530645}. Best is trial 167 with value: -2817800  
386.7356157.  
[I 2024-12-22 21:03:16,394] Trial 177 finished with value: -2817805157.574787 and  
parameters: {'alpha': 140.59064869373628}. Best is trial 167 with value: -2817800  
386.7356157.  
[I 2024-12-22 21:03:16,397] Trial 181 finished with value: -2817804848.8014007 an  
d parameters: {'alpha': 140.14168906817252}. Best is trial 167 with value: -28178  
00386.7356157.  
[I 2024-12-22 21:03:16,420] Trial 182 finished with value: -2818044171.2295203 an  
d parameters: {'alpha': 230.15994367251452}. Best is trial 167 with value: -28178  
00386.7356157.  
[I 2024-12-22 21:03:16,431] Trial 184 finished with value: -2817804940.066073 and  
parameters: {'alpha': 140.27592113522306}. Best is trial 167 with value: -2817800  
386.7356157.  
[I 2024-12-22 21:03:16,441] Trial 183 finished with value: -2817811919.8361716 an  
d parameters: {'alpha': 107.04394421693613}. Best is trial 167 with value: -28178  
00386.7356157.  
[I 2024-12-22 21:03:16,472] Trial 185 finished with value: -2817804445.862981 and  
parameters: {'alpha': 139.5323922065159}. Best is trial 167 with value: -28178003  
86.7356157.  
[I 2024-12-22 21:03:16,489] Trial 188 finished with value: -2817803864.3505716 an  
d parameters: {'alpha': 138.59841100100516}. Best is trial 167 with value: -28178  
00386.7356157.  
[I 2024-12-22 21:03:16,515] Trial 186 finished with value: -2817805318.725756 and  
parameters: {'alpha': 140.8193483833444}. Best is trial 167 with value: -28178003  
86.7356157.  
[I 2024-12-22 21:03:16,518] Trial 187 finished with value: -2817803209.2549167 an  
d parameters: {'alpha': 137.44933437677466}. Best is trial 167 with value: -28178  
00386.7356157.  
[I 2024-12-22 21:03:16,529] Trial 190 finished with value: -2817804700.8852205 an  
d parameters: {'alpha': 139.9212620496737}. Best is trial 167 with value: -281780  
0386.7356157.  
[I 2024-12-22 21:03:16,531] Trial 189 finished with value: -2817804982.8756003 an  
d parameters: {'alpha': 140.33843391892964}. Best is trial 167 with value: -28178  
00386.7356157.  
[I 2024-12-22 21:03:16,544] Trial 191 finished with value: -2817987609.531866 and  
parameters: {'alpha': 216.70294545329654}. Best is trial 167 with value: -2817800  
386.7356157.  
[I 2024-12-22 21:03:16,611] Trial 192 finished with value: -2817836319.6845846 an  
d parameters: {'alpha': 92.4764066896298}. Best is trial 167 with value: -2817800  
386.7356157.  
[I 2024-12-22 21:03:16,632] Trial 193 finished with value: -2817963589.6894174 an  
d parameters: {'alpha': 210.43256562483708}. Best is trial 167 with value: -28178  
00386.7356157.  
[I 2024-12-22 21:03:16,637] Trial 194 finished with value: -2818153243.250995 and  
parameters: {'alpha': 252.5966764774994}. Best is trial 167 with value: -28178003  
86.7356157.  
[I 2024-12-22 21:03:16,640] Trial 198 finished with value: -2818315640.357292 and  
parameters: {'alpha': 280.8173692015655}. Best is trial 167 with value: -28178003  
86.7356157.  
[I 2024-12-22 21:03:16,645] Trial 196 finished with value: -2817800612.2283072 an  
d parameters: {'alpha': 130.02339033668886}. Best is trial 167 with value: -28178  
00386.7356157.  
[I 2024-12-22 21:03:16,648] Trial 195 finished with value: -2817800550.4552255 an  
d parameters: {'alpha': 129.59434657543676}. Best is trial 167 with value: -28178  
00386.7356157.  
[I 2024-12-22 21:03:16,663] Trial 197 finished with value: -2817800514.3158507 an  
d parameters: {'alpha': 129.30481424089731}. Best is trial 167 with value: -28178  
00386.7356157.  
[I 2024-12-22 21:03:16,665] Trial 199 finished with value: -2817800522.3040857 an
```

```
d parameters: {'alpha': 129.37200827031126}. Best is trial 167 with value: -2817800386.7356157.
[I 2024-12-22 21:03:16,690] Trial 200 finished with value: -2817801165.8455954 and parameters: {'alpha': 132.52280134523232}. Best is trial 167 with value: -2817800386.7356157.
[I 2024-12-22 21:03:16,724] Trial 201 finished with value: -2817800525.8756933 and parameters: {'alpha': 129.40141304069135}. Best is trial 167 with value: -2817800386.7356157.
[I 2024-12-22 21:03:16,740] Trial 203 finished with value: -2817800792.4886007 and parameters: {'alpha': 131.01535580024094}. Best is trial 167 with value: -2817800386.7356157.
[I 2024-12-22 21:03:16,751] Trial 205 finished with value: -2817800574.387099 and parameters: {'alpha': 129.76878068314113}. Best is trial 167 with value: -2817800386.7356157.
[I 2024-12-22 21:03:16,764] Trial 204 finished with value: -2817801735.3968973 and parameters: {'alpha': 120.13926660170061}. Best is trial 167 with value: -2817800386.7356157.
[I 2024-12-22 21:03:16,771] Trial 202 finished with value: -2817800695.339961 and parameters: {'alpha': 130.5166301296988}. Best is trial 167 with value: -2817800386.7356157.
[I 2024-12-22 21:03:16,784] Trial 206 finished with value: -2817800414.6339936 and parameters: {'alpha': 128.14638681278234}. Best is trial 167 with value: -2817800386.7356157.
[I 2024-12-22 21:03:16,823] Trial 207 finished with value: -2817800554.646349 and parameters: {'alpha': 129.62576787657397}. Best is trial 167 with value: -2817800386.7356157.
[I 2024-12-22 21:03:16,863] Trial 209 finished with value: -2817801967.725543 and parameters: {'alpha': 119.56649860103968}. Best is trial 167 with value: -2817800386.7356157.
[I 2024-12-22 21:03:16,875] Trial 210 finished with value: -2817800562.676547 and parameters: {'alpha': 129.6849007468686}. Best is trial 167 with value: -2817800386.7356157.
[I 2024-12-22 21:03:16,878] Trial 211 finished with value: -2817800848.289735 and parameters: {'alpha': 131.27508797393625}. Best is trial 167 with value: -2817800386.7356157.
[I 2024-12-22 21:03:16,882] Trial 208 finished with value: -2817800941.373834 and parameters: {'alpha': 131.67587193240055}. Best is trial 167 with value: -2817800386.7356157.
[I 2024-12-22 21:03:16,895] Trial 212 finished with value: -2817800487.258168 and parameters: {'alpha': 129.0600439190303}. Best is trial 167 with value: -2817800386.7356157.
[I 2024-12-22 21:03:16,949] Trial 213 finished with value: -2817801375.755027 and parameters: {'alpha': 121.13603957740133}. Best is trial 167 with value: -2817800386.7356157.
[I 2024-12-22 21:03:16,968] Trial 215 finished with value: -2817801497.588727 and parameters: {'alpha': 120.78038067182683}. Best is trial 167 with value: -2817800386.7356157.
[I 2024-12-22 21:03:17,001] Trial 217 finished with value: -2817801785.6111937 and parameters: {'alpha': 120.011456098069}. Best is trial 167 with value: -2817800386.7356157.
[I 2024-12-22 21:03:17,003] Trial 216 finished with value: -2817800987.2606 and parameters: {'alpha': 122.45176977983039}. Best is trial 167 with value: -2817800386.7356157.
[I 2024-12-22 21:03:17,016] Trial 214 finished with value: -2817801529.0752497 and parameters: {'alpha': 120.6917326963432}. Best is trial 167 with value: -2817800386.7356157.
[I 2024-12-22 21:03:17,038] Trial 218 finished with value: -2817801606.571999 and parameters: {'alpha': 120.47869806419638}. Best is trial 167 with value: -2817800386.7356157.
[I 2024-12-22 21:03:17,051] Trial 220 finished with value: -2817802082.307317 and
```

```
parameters: {'alpha': 119.29984998695096}. Best is trial 167 with value: -2817800  
386.7356157.  
[I 2024-12-22 21:03:17,057] Trial 219 finished with value: -2817800697.6414623 an  
d parameters: {'alpha': 123.75850725445105}. Best is trial 167 with value: -28178  
00386.7356157.  
[I 2024-12-22 21:03:17,083] Trial 224 finished with value: -2817801466.8252077 an  
d parameters: {'alpha': 120.86823480450813}. Best is trial 167 with value: -28178  
00386.7356157.  
[I 2024-12-22 21:03:17,094] Trial 223 finished with value: -2817801758.3741684 an  
d parameters: {'alpha': 120.08048714342472}. Best is trial 167 with value: -28178  
00386.7356157.  
[I 2024-12-22 21:03:17,099] Trial 221 finished with value: -2817801078.8871756 an  
d parameters: {'alpha': 122.1096461605418}. Best is trial 167 with value: -281780  
0386.7356157.  
[I 2024-12-22 21:03:17,103] Trial 222 finished with value: -2817801786.5237036 an  
d parameters: {'alpha': 120.00915528144068}. Best is trial 167 with value: -28178  
00386.7356157.  
[I 2024-12-22 21:03:17,119] Trial 226 finished with value: -2817801506.145402 and  
parameters: {'alpha': 120.7561650081495}. Best is trial 167 with value: -28178003  
86.7356157.  
[I 2024-12-22 21:03:17,121] Trial 225 finished with value: -2817801732.9014297 an  
d parameters: {'alpha': 120.14568098374602}. Best is trial 167 with value: -28178  
00386.7356157.  
[I 2024-12-22 21:03:17,137] Trial 227 finished with value: -2817802083.189588 and  
parameters: {'alpha': 119.29783307768874}. Best is trial 167 with value: -2817800  
386.7356157.  
[I 2024-12-22 21:03:17,150] Trial 228 finished with value: -2817801396.6588745 an  
d parameters: {'alpha': 121.07349719354605}. Best is trial 167 with value: -28178  
00386.7356157.  
[I 2024-12-22 21:03:17,228] Trial 231 finished with value: -2817801796.776564 and  
parameters: {'alpha': 119.98335588527524}. Best is trial 167 with value: -2817800  
386.7356157.  
[I 2024-12-22 21:03:17,237] Trial 229 finished with value: -2817809933.053748 and  
parameters: {'alpha': 108.80962129604771}. Best is trial 167 with value: -2817800  
386.7356157.  
[I 2024-12-22 21:03:17,240] Trial 230 finished with value: -2817801165.474484 and  
parameters: {'alpha': 121.80686127610714}. Best is trial 167 with value: -2817800  
386.7356157.  
[I 2024-12-22 21:03:17,256] Trial 232 finished with value: -2817801417.1604323 an  
d parameters: {'alpha': 121.01279361215954}. Best is trial 167 with value: -28178  
00386.7356157.  
[I 2024-12-22 21:03:17,265] Trial 233 finished with value: -2817801681.0846624 an  
d parameters: {'alpha': 120.2802652911424}. Best is trial 167 with value: -281780  
00386.7356157.  
[I 2024-12-22 21:03:17,332] Trial 235 finished with value: -2817808382.599216 and  
parameters: {'alpha': 110.32750515340322}. Best is trial 167 with value: -2817800  
386.7356157.  
[I 2024-12-22 21:03:17,336] Trial 234 finished with value: -2817801222.8738184 an  
d parameters: {'alpha': 121.61547231397745}. Best is trial 167 with value: -28178  
00386.7356157.  
[I 2024-12-22 21:03:17,346] Trial 237 finished with value: -2817800735.247704 and  
parameters: {'alpha': 123.56127867044049}. Best is trial 167 with value: -2817800  
386.7356157.  
[I 2024-12-22 21:03:17,459] Trial 238 finished with value: -2817800552.7868514 an  
d parameters: {'alpha': 124.66334910218704}. Best is trial 167 with value: -28178  
00386.7356157.  
[I 2024-12-22 21:03:17,467] Trial 236 finished with value: -2817800737.774282 and  
parameters: {'alpha': 123.54842206715726}. Best is trial 167 with value: -2817800  
386.7356157.  
[I 2024-12-22 21:03:17,490] Trial 239 finished with value: -2817800456.540217 and
```

```
parameters: {'alpha': 125.52893761594518}. Best is trial 167 with value: -2817800  
386.7356157.  
[I 2024-12-22 21:03:17,491] Trial 240 finished with value: -2817810356.101142 and  
parameters: {'alpha': 108.41846070986178}. Best is trial 167 with value: -2817800  
386.7356157.  
[I 2024-12-22 21:03:17,495] Trial 243 finished with value: -2817800387.2927103 an  
d parameters: {'alpha': 126.9823751690942}. Best is trial 167 with value: -2817800  
386.7356157.  
[I 2024-12-22 21:03:17,496] Trial 241 finished with value: -2817802327.648612 and  
parameters: {'alpha': 135.67098211267546}. Best is trial 167 with value: -2817800  
386.7356157.  
[I 2024-12-22 21:03:17,519] Trial 242 finished with value: -2817800459.06348 and  
parameters: {'alpha': 125.50032096296167}. Best is trial 167 with value: -2817800  
386.7356157.  
[I 2024-12-22 21:03:17,542] Trial 246 finished with value: -2817809693.585288 and  
parameters: {'alpha': 109.03510145192064}. Best is trial 167 with value: -2817800  
386.7356157.  
[I 2024-12-22 21:03:17,559] Trial 244 finished with value: -2817808340.3471537 an  
d parameters: {'alpha': 110.37094566066034}. Best is trial 167 with value: -2817800  
386.7356157.  
[I 2024-12-22 21:03:17,573] Trial 247 finished with value: -2817809199.6755195 an  
d parameters: {'alpha': 109.51001979463811}. Best is trial 167 with value: -2817800  
386.7356157.  
[I 2024-12-22 21:03:17,588] Trial 245 finished with value: -2817801755.7560215 an  
d parameters: {'alpha': 134.29242940651076}. Best is trial 167 with value: -2817800  
386.7356157.  
[I 2024-12-22 21:03:17,598] Trial 248 finished with value: -2817807357.7531714 an  
d parameters: {'alpha': 111.41755045738334}. Best is trial 167 with value: -2817800  
386.7356157.  
[I 2024-12-22 21:03:17,657] Trial 249 finished with value: -2817802236.3126297 an  
d parameters: {'alpha': 135.46575006534476}. Best is trial 167 with value: -2817800  
386.7356157.  
[I 2024-12-22 21:03:17,659] Trial 252 finished with value: -2817801841.416566 and  
parameters: {'alpha': 134.514897056622}. Best is trial 167 with value: -281780038  
6.7356157.  
[I 2024-12-22 21:03:17,670] Trial 253 finished with value: -2817801637.6595716 an  
d parameters: {'alpha': 133.97416001436983}. Best is trial 167 with value: -2817800  
386.7356157.  
[I 2024-12-22 21:03:17,673] Trial 251 finished with value: -2817800390.002373 and  
parameters: {'alpha': 127.47955728814041}. Best is trial 167 with value: -2817800  
386.7356157.  
[I 2024-12-22 21:03:17,689] Trial 250 finished with value: -2817800413.481578 and  
parameters: {'alpha': 128.12518603704018}. Best is trial 167 with value: -2817800  
386.7356157.  
[I 2024-12-22 21:03:17,727] Trial 256 finished with value: -2817802165.223764 and  
parameters: {'alpha': 135.3025442729454}. Best is trial 167 with value: -28178003  
86.7356157.  
[I 2024-12-22 21:03:17,756] Trial 257 finished with value: -2817801357.3128242 an  
d parameters: {'alpha': 133.1532379952672}. Best is trial 167 with value: -2817800  
386.7356157.  
[I 2024-12-22 21:03:17,758] Trial 255 finished with value: -2817801714.562095 and  
parameters: {'alpha': 134.18300636489315}. Best is trial 167 with value: -2817800  
386.7356157.  
[I 2024-12-22 21:03:17,775] Trial 258 finished with value: -2817802111.034354 and  
parameters: {'alpha': 135.17597210579868}. Best is trial 167 with value: -2817800  
386.7356157.  
[I 2024-12-22 21:03:17,780] Trial 254 finished with value: -2817801942.8779716 an  
d parameters: {'alpha': 134.77021833374647}. Best is trial 167 with value: -2817800  
386.7356157.  
[I 2024-12-22 21:03:17,789] Trial 260 finished with value: -2817801931.465387 and
```

```
parameters: {'alpha': 134.7419164713044}. Best is trial 167 with value: -28178003  
86.7356157.  
[I 2024-12-22 21:03:17,799] Trial 259 finished with value: -2817801393.881337 and  
parameters: {'alpha': 133.26641805060734}. Best is trial 167 with value: -2817800  
386.7356157.  
[I 2024-12-22 21:03:17,850] Trial 261 finished with value: -2817801811.972245 and  
parameters: {'alpha': 134.4391735349814}. Best is trial 167 with value: -2817800  
386.7356157.  
[I 2024-12-22 21:03:17,862] Trial 265 finished with value: -2817802041.690215 and  
parameters: {'alpha': 135.01111568509612}. Best is trial 167 with value: -2817800  
386.7356157.  
[I 2024-12-22 21:03:17,869] Trial 263 finished with value: -2817801986.72504 and  
parameters: {'alpha': 134.87801580759324}. Best is trial 167 with value: -2817800  
386.7356157.  
[I 2024-12-22 21:03:17,874] Trial 264 finished with value: -2817801663.6730266 an  
d parameters: {'alpha': 134.04549550165586}. Best is trial 167 with value: -28178  
00386.7356157.  
[I 2024-12-22 21:03:17,902] Trial 266 finished with value: -2817802263.156295 and  
parameters: {'alpha': 135.52657430429028}. Best is trial 167 with value: -2817800  
386.7356157.  
[I 2024-12-22 21:03:17,942] Trial 267 finished with value: -2817800420.5224648 an  
d parameters: {'alpha': 128.24847951752682}. Best is trial 167 with value: -28178  
00386.7356157.  
[I 2024-12-22 21:03:17,957] Trial 262 finished with value: -2817801909.6694813 an  
d parameters: {'alpha': 134.68757795653576}. Best is trial 167 with value: -28178  
00386.7356157.  
[I 2024-12-22 21:03:17,997] Trial 272 finished with value: -2817800410.901343 and  
parameters: {'alpha': 128.07600204656546}. Best is trial 167 with value: -2817800  
386.7356157.  
[I 2024-12-22 21:03:17,999] Trial 270 finished with value: -2817800393.257507 and  
parameters: {'alpha': 127.62241780853246}. Best is trial 167 with value: -2817800  
386.7356157.  
[I 2024-12-22 21:03:18,000] Trial 269 finished with value: -2817800386.698841 and  
parameters: {'alpha': 127.13600873051143}. Best is trial 269 with value: -2817800  
386.698841.  
[I 2024-12-22 21:03:18,004] Trial 268 finished with value: -2817801998.16829 and  
parameters: {'alpha': 134.9059090603942}. Best is trial 269 with value: -28178003  
86.698841.  
[I 2024-12-22 21:03:18,036] Trial 271 finished with value: -2817800442.3366804 an  
d parameters: {'alpha': 128.56491284790619}. Best is trial 269 with value: -28178  
00386.698841.  
[I 2024-12-22 21:03:18,042] Trial 274 finished with value: -2817800387.3868585 an  
d parameters: {'alpha': 126.97109010749149}. Best is trial 269 with value: -28178  
00386.698841.  
[I 2024-12-22 21:03:18,056] Trial 273 finished with value: -2817800647.24932 and  
parameters: {'alpha': 130.2406764007367}. Best is trial 269 with value: -28178003  
86.698841.  
[I 2024-12-22 21:03:18,079] Trial 275 finished with value: -2817800415.7221513 an  
d parameters: {'alpha': 126.09732939362623}. Best is trial 269 with value: -28178  
00386.698841.  
[I 2024-12-22 21:03:18,081] Trial 277 finished with value: -2817800387.268448 and  
parameters: {'alpha': 126.98542572852924}. Best is trial 269 with value: -2817800  
386.698841.  
[I 2024-12-22 21:03:18,093] Trial 276 finished with value: -2817800393.9472218 an  
d parameters: {'alpha': 127.64765329049548}. Best is trial 269 with value: -28178  
00386.698841.  
[I 2024-12-22 21:03:18,121] Trial 278 finished with value: -2817800391.7084684 an  
d parameters: {'alpha': 126.70086946775409}. Best is trial 269 with value: -28178  
00386.698841.  
[I 2024-12-22 21:03:18,157] Trial 279 finished with value: -2817800387.239863 and
```

```
parameters: {'alpha': 127.27176353762694}. Best is trial 269 with value: -2817800  
386.698841.  
[I 2024-12-22 21:03:18,167] Trial 280 finished with value: -2817800387.3128195 an  
d parameters: {'alpha': 127.2809806103452}. Best is trial 269 with value: -281780  
0386.698841.  
[I 2024-12-22 21:03:18,191] Trial 282 finished with value: -2817800472.7125473 an  
d parameters: {'alpha': 128.91473905440728}. Best is trial 269 with value: -281780  
0386.698841.  
[I 2024-12-22 21:03:18,203] Trial 283 finished with value: -2817800390.9003434 an  
d parameters: {'alpha': 127.52417076125299}. Best is trial 269 with value: -281780  
0386.698841.  
[I 2024-12-22 21:03:18,222] Trial 281 finished with value: -2817800386.793055 and  
parameters: {'alpha': 127.1896106432376}. Best is trial 269 with value: -28178003  
86.698841.  
[I 2024-12-22 21:03:18,230] Trial 286 finished with value: -2817800387.2696347 an  
d parameters: {'alpha': 126.98527507085791}. Best is trial 269 with value: -281780  
0386.698841.  
[I 2024-12-22 21:03:18,236] Trial 285 finished with value: -2817800391.4211473 an  
d parameters: {'alpha': 127.54786955670562}. Best is trial 269 with value: -281780  
0386.698841.  
[I 2024-12-22 21:03:18,249] Trial 284 finished with value: -2817800408.7955394 an  
d parameters: {'alpha': 128.03388633563418}. Best is trial 269 with value: -281780  
0386.698841.  
[I 2024-12-22 21:03:18,258] Trial 287 finished with value: -2817800390.383418 and  
parameters: {'alpha': 127.49914760694213}. Best is trial 269 with value: -2817800  
386.698841.  
[I 2024-12-22 21:03:18,310] Trial 288 finished with value: -2817800389.5691633 an  
d parameters: {'alpha': 127.45585769320064}. Best is trial 269 with value: -281780  
0386.698841.  
[I 2024-12-22 21:03:18,317] Trial 289 finished with value: -2817800418.657834 and  
parameters: {'alpha': 128.2171853687704}. Best is trial 269 with value: -28178003  
86.698841.  
[I 2024-12-22 21:03:18,341] Trial 290 finished with value: -2817800408.034074 and  
parameters: {'alpha': 128.0181670223766}. Best is trial 269 with value: -28178003  
86.698841.  
[I 2024-12-22 21:03:18,350] Trial 292 finished with value: -2817812124.125435 and  
parameters: {'alpha': 148.40995226966717}. Best is trial 269 with value: -2817800  
386.698841.  
[I 2024-12-22 21:03:18,360] Trial 291 finished with value: -2817800392.6922317 an  
d parameters: {'alpha': 126.66061210939928}. Best is trial 269 with value: -281780  
0386.698841.  
[I 2024-12-22 21:03:18,385] Trial 293 finished with value: -2817813597.8141723 an  
d parameters: {'alpha': 149.7353768031004}. Best is trial 269 with value: -281780  
0386.698841.  
[I 2024-12-22 21:03:18,396] Trial 298 finished with value: -2817811373.0259633 an  
d parameters: {'alpha': 147.70362148412462}. Best is trial 269 with value: -281780  
0386.698841.  
[I 2024-12-22 21:03:18,399] Trial 294 finished with value: -2817810880.2232633 an  
d parameters: {'alpha': 147.22750567886695}. Best is trial 269 with value: -281780  
0386.698841.  
[I 2024-12-22 21:03:18,421] Trial 295 finished with value: -2817800386.781373 and  
parameters: {'alpha': 127.18585384780222}. Best is trial 269 with value: -2817800  
386.698841.  
[I 2024-12-22 21:03:18,450] Trial 296 finished with value: -2817809405.1664796 an  
d parameters: {'alpha': 145.73397968109853}. Best is trial 269 with value: -281780  
0386.698841.  
[I 2024-12-22 21:03:18,485] Trial 297 finished with value: -2817814421.559251 and  
parameters: {'alpha': 150.44537517453034}. Best is trial 269 with value: -2817800  
386.698841.  
[I 2024-12-22 21:03:18,489] Trial 301 finished with value: -2817814091.021769 and
```

```
parameters: {'alpha': 150.1629449271128}. Best is trial 269 with value: -28178003  
86.698841.  
[I 2024-12-22 21:03:18,491] Trial 299 finished with value: -2817811461.1851797 an  
d parameters: {'alpha': 147.7877038987359}. Best is trial 269 with value: -281780  
0386.698841.  
[I 2024-12-22 21:03:18,532] Trial 302 finished with value: -2817813696.2233653 an  
d parameters: {'alpha': 149.82129229907738}. Best is trial 269 with value: -281780  
0386.698841.  
[I 2024-12-22 21:03:18,536] Trial 300 finished with value: -2817813021.2467356 an  
d parameters: {'alpha': 149.2257160629398}. Best is trial 269 with value: -281780  
0386.698841.  
[I 2024-12-22 21:03:18,569] Trial 303 finished with value: -2817807980.675689 and  
parameters: {'alpha': 144.17494021063524}. Best is trial 269 with value: -281780  
386.698841.  
[I 2024-12-22 21:03:18,570] Trial 305 finished with value: -2817812420.2117567 an  
d parameters: {'alpha': 148.68239646438383}. Best is trial 269 with value: -281780  
0386.698841.  
[I 2024-12-22 21:03:18,577] Trial 304 finished with value: -2817808670.410738 and  
parameters: {'alpha': 144.94599431160032}. Best is trial 269 with value: -281780  
386.698841.  
[I 2024-12-22 21:03:18,612] Trial 306 finished with value: -2817813761.3806844 an  
d parameters: {'alpha': 149.87800994621085}. Best is trial 269 with value: -281780  
0386.698841.  
[I 2024-12-22 21:03:18,639] Trial 307 finished with value: -2817809283.3267145 an  
d parameters: {'alpha': 145.60551720841607}. Best is trial 269 with value: -281780  
0386.698841.  
[I 2024-12-22 21:03:18,649] Trial 309 finished with value: -2817812012.1491833 an  
d parameters: {'alpha': 148.30605808632006}. Best is trial 269 with value: -281780  
0386.698841.  
[I 2024-12-22 21:03:18,657] Trial 311 finished with value: -2818171667.8244977 an  
d parameters: {'alpha': 32.71179754633465}. Best is trial 269 with value: -281780  
0386.698841.  
[I 2024-12-22 21:03:18,680] Trial 308 finished with value: -2817807153.3048744 an  
d parameters: {'alpha': 143.203820899679}. Best is trial 269 with value: -281780  
386.698841.  
[I 2024-12-22 21:03:18,684] Trial 310 finished with value: -2817804976.214152 and  
parameters: {'alpha': 114.33057906669457}. Best is trial 269 with value: -281780  
386.698841.  
[I 2024-12-22 21:03:18,726] Trial 313 finished with value: -2817805012.433503 and  
parameters: {'alpha': 114.28102208052185}. Best is trial 269 with value: -281780  
386.698841.  
[I 2024-12-22 21:03:18,742] Trial 314 finished with value: -2817899476.9679456 an  
d parameters: {'alpha': 191.2033039249439}. Best is trial 269 with value: -281780  
0386.698841.  
[I 2024-12-22 21:03:18,749] Trial 312 finished with value: -2817804640.1237254 an  
d parameters: {'alpha': 114.80044150964662}. Best is trial 269 with value: -281780  
0386.698841.  
[I 2024-12-22 21:03:18,775] Trial 317 finished with value: -2817807394.870215 and  
parameters: {'alpha': 111.3766615686625}. Best is trial 269 with value: -28178003  
86.698841.  
[I 2024-12-22 21:03:18,780] Trial 316 finished with value: -2817805223.7313056 an  
d parameters: {'alpha': 113.99583854997131}. Best is trial 269 with value: -281780  
0386.698841.  
[I 2024-12-22 21:03:18,807] Trial 315 finished with value: -2817805211.6181364 an  
d parameters: {'alpha': 114.01201084059907}. Best is trial 269 with value: -281780  
0386.698841.  
[I 2024-12-22 21:03:18,814] Trial 318 finished with value: -2817804781.7129493 an  
d parameters: {'alpha': 114.60023647527413}. Best is trial 269 with value: -281780  
0386.698841.  
[I 2024-12-22 21:03:18,838] Trial 320 finished with value: -2817804717.4150734 an
```

```
d parameters: {'alpha': 114.6907328001846}. Best is trial 269 with value: -281780  
0386.698841.  
[I 2024-12-22 21:03:18,849] Trial 319 finished with value: -2817803379.2365785 an  
d parameters: {'alpha': 116.76151199905425}. Best is trial 269 with value: -28178  
0386.698841.  
[I 2024-12-22 21:03:18,857] Trial 321 finished with value: -2817804552.076796 and  
parameters: {'alpha': 114.92668028510748}. Best is trial 269 with value: -2817800  
386.698841.  
[I 2024-12-22 21:03:18,864] Trial 325 finished with value: -2817804738.2330813 an  
d parameters: {'alpha': 114.66135678645033}. Best is trial 269 with value: -28178  
0386.698841.  
[I 2024-12-22 21:03:18,874] Trial 322 finished with value: -2817805002.230717 and  
parameters: {'alpha': 114.29496161287076}. Best is trial 269 with value: -2817800  
386.698841.  
[I 2024-12-22 21:03:18,884] Trial 323 finished with value: -2818099781.503273 and  
parameters: {'alpha': 39.768518161424225}. Best is trial 269 with value: -2817800  
386.698841.  
[I 2024-12-22 21:03:18,893] Trial 324 finished with value: -2817804574.0820208 an  
d parameters: {'alpha': 114.89500165387548}. Best is trial 269 with value: -28178  
0386.698841.  
[I 2024-12-22 21:03:18,944] Trial 326 finished with value: -2817804422.036744 and  
parameters: {'alpha': 115.115676916106}. Best is trial 269 with value: -281780038  
6.698841.  
[I 2024-12-22 21:03:18,962] Trial 329 finished with value: -2817804483.235179 and  
parameters: {'alpha': 115.02634684859498}. Best is trial 269 with value: -2817800  
386.698841.  
[I 2024-12-22 21:03:18,968] Trial 327 finished with value: -2817805235.779505 and  
parameters: {'alpha': 113.97977380983795}. Best is trial 269 with value: -2817800  
386.698841.  
[I 2024-12-22 21:03:18,980] Trial 328 finished with value: -2817804900.00441 and  
parameters: {'alpha': 114.43551829491608}. Best is trial 269 with value: -2817800  
386.698841.  
[I 2024-12-22 21:03:19,068] Trial 330 finished with value: -2817806259.280055 and  
parameters: {'alpha': 112.68359139697608}. Best is trial 269 with value: -2817800  
386.698841.  
[I 2024-12-22 21:03:19,076] Trial 331 finished with value: -2817803628.2137513 an  
d parameters: {'alpha': 116.34465491566515}. Best is trial 269 with value: -28178  
0386.698841.  
[I 2024-12-22 21:03:19,080] Trial 333 finished with value: -2817803535.9058294 an  
d parameters: {'alpha': 116.49721638079465}. Best is trial 269 with value: -28178  
0386.698841.  
[I 2024-12-22 21:03:19,082] Trial 332 finished with value: -2817803157.47839 and  
parameters: {'alpha': 117.1480792642928}. Best is trial 269 with value: -2817800  
86.698841.  
[I 2024-12-22 21:03:19,096] Trial 335 finished with value: -2817800640.799947 and  
parameters: {'alpha': 124.08105330525119}. Best is trial 269 with value: -2817800  
386.698841.  
[I 2024-12-22 21:03:19,110] Trial 334 finished with value: -2817803306.8868575 an  
d parameters: {'alpha': 116.88596283943879}. Best is trial 269 with value: -28178  
0386.698841.  
[I 2024-12-22 21:03:19,127] Trial 336 finished with value: -2817818884.930985 and  
parameters: {'alpha': 101.88574828786125}. Best is trial 269 with value: -2817800  
386.698841.  
[I 2024-12-22 21:03:19,159] Trial 337 finished with value: -2817800842.8489695 an  
d parameters: {'alpha': 123.04990900198149}. Best is trial 269 with value: -28178  
0386.698841.  
[I 2024-12-22 21:03:19,164] Trial 338 finished with value: -2817800532.190466 and  
parameters: {'alpha': 124.82094046331144}. Best is trial 269 with value: -2817800  
386.698841.  
[I 2024-12-22 21:03:19,177] Trial 342 finished with value: -2817819742.436397 and
```

```
parameters: {'alpha': 101.32926862319131}. Best is trial 269 with value: -2817800  
386.698841.  
[I 2024-12-22 21:03:19,178] Trial 341 finished with value: -2817800627.0192633 an  
d parameters: {'alpha': 124.16459367234776}. Best is trial 269 with value: -28178  
00386.698841.  
[I 2024-12-22 21:03:19,181] Trial 339 finished with value: -2817800462.9724317 an  
d parameters: {'alpha': 125.45696057029714}. Best is trial 269 with value: -28178  
00386.698841.  
[I 2024-12-22 21:03:19,197] Trial 340 finished with value: -2817800611.893629 and  
parameters: {'alpha': 124.2591152257484}. Best is trial 269 with value: -28178003  
86.698841.  
[I 2024-12-22 21:03:19,203] Trial 343 finished with value: -2817823515.0780396 an  
d parameters: {'alpha': 99.0276237423196}. Best is trial 269 with value: -2817800  
386.698841.  
[I 2024-12-22 21:03:19,229] Trial 344 finished with value: -2818536160.501732 and  
parameters: {'alpha': 10.901912310854868}. Best is trial 269 with value: -2817800  
386.698841.  
[I 2024-12-22 21:03:19,274] Trial 347 finished with value: -2817800544.7248836 an  
d parameters: {'alpha': 124.72379444213448}. Best is trial 269 with value: -28178  
00386.698841.  
[I 2024-12-22 21:03:19,283] Trial 345 finished with value: -2817800387.7263083 an  
d parameters: {'alpha': 126.93576286763938}. Best is trial 269 with value: -28178  
00386.698841.  
[I 2024-12-22 21:03:19,290] Trial 346 finished with value: -2817818123.4961514 an  
d parameters: {'alpha': 102.39171508873532}. Best is trial 269 with value: -28178  
00386.698841.  
[I 2024-12-22 21:03:19,301] Trial 349 finished with value: -2817800621.5332284 an  
d parameters: {'alpha': 124.1985204733569}. Best is trial 269 with value: -281780  
0386.698841.  
[I 2024-12-22 21:03:19,351] Trial 348 finished with value: -2817800753.82521 and  
parameters: {'alpha': 123.46781389947536}. Best is trial 269 with value: -2817800  
386.698841.  
[I 2024-12-22 21:03:19,381] Trial 351 finished with value: -2817800684.5747304 an  
d parameters: {'alpha': 123.82983025288891}. Best is trial 269 with value: -28178  
00386.698841.  
[I 2024-12-22 21:03:19,395] Trial 352 finished with value: -2817800487.9063735 an  
d parameters: {'alpha': 125.2033309672514}. Best is trial 269 with value: -281780  
0386.698841.  
[I 2024-12-22 21:03:19,399] Trial 353 finished with value: -2817817392.774742 and  
parameters: {'alpha': 102.88843470424942}. Best is trial 269 with value: -2817800  
386.698841.  
[I 2024-12-22 21:03:19,408] Trial 350 finished with value: -2817800595.6008654 an  
d parameters: {'alpha': 124.36458086684432}. Best is trial 269 with value: -28178  
00386.698841.  
[I 2024-12-22 21:03:19,426] Trial 354 finished with value: -2817800523.2333646 an  
d parameters: {'alpha': 124.89296606406738}. Best is trial 269 with value: -28178  
00386.698841.  
[I 2024-12-22 21:03:19,430] Trial 355 finished with value: -2817800666.921792 and  
parameters: {'alpha': 123.92873999638006}. Best is trial 269 with value: -2817800  
386.698841.  
[I 2024-12-22 21:03:19,475] Trial 356 finished with value: -2817805440.255613 and  
parameters: {'alpha': 140.98942453219792}. Best is trial 269 with value: -2817800  
386.698841.  
[I 2024-12-22 21:03:19,529] Trial 357 finished with value: -2817800680.49569 and  
parameters: {'alpha': 130.43388421375766}. Best is trial 269 with value: -2817800  
386.698841.  
[I 2024-12-22 21:03:19,576] Trial 358 finished with value: -2818838355.1923003 an  
d parameters: {'alpha': 1.4443781106388371}. Best is trial 269 with value: -28178  
00386.698841.  
[I 2024-12-22 21:03:19,582] Trial 361 finished with value: -2817804417.788082 and
```

```
parameters: {'alpha': 139.48886351372548}. Best is trial 269 with value: -2817800  
386.698841.  
[I 2024-12-22 21:03:19,588] Trial 359 finished with value: -2818415856.387208 and  
parameters: {'alpha': 16.327724629682763}. Best is trial 269 with value: -2817800  
386.698841.  
[I 2024-12-22 21:03:19,597] Trial 360 finished with value: -2817800709.388295 and  
parameters: {'alpha': 130.59313902825843}. Best is trial 269 with value: -2817800  
386.698841.  
[I 2024-12-22 21:03:19,599] Trial 363 finished with value: -2817803708.2495947 an  
d parameters: {'alpha': 138.33494204155835}. Best is trial 269 with value: -2817800  
00386.698841.  
[I 2024-12-22 21:03:19,619] Trial 362 finished with value: -2817802908.704394 and  
parameters: {'alpha': 136.87851289447886}. Best is trial 269 with value: -2817800  
386.698841.  
[I 2024-12-22 21:03:19,637] Trial 366 finished with value: -2817801065.71175 and  
parameters: {'alpha': 132.16234915891735}. Best is trial 269 with value: -2817800  
386.698841.  
[I 2024-12-22 21:03:19,643] Trial 364 finished with value: -2817805878.7218885 an  
d parameters: {'alpha': 141.58709396885573}. Best is trial 269 with value: -2817800  
00386.698841.  
[I 2024-12-22 21:03:19,664] Trial 365 finished with value: -2817804723.170159 and  
parameters: {'alpha': 139.95470431124477}. Best is trial 269 with value: -2817800  
386.698841.  
[I 2024-12-22 21:03:19,700] Trial 368 finished with value: -2817805869.475955 and  
parameters: {'alpha': 141.57473542570415}. Best is trial 269 with value: -2817800  
386.698841.  
[I 2024-12-22 21:03:19,729] Trial 369 finished with value: -2817804328.1323767 an  
d parameters: {'alpha': 139.3488580740633}. Best is trial 269 with value: -2817800  
0386.698841.  
[I 2024-12-22 21:03:19,732] Trial 367 finished with value: -2818021980.1758504 an  
d parameters: {'alpha': 49.35284689663405}. Best is trial 269 with value: -2817800  
0386.698841.  
[I 2024-12-22 21:03:19,736] Trial 371 finished with value: -2817800856.643117 and  
parameters: {'alpha': 131.31260025494186}. Best is trial 269 with value: -2817800  
386.698841.  
[I 2024-12-22 21:03:19,748] Trial 370 finished with value: -2817803003.9454913 an  
d parameters: {'alpha': 137.06283904380683}. Best is trial 269 with value: -2817800  
0386.698841.  
[I 2024-12-22 21:03:19,766] Trial 372 finished with value: -2817803460.8533664 an  
d parameters: {'alpha': 137.90466513132318}. Best is trial 269 with value: -2817800  
0386.698841.  
[I 2024-12-22 21:03:19,803] Trial 375 finished with value: -2817803294.210937 and  
parameters: {'alpha': 137.6052242835546}. Best is trial 269 with value: -28178003  
86.698841.  
[I 2024-12-22 21:03:19,812] Trial 373 finished with value: -2817803844.392706 and  
parameters: {'alpha': 138.5650525400193}. Best is trial 269 with value: -28178003  
86.698841.  
[I 2024-12-22 21:03:19,824] Trial 376 finished with value: -2817803713.2739387 an  
d parameters: {'alpha': 138.34351521593874}. Best is trial 269 with value: -2817800  
0386.698841.  
[I 2024-12-22 21:03:19,846] Trial 374 finished with value: -2817805598.373509 and  
parameters: {'alpha': 141.20775501743694}. Best is trial 269 with value: -2817800  
386.698841.  
[I 2024-12-22 21:03:19,862] Trial 377 finished with value: -2817804069.4555674 an  
d parameters: {'alpha': 138.93596269382124}. Best is trial 269 with value: -2817800  
00386.698841.  
[I 2024-12-22 21:03:19,909] Trial 379 finished with value: -2817800956.114656 and  
parameters: {'alpha': 131.73618813586242}. Best is trial 269 with value: -2817800  
386.698841.  
[I 2024-12-22 21:03:19,923] Trial 381 finished with value: -2817804533.766831 and
```

```
parameters: {'alpha': 139.6677420551189}. Best is trial 269 with value: -28178003  
86.698841.  
[I 2024-12-22 21:03:19,931] Trial 380 finished with value: -2817800991.6223063 an  
d parameters: {'alpha': 131.87838031176517}. Best is trial 269 with value: -28178  
00386.698841.  
[I 2024-12-22 21:03:19,940] Trial 378 finished with value: -2817803229.8744226 an  
d parameters: {'alpha': 137.48737873205408}. Best is trial 269 with value: -28178  
00386.698841.  
[I 2024-12-22 21:03:19,962] Trial 382 finished with value: -2817800776.4562693 an  
d parameters: {'alpha': 130.93750111336757}. Best is trial 269 with value: -28178  
00386.698841.  
[I 2024-12-22 21:03:19,975] Trial 383 finished with value: -2817801075.85197 and  
parameters: {'alpha': 132.19999698333666}. Best is trial 269 with value: -2817800  
386.698841.  
[I 2024-12-22 21:03:19,985] Trial 385 finished with value: -2817800960.8287473 an  
d parameters: {'alpha': 131.75531368781066}. Best is trial 269 with value: -28178  
00386.698841.  
[I 2024-12-22 21:03:19,992] Trial 384 finished with value: -2817800968.408929 and  
parameters: {'alpha': 131.78590505011985}. Best is trial 269 with value: -2817800  
386.698841.  
[I 2024-12-22 21:03:19,999] Trial 386 finished with value: -2817800684.005095 and  
parameters: {'alpha': 130.45363043206999}. Best is trial 269 with value: -2817800  
386.698841.  
[I 2024-12-22 21:03:20,080] Trial 387 finished with value: -2817800828.6950393 an  
d parameters: {'alpha': 131.1857524637312}. Best is trial 269 with value: -281780  
0386.698841.  
[I 2024-12-22 21:03:20,091] Trial 391 finished with value: -2817800797.3086863 an  
d parameters: {'alpha': 131.03846330812297}. Best is trial 269 with value: -28178  
00386.698841.  
[I 2024-12-22 21:03:20,096] Trial 390 finished with value: -2817800911.8011937 an  
d parameters: {'alpha': 131.55242536479835}. Best is trial 269 with value: -28178  
00386.698841.  
[I 2024-12-22 21:03:20,125] Trial 389 finished with value: -2817800921.7625256 an  
d parameters: {'alpha': 131.59438303404903}. Best is trial 269 with value: -28178  
00386.698841.  
[I 2024-12-22 21:03:20,150] Trial 388 finished with value: -2817801014.1925473 an  
d parameters: {'alpha': 131.96662467441882}. Best is trial 269 with value: -28178  
00386.698841.  
[I 2024-12-22 21:03:20,170] Trial 392 finished with value: -2817800692.6236773 an  
d parameters: {'alpha': 130.5016389460995}. Best is trial 269 with value: -281780  
0386.698841.  
[I 2024-12-22 21:03:20,177] Trial 393 finished with value: -2817800508.10709 and  
parameters: {'alpha': 129.25112983626076}. Best is trial 269 with value: -2817800  
386.698841.  
[I 2024-12-22 21:03:20,188] Trial 394 finished with value: -2817800619.625909 and  
parameters: {'alpha': 130.07061264209182}. Best is trial 269 with value: -2817800  
386.698841.  
[I 2024-12-22 21:03:20,206] Trial 395 finished with value: -2817800721.3771334 an  
d parameters: {'alpha': 130.65713433709075}. Best is trial 269 with value: -28178  
00386.698841.  
[I 2024-12-22 21:03:20,210] Trial 396 finished with value: -2817889142.148091 and  
parameters: {'alpha': 74.51391753827505}. Best is trial 269 with value: -28178003  
86.698841.  
[I 2024-12-22 21:03:20,221] Trial 397 finished with value: -2817800589.183175 and  
parameters: {'alpha': 129.87112504848014}. Best is trial 269 with value: -2817800  
386.698841.  
[I 2024-12-22 21:03:20,262] Trial 398 finished with value: -2817800638.2247367 an  
d parameters: {'alpha': 130.18614693819546}. Best is trial 269 with value: -28178  
00386.698841.  
[I 2024-12-22 21:03:20,280] Trial 400 finished with value: -2817801685.5381527 an
```

```
d parameters: {'alpha': 120.26859173262687}. Best is trial 269 with value: -2817800386.698841.
[I 2024-12-22 21:03:20,293] Trial 399 finished with value: -2817800695.095834 and
parameters: {'alpha': 130.51528547370765}. Best is trial 269 with value: -2817800386.698841.
[I 2024-12-22 21:03:20,304] Trial 403 finished with value: -2817801529.0409174 an
d parameters: {'alpha': 120.6918286749325}. Best is trial 269 with value: -2817800386.698841.
[I 2024-12-22 21:03:20,331] Trial 404 finished with value: -2817801442.959946 and
parameters: {'alpha': 120.93726810864568}. Best is trial 269 with value: -2817800386.698841.
[I 2024-12-22 21:03:20,342] Trial 402 finished with value: -2817801975.0540338 an
d parameters: {'alpha': 119.54915494387761}. Best is trial 269 with value: -2817800386.698841.
[I 2024-12-22 21:03:20,352] Trial 401 finished with value: -2817800565.8665547 an
d parameters: {'alpha': 129.70801813618024}. Best is trial 269 with value: -2817800386.698841.
[I 2024-12-22 21:03:20,373] Trial 405 finished with value: -2817801809.239049 and
parameters: {'alpha': 119.95212466833156}. Best is trial 269 with value: -2817800386.698841.
[I 2024-12-22 21:03:20,377] Trial 407 finished with value: -2817801779.371468 and
parameters: {'alpha': 120.02720955096244}. Best is trial 269 with value: -2817800386.698841.
[I 2024-12-22 21:03:20,387] Trial 406 finished with value: -2817801876.021375 and
parameters: {'alpha': 119.78709158745694}. Best is trial 269 with value: -2817800386.698841.
[I 2024-12-22 21:03:20,416] Trial 408 finished with value: -2817801753.0105257 an
d parameters: {'alpha': 120.09416306070419}. Best is trial 269 with value: -2817800386.698841.
[I 2024-12-22 21:03:20,457] Trial 409 finished with value: -2817801477.627613 and
parameters: {'alpha': 120.83724232235664}. Best is trial 269 with value: -2817800386.698841.
[I 2024-12-22 21:03:20,483] Trial 413 finished with value: -2817801700.638528 and
parameters: {'alpha': 120.22916124515861}. Best is trial 269 with value: -2817800386.698841.
[I 2024-12-22 21:03:20,491] Trial 410 finished with value: -2817801635.02571 and
parameters: {'alpha': 120.40221504680498}. Best is trial 269 with value: -2817800386.698841.
[I 2024-12-22 21:03:20,499] Trial 414 finished with value: -2817801720.724803 and
parameters: {'alpha': 120.17706710876016}. Best is trial 269 with value: -2817800386.698841.
[I 2024-12-22 21:03:20,501] Trial 412 finished with value: -2817801483.5570726 an
d parameters: {'alpha': 120.8202967505741}. Best is trial 269 with value: -2817800386.698841.
[I 2024-12-22 21:03:20,514] Trial 411 finished with value: -2817801220.6241713 an
d parameters: {'alpha': 121.6228456312261}. Best is trial 269 with value: -2817800386.698841.
[I 2024-12-22 21:03:20,538] Trial 415 finished with value: -2817801509.832861 and
parameters: {'alpha': 120.74575838777092}. Best is trial 269 with value: -2817800386.698841.
[I 2024-12-22 21:03:20,560] Trial 416 finished with value: -2817801696.0083404 an
d parameters: {'alpha': 120.24122708323864}. Best is trial 269 with value: -2817800386.698841.
[I 2024-12-22 21:03:20,593] Trial 417 finished with value: -2817801741.014368 and
parameters: {'alpha': 120.12484945077973}. Best is trial 269 with value: -2817800386.698841.
[I 2024-12-22 21:03:20,603] Trial 418 finished with value: -2817801800.2069693 an
d parameters: {'alpha': 119.97474525410597}. Best is trial 269 with value: -2817800386.698841.
[I 2024-12-22 21:03:20,604] Trial 419 finished with value: -2817801201.550013 and
```

```
parameters: {'alpha': 121.68577164033056}. Best is trial 269 with value: -2817800  
386.698841.  
[I 2024-12-22 21:03:20,613] Trial 420 finished with value: -2817801846.964378 and  
parameters: {'alpha': 119.85842429574576}. Best is trial 269 with value: -2817800  
386.698841.  
[I 2024-12-22 21:03:20,632] Trial 421 finished with value: -2817801497.159873 and  
parameters: {'alpha': 120.78159683224246}. Best is trial 269 with value: -2817800  
386.698841.  
[I 2024-12-22 21:03:20,637] Trial 422 finished with value: -2817801497.8591933 an  
d parameters: {'alpha': 120.77961379722412}. Best is trial 269 with value: -2817800  
386.698841.  
[I 2024-12-22 21:03:20,691] Trial 423 finished with value: -2817801624.7548137 an  
d parameters: {'alpha': 120.42971974396174}. Best is trial 269 with value: -2817800  
386.698841.  
[I 2024-12-22 21:03:20,715] Trial 424 finished with value: -2817800728.546674 and  
parameters: {'alpha': 123.59560661691586}. Best is trial 269 with value: -2817800  
386.698841.  
[I 2024-12-22 21:03:20,729] Trial 426 finished with value: -2817809941.2097254 an  
d parameters: {'alpha': 108.80199456029669}. Best is trial 269 with value: -2817800  
386.698841.  
[I 2024-12-22 21:03:20,749] Trial 425 finished with value: -2817809524.5105104 an  
d parameters: {'alpha': 109.19614690429222}. Best is trial 269 with value: -2817800  
386.698841.  
[I 2024-12-22 21:03:20,772] Trial 427 finished with value: -2817812217.2544622 an  
d parameters: {'alpha': 106.79394152539992}. Best is trial 269 with value: -2817800  
386.698841.  
[I 2024-12-22 21:03:20,782] Trial 428 finished with value: -2817811012.3630714 an  
d parameters: {'alpha': 107.82863176569433}. Best is trial 269 with value: -2817800  
386.698841.  
[I 2024-12-22 21:03:20,809] Trial 430 finished with value: -2817813909.1262407 an  
d parameters: {'alpha': 105.43149523397486}. Best is trial 269 with value: -2817800  
386.698841.  
[I 2024-12-22 21:03:20,820] Trial 429 finished with value: -2817812646.235112 and  
parameters: {'alpha': 106.43916172034679}. Best is trial 269 with value: -2817800  
386.698841.  
[I 2024-12-22 21:03:20,835] Trial 431 finished with value: -2817812455.935143 and  
parameters: {'alpha': 106.59571730853028}. Best is trial 269 with value: -2817800  
386.698841.  
[I 2024-12-22 21:03:20,837] Trial 432 finished with value: -2817810399.469694 and  
parameters: {'alpha': 108.37886035913573}. Best is trial 269 with value: -2817800  
386.698841.  
[I 2024-12-22 21:03:20,878] Trial 433 finished with value: -2818191590.9018793 an  
d parameters: {'alpha': 259.7130463441758}. Best is trial 269 with value: -2817800  
386.698841.  
[I 2024-12-22 21:03:20,901] Trial 435 finished with value: -2817809555.078553 and  
parameters: {'alpha': 109.16691500847651}. Best is trial 269 with value: -2817800  
386.698841.  
[I 2024-12-22 21:03:20,907] Trial 434 finished with value: -2818238542.5112634 an  
d parameters: {'alpha': 268.01170133185286}. Best is trial 269 with value: -2817800  
386.698841.  
[I 2024-12-22 21:03:20,919] Trial 437 finished with value: -2817809201.496432 and  
parameters: {'alpha': 109.50824351505057}. Best is trial 269 with value: -2817800  
386.698841.  
[I 2024-12-22 21:03:20,925] Trial 436 finished with value: -2817813612.311514 and  
parameters: {'alpha': 105.66365344766798}. Best is trial 269 with value: -2817800  
386.698841.  
[I 2024-12-22 21:03:20,938] Trial 441 finished with value: -2817811265.1356063 an  
d parameters: {'alpha': 107.60660554437283}. Best is trial 269 with value: -2817800  
386.698841.  
[I 2024-12-22 21:03:20,945] Trial 438 finished with value: -2817800386.9505935 an
```

```
d parameters: {'alpha': 127.03392658086237}. Best is trial 269 with value: -2817800386.698841.
[I 2024-12-22 21:03:20,976] Trial 439 finished with value: -2817809782.2412558 and parameters: {'alpha': 108.95127161791214}. Best is trial 269 with value: -2817800386.698841.
[I 2024-12-22 21:03:20,987] Trial 444 finished with value: -2817812958.885046 and parameters: {'alpha': 106.18473303958663}. Best is trial 269 with value: -2817800386.698841.
[I 2024-12-22 21:03:20,987] Trial 440 finished with value: -2817800395.545952 and parameters: {'alpha': 126.55970217003}. Best is trial 269 with value: -2817800386.698841.
[I 2024-12-22 21:03:21,000] Trial 445 finished with value: -2817800386.8765225 and parameters: {'alpha': 127.04929553436966}. Best is trial 269 with value: -2817800386.698841.
[I 2024-12-22 21:03:21,003] Trial 442 finished with value: -2817800393.145919 and parameters: {'alpha': 126.64316755962481}. Best is trial 269 with value: -2817800386.698841.
[I 2024-12-22 21:03:21,038] Trial 443 finished with value: -2817809118.6447134 and parameters: {'alpha': 109.58926078321765}. Best is trial 269 with value: -2817800386.698841.
[I 2024-12-22 21:03:21,057] Trial 446 finished with value: -2817800412.885421 and parameters: {'alpha': 126.14905196419046}. Best is trial 269 with value: -2817800386.698841.
[I 2024-12-22 21:03:21,083] Trial 448 finished with value: -2817800422.894956 and parameters: {'alpha': 125.97688157006347}. Best is trial 269 with value: -2817800386.698841.
[I 2024-12-22 21:03:21,091] Trial 450 finished with value: -2817800389.244569 and parameters: {'alpha': 126.82413884573391}. Best is trial 269 with value: -2817800386.698841.
[I 2024-12-22 21:03:21,092] Trial 447 finished with value: -2817800390.4012933 and parameters: {'alpha': 126.76110092242232}. Best is trial 269 with value: -2817800386.698841.
[I 2024-12-22 21:03:21,113] Trial 449 finished with value: -2817800420.427035 and parameters: {'alpha': 126.01684680311341}. Best is trial 269 with value: -2817800386.698841.
[I 2024-12-22 21:03:21,159] Trial 451 finished with value: -2817800445.6214294 and parameters: {'alpha': 125.65920911394012}. Best is trial 269 with value: -2817800386.698841.
[I 2024-12-22 21:03:21,204] Trial 452 finished with value: -2817800394.2835493 and parameters: {'alpha': 126.60195539676455}. Best is trial 269 with value: -2817800386.698841.
[I 2024-12-22 21:03:21,207] Trial 453 finished with value: -2817800412.8893714 and parameters: {'alpha': 126.14897803445902}. Best is trial 269 with value: -2817800386.698841.
[I 2024-12-22 21:03:21,215] Trial 454 finished with value: -2817800393.5980577 and parameters: {'alpha': 126.62638386618605}. Best is trial 269 with value: -2817800386.698841.
[I 2024-12-22 21:03:21,233] Trial 455 finished with value: -2817800398.1096163 and parameters: {'alpha': 127.77947703328529}. Best is trial 269 with value: -2817800386.698841.
[I 2024-12-22 21:03:21,298] Trial 456 finished with value: -2817800416.3888445 and parameters: {'alpha': 126.0855463033828}. Best is trial 269 with value: -2817800386.698841.
[I 2024-12-22 21:03:21,299] Trial 457 finished with value: -2817800396.796384 and parameters: {'alpha': 126.52073502994065}. Best is trial 269 with value: -2817800386.698841.
[I 2024-12-22 21:03:21,344] Trial 458 finished with value: -2817800396.7615995 and parameters: {'alpha': 126.52178520200012}. Best is trial 269 with value: -2817800386.698841.
[I 2024-12-22 21:03:21,350] Trial 459 finished with value: -2817802047.207055 and
```

```
parameters: {'alpha': 135.02435405752306}. Best is trial 269 with value: -2817800  
386.698841.  
[I 2024-12-22 21:03:21,405] Trial 461 finished with value: -2817802428.0882354 an  
d parameters: {'alpha': 135.89126883485503}. Best is trial 269 with value: -28178  
00386.698841.  
[I 2024-12-22 21:03:21,406] Trial 460 finished with value: -2817802198.398934 and  
parameters: {'alpha': 135.37909905828278}. Best is trial 269 with value: -2817800  
386.698841.  
[I 2024-12-22 21:03:21,422] Trial 462 finished with value: -2817802698.106591 and  
parameters: {'alpha': 136.4584135808494}. Best is trial 269 with value: -28178003  
86.698841.  
[I 2024-12-22 21:03:21,426] Trial 463 finished with value: -2817802678.689915 and  
parameters: {'alpha': 136.4187537223449}. Best is trial 269 with value: -28178003  
86.698841.  
[I 2024-12-22 21:03:21,435] Trial 465 finished with value: -2817802719.5259695 an  
d parameters: {'alpha': 136.5019751115519}. Best is trial 269 with value: -281780  
0386.698841.  
[I 2024-12-22 21:03:21,455] Trial 467 finished with value: -2817802625.176173 and  
parameters: {'alpha': 136.3085875685963}. Best is trial 269 with value: -28178003  
86.698841.  
[I 2024-12-22 21:03:21,465] Trial 470 finished with value: -2817802029.720893 and  
parameters: {'alpha': 134.9823189444377}. Best is trial 269 with value: -28178003  
86.698841.  
[I 2024-12-22 21:03:21,495] Trial 464 finished with value: -2817802600.114909 and  
parameters: {'alpha': 136.25655134715643}. Best is trial 269 with value: -2817800  
386.698841.  
[I 2024-12-22 21:03:21,509] Trial 469 finished with value: -2818417984.756481 and  
parameters: {'alpha': 296.55696940679314}. Best is trial 269 with value: -2817800  
386.698841.  
[I 2024-12-22 21:03:21,513] Trial 466 finished with value: -2817802332.5236816 an  
d parameters: {'alpha': 135.68180164502272}. Best is trial 269 with value: -28178  
00386.698841.  
[I 2024-12-22 21:03:21,553] Trial 468 finished with value: -2817803022.7194877 an  
d parameters: {'alpha': 137.09878378575718}. Best is trial 269 with value: -28178  
00386.698841.  
[I 2024-12-22 21:03:21,560] Trial 471 finished with value: -2817802490.4139915 an  
d parameters: {'alpha': 136.0252955031712}. Best is trial 269 with value: -281780  
0386.698841.  
[I 2024-12-22 21:03:21,593] Trial 472 finished with value: -2817803043.0628386 an  
d parameters: {'alpha': 137.13759201110423}. Best is trial 269 with value: -28178  
00386.698841.  
[I 2024-12-22 21:03:21,617] Trial 475 finished with value: -2818425685.6894317 an  
d parameters: {'alpha': 297.692284177768}. Best is trial 269 with value: -2817800  
386.698841.  
[I 2024-12-22 21:03:21,627] Trial 474 finished with value: -2817802329.576465 and  
parameters: {'alpha': 135.67526230587598}. Best is trial 269 with value: -2817800  
386.698841.  
[I 2024-12-22 21:03:21,640] Trial 473 finished with value: -2817802163.591356 and  
parameters: {'alpha': 135.29875930758914}. Best is trial 269 with value: -2817800  
386.698841.  
[I 2024-12-22 21:03:21,652] Trial 477 finished with value: -2817802886.268573 and  
parameters: {'alpha': 136.8345977394102}. Best is trial 269 with value: -28178003  
86.698841.  
[I 2024-12-22 21:03:21,672] Trial 476 finished with value: -2817803171.7311163 an  
d parameters: {'alpha': 137.37974988945462}. Best is trial 269 with value: -28178  
00386.698841.  
[I 2024-12-22 21:03:21,691] Trial 480 finished with value: -2817808033.7117286 an  
d parameters: {'alpha': 144.23540021753578}. Best is trial 269 with value: -28178  
00386.698841.  
[I 2024-12-22 21:03:21,732] Trial 478 finished with value: -2817802492.0857806 an
```

```
d parameters: {'alpha': 136.0288635332255}. Best is trial 269 with value: -281780  
0386.698841.  
[I 2024-12-22 21:03:21,750] Trial 481 finished with value: -2817807306.016098 and  
parameters: {'alpha': 143.3872182682841}. Best is trial 269 with value: -28178003  
86.698841.  
[I 2024-12-22 21:03:21,756] Trial 482 finished with value: -2817807992.1999555 an  
d parameters: {'alpha': 144.18809496037096}. Best is trial 269 with value: -28178  
00386.698841.  
[I 2024-12-22 21:03:21,765] Trial 479 finished with value: -2817802752.0516768 an  
d parameters: {'alpha': 136.5677509024637}. Best is trial 269 with value: -281780  
0386.698841.  
[I 2024-12-22 21:03:21,769] Trial 483 finished with value: -2817801673.200513 and  
parameters: {'alpha': 134.071442948153}. Best is trial 269 with value: -281780038  
6.698841.  
[I 2024-12-22 21:03:21,790] Trial 484 finished with value: -2817807595.3338823 an  
d parameters: {'alpha': 143.7293775819771}. Best is trial 269 with value: -281780  
0386.698841.  
[I 2024-12-22 21:03:21,795] Trial 485 finished with value: -2817807402.544638 and  
parameters: {'alpha': 143.50213371368218}. Best is trial 269 with value: -2817800  
386.698841.  
[I 2024-12-22 21:03:21,815] Trial 489 finished with value: -2817806815.5673943 an  
d parameters: {'alpha': 142.7909570315073}. Best is trial 269 with value: -281780  
0386.698841.  
[I 2024-12-22 21:03:21,817] Trial 486 finished with value: -2817807516.7551074 an  
d parameters: {'alpha': 143.63711501856383}. Best is trial 269 with value: -28178  
00386.698841.  
[I 2024-12-22 21:03:21,822] Trial 487 finished with value: -2817806525.280869 and  
parameters: {'alpha': 142.42761731709749}. Best is trial 269 with value: -2817800  
386.698841.  
[I 2024-12-22 21:03:21,824] Trial 490 finished with value: -2817806979.914076 and  
parameters: {'alpha': 142.9931407517469}. Best is trial 269 with value: -28178003  
86.698841.  
[I 2024-12-22 21:03:21,829] Trial 492 finished with value: -2817808882.110395 and  
parameters: {'alpha': 145.1763749556411}. Best is trial 269 with value: -28178003  
86.698841.  
[I 2024-12-22 21:03:21,833] Trial 491 finished with value: -2817809127.17348 and  
parameters: {'alpha': 145.4396283826434}. Best is trial 269 with value: -28178003  
86.698841.  
[I 2024-12-22 21:03:21,849] Trial 488 finished with value: -2817889630.250127 and  
parameters: {'alpha': 187.786444811556705}. Best is trial 269 with value: -2817800  
386.698841.  
[I 2024-12-22 21:03:21,860] Trial 493 finished with value: -2817805791.221604 and  
parameters: {'alpha': 141.46972891086682}. Best is trial 269 with value: -2817800  
386.698841.  
[I 2024-12-22 21:03:21,864] Trial 495 finished with value: -2817807532.8897495 an  
d parameters: {'alpha': 143.65609935893957}. Best is trial 269 with value: -28178  
00386.698841.  
[I 2024-12-22 21:03:21,865] Trial 494 finished with value: -2817807197.5118113 an  
d parameters: {'alpha': 143.25711520949037}. Best is trial 269 with value: -28178  
00386.698841.  
[I 2024-12-22 21:03:21,869] Trial 497 finished with value: -2817806067.74986 and  
parameters: {'alpha': 141.83757872227994}. Best is trial 269 with value: -2817800  
386.698841.  
[I 2024-12-22 21:03:21,873] Trial 496 finished with value: -2817806265.668998 and  
parameters: {'alpha': 142.0955463114787}. Best is trial 269 with value: -28178003  
86.698841.  
[I 2024-12-22 21:03:21,875] Trial 498 finished with value: -2817806986.180377 and  
parameters: {'alpha': 143.00080110465984}. Best is trial 269 with value: -2817800  
386.698841.  
[I 2024-12-22 21:03:21,880] Trial 499 finished with value: -2817805480.3445315 an
```

```
d parameters: {'alpha': 113.65804322788497}. Best is trial 269 with value: -28178  
00386.698841.  
Best Hyperparameters: {'alpha': 127.13600873051143}
```

MODEL EVALUATION

```
In [43]: best_params = study.best_params  
best_model = Ridge(**best_params, random_state=42)  
best_model.fit(X_train_scaled, y_train)  
  
y_pred = best_model.predict(X_test_scaled)  
  
mse = mean_squared_error(y_test, y_pred)  
mape = mean_absolute_percentage_error(y_test, y_pred)  
rmse = np.sqrt(mse)  
r2 = r2_score(y_test, y_pred)  
  
print(f"Mean Squared Error (MSE): {mse}")  
print(f"Mean Absolute Percentage Error (MAPE): {mape}")  
print(f"Root Mean Squared Error (RMSE): {rmse}")  
print(f"R-squared (R²): {r2}")
```

```
Mean Squared Error (MSE): 2791119060.614967  
Mean Absolute Percentage Error (MAPE): 7.950442374486675e+19  
Root Mean Squared Error (RMSE): 52831.042584970506  
R-squared (R²): 0.2766742901336461
```

MSE and RMSE values are really high, this means that the model's predictions are far from the actual values. MAPE (7.95) has a low value considering the previous ones and R² is low (0.27), this means that the independent 'balance' variable doesn't explain properly the variation in the dependent ones. So overall, the model is not performing good, this could be due to outliers in the 'balance' variable, but using the 'exited' variable as a target variable doesn't make sense for regression in our work.

Generalized linear regression

Generalized Linear Models using the 'TweedieRegressor' library, is a variant of the linear regression that allows a distributions of the target variable. Again, we will use Optuna to optimize the hyperparameters of the model, in this case, 100 tries will be enough to get appropriate hyperparameters:

- power: Determines the variance structure of the target variable. We have set a range between 1 and 2.
- alpha: As with the linear regression, we will measure the penalty applied to the model to reduce overfitting. We have set a range of 0.00001 to 10.

Again, we don't expect the model to perform well because of the target variable issue, but at least better than the default linear regression model.

```
In [30]: X = dfFeature.drop(['Balance'], axis=1)  
y = dfFeature['Balance']  
  
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_
```

```
scaler = StandardScaler()
X_train_scaled = scaler.fit_transform(X_train)
X_test_scaled = scaler.transform(X_test)

def objective(trial):
    power = trial.suggest_float('power', 1.0, 2.0)
    alpha = trial.suggest_float('alpha', 1e-5, 10)

    model = TweedieRegressor(power=power, alpha=alpha, link='log', max_iter=1000)

    score = cross_val_score(model, X_train_scaled, y_train, cv=5, scoring='neg_mse')
    return score.mean()

study = optuna.create_study(direction='maximize')
study.optimize(objective, n_trials=100, n_jobs=-1)

print(f"Best Hyperparameters: {study.best_params}")
```

```
[I 2024-12-23 09:57:31,507] A new study created in memory with name: no-name-7583  
4f5c-715b-4627-88e3-04e32d45c2a0  
[I 2024-12-23 09:57:32,291] Trial 9 finished with value: -3030705092.0293593 and  
parameters: {'power': 1.8172887224112206, 'alpha': 5.454468865900589}. Best is tri  
al 9 with value: -3030705092.0293593.  
[I 2024-12-23 09:57:32,503] Trial 7 finished with value: -3038231312.674311 and p  
arameters: {'power': 1.7827196307050754, 'alpha': 8.769636967124773}. Best is tri  
al 9 with value: -3030705092.0293593.  
[I 2024-12-23 09:57:32,594] Trial 5 finished with value: -3051281988.3691854 and  
parameters: {'power': 1.789249119607181, 'alpha': 9.096877648993274}. Best is tri  
al 9 with value: -3030705092.0293593.  
[I 2024-12-23 09:57:32,617] Trial 14 finished with value: -3017488797.9166923 and  
parameters: {'power': 1.8349029252776041, 'alpha': 3.037267248954948}. Best is tri  
al 14 with value: -3017488797.9166923.  
[I 2024-12-23 09:57:32,673] Trial 4 finished with value: -3023494225.3002214 and  
parameters: {'power': 1.839684082125748, 'alpha': 2.3712399091216465}. Best is tri  
al 14 with value: -3017488797.9166923.  
[I 2024-12-23 09:57:32,681] Trial 2 finished with value: -3253965683.3146906 and  
parameters: {'power': 1.904615426633168, 'alpha': 6.247897349658438}. Best is tri  
al 14 with value: -3017488797.9166923.  
[I 2024-12-23 09:57:32,728] Trial 16 finished with value: -3122547520.5785213 and  
parameters: {'power': 1.8490750066193016, 'alpha': 6.965395014156867}. Best is tri  
al 14 with value: -3017488797.9166923.  
[I 2024-12-23 09:57:32,794] Trial 3 finished with value: -3549126266.043401 and p  
arameters: {'power': 1.9800068378292335, 'alpha': 7.653508696469803}. Best is tri  
al 14 with value: -3017488797.9166923.  
[I 2024-12-23 09:57:32,899] Trial 13 finished with value: -3101763921.4050646 and  
parameters: {'power': 1.6598388426464692, 'alpha': 4.875784368954788}. Best is tri  
al 14 with value: -3017488797.9166923.  
[I 2024-12-23 09:57:32,978] Trial 12 finished with value: -3143679483.069135 and  
parameters: {'power': 1.6194073555330326, 'alpha': 3.231100986161331}. Best is tri  
al 14 with value: -3017488797.9166923.  
[I 2024-12-23 09:57:33,096] Trial 20 finished with value: -3200455800.3277698 and  
parameters: {'power': 1.8907353012822052, 'alpha': 6.0107511422209905}. Best is t  
rial 14 with value: -3017488797.9166923.  
[I 2024-12-23 09:57:33,101] Trial 11 finished with value: -3137837098.9975433 and  
parameters: {'power': 1.5547796932364104, 'alpha': 4.126739789811453}. Best is tri  
al 14 with value: -3017488797.9166923.  
[I 2024-12-23 09:57:33,183] Trial 15 finished with value: -3103546743.7677617 and  
parameters: {'power': 1.6420222532666742, 'alpha': 5.457500102671575}. Best is tri  
al 14 with value: -3017488797.9166923.  
[I 2024-12-23 09:57:33,211] Trial 8 finished with value: -3110504326.276181 and p  
arameters: {'power': 1.4077339588404603, 'alpha': 5.051812970099609}. Best is tri  
al 14 with value: -3017488797.9166923.  
[I 2024-12-23 09:57:33,216] Trial 6 finished with value: -3108826357.0257816 and  
parameters: {'power': 1.424432819490909, 'alpha': 9.009032770391208}. Best is tri  
al 14 with value: -3017488797.9166923.  
[I 2024-12-23 09:57:33,274] Trial 0 finished with value: -3172106672.3556757 and  
parameters: {'power': 1.6441282104926163, 'alpha': 1.5378913116918527}. Best is t  
rial 14 with value: -3017488797.9166923.  
[I 2024-12-23 09:57:33,341] Trial 10 finished with value: -3119750317.9521036 and  
parameters: {'power': 1.4345149156336974, 'alpha': 3.0041970211267235}. Best is t  
rial 14 with value: -3017488797.9166923.  
[I 2024-12-23 09:57:33,372] Trial 17 finished with value: -3097599662.9833655 and  
parameters: {'power': 1.35962750204637, 'alpha': 7.914130649476463}. Best is tri  
al 14 with value: -3017488797.9166923.  
[I 2024-12-23 09:57:33,393] Trial 19 finished with value: -3063415674.4483986 and  
parameters: {'power': 1.1901188070043678, 'alpha': 0.9973934764057821}. Best is t  
rial 14 with value: -3017488797.9166923.  
[I 2024-12-23 09:57:33,467] Trial 18 finished with value: -3065079541.4371634 and
```

```
parameters: {'power': 1.1985230463157852, 'alpha': 0.7209947282809022}. Best is trial 14 with value: -3017488797.9166923.
[I 2024-12-23 09:57:33,689] Trial 1 finished with value: -3047824416.542951 and parameters: {'power': 1.1036875405873907, 'alpha': 8.549638872289066}. Best is trial 14 with value: -3017488797.9166923.
[I 2024-12-23 09:57:33,983] Trial 27 finished with value: -3030727279.524846 and parameters: {'power': 1.8512790958351424, 'alpha': 3.689279014001203}. Best is trial 14 with value: -3017488797.9166923.
[I 2024-12-23 09:57:34,010] Trial 23 finished with value: -3123421884.782698 and parameters: {'power': 1.5006768117925462, 'alpha': 6.492752086931994}. Best is trial 14 with value: -3017488797.9166923.
[I 2024-12-23 09:57:34,015] Trial 25 finished with value: -3033517046.919484 and parameters: {'power': 1.753355973489701, 'alpha': 4.589935181986517}. Best is trial 14 with value: -3017488797.9166923.
[I 2024-12-23 09:57:34,064] Trial 21 finished with value: -3050461854.7164116 and parameters: {'power': 1.1189285544272733, 'alpha': 3.940867594091547}. Best is trial 14 with value: -3017488797.9166923.
[I 2024-12-23 09:57:34,095] Trial 26 finished with value: -3028190202.5905366 and parameters: {'power': 1.756519728163486, 'alpha': 4.7983981988131585}. Best is trial 14 with value: -3017488797.9166923.
[I 2024-12-23 09:57:34,216] Trial 37 finished with value: -3175901830.090158 and parameters: {'power': 1.9876319786923626, 'alpha': 0.17594101159904163}. Best is trial 14 with value: -3017488797.9166923.
[I 2024-12-23 09:57:34,237] Trial 22 finished with value: -3108441792.7744584 and parameters: {'power': 1.3986912730881378, 'alpha': 5.051215910192683}. Best is trial 14 with value: -3017488797.9166923.
[I 2024-12-23 09:57:34,252] Trial 38 finished with value: -3346045935.4393497 and parameters: {'power': 1.9993833042036133, 'alpha': 0.05364567581476454}. Best is trial 14 with value: -3017488797.9166923.
[I 2024-12-23 09:57:34,351] Trial 24 finished with value: -3076910914.756849 and parameters: {'power': 1.2585554536363173, 'alpha': 4.4017537407788225}. Best is trial 14 with value: -3017488797.9166923.
[I 2024-12-23 09:57:34,605] Trial 28 finished with value: -3035899623.7160406 and parameters: {'power': 1.0236894799023277, 'alpha': 5.317450466338877}. Best is trial 14 with value: -3017488797.9166923.
[I 2024-12-23 09:57:34,706] Trial 30 finished with value: -3079045957.872026 and parameters: {'power': 1.2650336345778763, 'alpha': 0.7752977597200912}. Best is trial 14 with value: -3017488797.9166923.
[I 2024-12-23 09:57:34,723] Trial 29 finished with value: -3077237476.8966246 and parameters: {'power': 1.25660318605766, 'alpha': 0.44412113422372457}. Best is trial 14 with value: -3017488797.9166923.
[I 2024-12-23 09:57:34,823] Trial 33 finished with value: -3063128242.975765 and parameters: {'power': 1.1884658502351995, 'alpha': 0.6077456952055136}. Best is trial 14 with value: -3017488797.9166923.
[I 2024-12-23 09:57:34,848] Trial 31 finished with value: -3088207413.2983007 and parameters: {'power': 1.3038699116685553, 'alpha': 0.37562434241017595}. Best is trial 14 with value: -3017488797.9166923.
[I 2024-12-23 09:57:34,872] Trial 40 finished with value: -3242805897.4339848 and parameters: {'power': 1.9951069785310238, 'alpha': 2.168908588505044}. Best is trial 14 with value: -3017488797.9166923.
[I 2024-12-23 09:57:34,920] Trial 42 finished with value: -3195152130.356248 and parameters: {'power': 1.9877509981723493, 'alpha': 1.977371336963139}. Best is trial 14 with value: -3017488797.9166923.
[I 2024-12-23 09:57:34,970] Trial 44 finished with value: -3253100741.225932 and parameters: {'power': 1.9833661683994581, 'alpha': 2.5674926922411}. Best is trial 14 with value: -3017488797.9166923.
[I 2024-12-23 09:57:34,990] Trial 34 finished with value: -3060243984.769715 and parameters: {'power': 1.17331787610469, 'alpha': 0.631564981101898}. Best is trial 14 with value: -3017488797.9166923.
[I 2024-12-23 09:57:35,037] Trial 36 finished with value: -3050230979.688018 and
```

```
parameters: {'power': 1.1167960901283136, 'alpha': 0.16722949100464435}. Best is trial 14 with value: -3017488797.9166923.  
[I 2024-12-23 09:57:35,164] Trial 39 finished with value: -3040666628.181873 and parameters: {'power': 1.0565821228696888, 'alpha': 2.2270333771930106}. Best is trial 14 with value: -3017488797.9166923.  
[I 2024-12-23 09:57:35,263] Trial 32 finished with value: -3039591725.891664 and parameters: {'power': 1.0491365779804187, 'alpha': 0.5606806935168915}. Best is trial 14 with value: -3017488797.9166923.  
[I 2024-12-23 09:57:35,380] Trial 43 finished with value: -3198354701.1950836 and parameters: {'power': 1.9847865750519496, 'alpha': 2.0694693460812426}. Best is trial 14 with value: -3017488797.9166923.  
[I 2024-12-23 09:57:35,406] Trial 45 finished with value: -3168610168.282951 and parameters: {'power': 1.989440213290167, 'alpha': 1.7488952904464923}. Best is trial 14 with value: -3017488797.9166923.  
[I 2024-12-23 09:57:35,467] Trial 35 finished with value: -3065725249.480745 and parameters: {'power': 1.2018155904304466, 'alpha': 0.7682455139688726}. Best is trial 14 with value: -3017488797.9166923.  
[I 2024-12-23 09:57:35,557] Trial 41 finished with value: -3121745751.731681 and parameters: {'power': 1.7431273795809252, 'alpha': 2.032275582601112}. Best is trial 14 with value: -3017488797.9166923.  
[I 2024-12-23 09:57:35,570] Trial 46 finished with value: -3137410764.0763083 and parameters: {'power': 1.721659737417256, 'alpha': 2.0152060256395696}. Best is trial 14 with value: -3017488797.9166923.  
[I 2024-12-23 09:57:35,597] Trial 48 finished with value: -3126777962.739979 and parameters: {'power': 1.7158955837704546, 'alpha': 2.3736367207784426}. Best is trial 14 with value: -3017488797.9166923.  
[I 2024-12-23 09:57:35,703] Trial 47 finished with value: -3160616168.210199 and parameters: {'power': 1.6720543902138505, 'alpha': 1.9151664554312413}. Best is trial 14 with value: -3017488797.9166923.  
[I 2024-12-23 09:57:35,742] Trial 49 finished with value: -3128265743.8846054 and parameters: {'power': 1.7198138343795857, 'alpha': 2.2673096217287845}. Best is trial 14 with value: -3017488797.9166923.  
[I 2024-12-23 09:57:35,981] Trial 50 finished with value: -3138177172.713576 and parameters: {'power': 1.7203172551051498, 'alpha': 2.016143592201635}. Best is trial 14 with value: -3017488797.9166923.  
[I 2024-12-23 09:57:36,083] Trial 51 finished with value: -3137107349.92549 and parameters: {'power': 1.7045844601952358, 'alpha': 2.2758852122420477}. Best is trial 14 with value: -3017488797.9166923.  
[I 2024-12-23 09:57:36,084] Trial 52 finished with value: -3141467382.2496395 and parameters: {'power': 1.7024516032774961, 'alpha': 2.1839962441898346}. Best is trial 14 with value: -3017488797.9166923.  
[I 2024-12-23 09:57:36,105] Trial 53 finished with value: -3124571224.4149575 and parameters: {'power': 1.7414689029178438, 'alpha': 2.000342122658595}. Best is trial 14 with value: -3017488797.9166923.  
[I 2024-12-23 09:57:36,110] Trial 60 finished with value: -3019939859.541687 and parameters: {'power': 1.8351792134027392, 'alpha': 3.6797712552130317}. Best is trial 14 with value: -3017488797.9166923.  
[I 2024-12-23 09:57:36,153] Trial 56 finished with value: -3121843251.8831015 and parameters: {'power': 1.7142746209956208, 'alpha': 2.5395429561277956}. Best is trial 14 with value: -3017488797.9166923.  
[I 2024-12-23 09:57:36,234] Trial 59 finished with value: -3087150819.2084155 and parameters: {'power': 1.7232616438776582, 'alpha': 3.39583991237575}. Best is trial 14 with value: -3017488797.9166923.  
[I 2024-12-23 09:57:36,241] Trial 57 finished with value: -3092606154.3347044 and parameters: {'power': 1.7179661370683026, 'alpha': 3.3618245880621567}. Best is trial 14 with value: -3017488797.9166923.  
[I 2024-12-23 09:57:36,248] Trial 54 finished with value: -3141333520.893745 and parameters: {'power': 1.7016413825123338, 'alpha': 2.1992962060159336}. Best is trial 14 with value: -3017488797.9166923.  
[I 2024-12-23 09:57:36,416] Trial 58 finished with value: -3171226035.3570147 and
```

```
parameters: {'power': 1.7011211868827827, 'alpha': 1.4194789414983622}. Best is trial 14 with value: -3017488797.9166923.
[I 2024-12-23 09:57:36,544] Trial 66 finished with value: -3034811692.3986626 and parameters: {'power': 1.8580996504144622, 'alpha': 3.5819840407263572}. Best is trial 14 with value: -3017488797.9166923.
[I 2024-12-23 09:57:36,635] Trial 67 finished with value: -3016806637.0471945 and parameters: {'power': 1.8255792613504949, 'alpha': 3.4381644195218715}. Best is trial 67 with value: -3016806637.0471945.
[I 2024-12-23 09:57:36,721] Trial 68 finished with value: -3017628111.8612747 and parameters: {'power': 1.8228005129428804, 'alpha': 3.2667420973514245}. Best is trial 67 with value: -3016806637.0471945.
[I 2024-12-23 09:57:36,745] Trial 55 finished with value: -3135342447.6753974 and parameters: {'power': 1.7249322685824962, 'alpha': 2.01623615510162}. Best is trial 67 with value: -3016806637.0471945.
[I 2024-12-23 09:57:36,755] Trial 69 finished with value: -3018809909.6467566 and parameters: {'power': 1.8347302006374584, 'alpha': 3.5661699573202643}. Best is trial 67 with value: -3016806637.0471945.
[I 2024-12-23 09:57:36,945] Trial 65 finished with value: -3029554423.9817753 and parameters: {'power': 1.854001556993646, 'alpha': 3.520102230995276}. Best is trial 67 with value: -3016806637.0471945.
[I 2024-12-23 09:57:36,960] Trial 62 finished with value: -3073727563.76905 and parameters: {'power': 1.7366752809449548, 'alpha': 3.450347438079625}. Best is trial 67 with value: -3016806637.0471945.
[I 2024-12-23 09:57:36,966] Trial 61 finished with value: -3082154645.2983665 and parameters: {'power': 1.7229863693225083, 'alpha': 3.580537730630951}. Best is trial 67 with value: -3016806637.0471945.
[I 2024-12-23 09:57:37,003] Trial 63 finished with value: -3011649758.4371915 and parameters: {'power': 1.7224120982555733, 'alpha': 9.832504889426804}. Best is trial 63 with value: -3011649758.4371915.
[I 2024-12-23 09:57:37,013] Trial 71 finished with value: -3017926648.467515 and parameters: {'power': 1.833429770811646, 'alpha': 3.4857597022574502}. Best is trial 63 with value: -3011649758.4371915.
[I 2024-12-23 09:57:37,176] Trial 73 finished with value: -3018779669.824095 and parameters: {'power': 1.8341150379797575, 'alpha': 3.5903110502859636}. Best is trial 63 with value: -3011649758.4371915.
[I 2024-12-23 09:57:37,194] Trial 64 finished with value: -3073178380.9787784 and parameters: {'power': 1.7345631555793288, 'alpha': 3.535853048571835}. Best is trial 63 with value: -3011649758.4371915.
[I 2024-12-23 09:57:37,210] Trial 70 finished with value: -3020934777.4673624 and parameters: {'power': 1.809355027437472, 'alpha': 3.31875639431198}. Best is trial 63 with value: -3011649758.4371915.
[I 2024-12-23 09:57:37,230] Trial 72 finished with value: -3019752410.790515 and parameters: {'power': 1.8367089481836978, 'alpha': 3.5908002507923786}. Best is trial 63 with value: -3011649758.4371915.
[I 2024-12-23 09:57:37,249] Trial 74 finished with value: -3023245961.0059795 and parameters: {'power': 1.8424314102690713, 'alpha': 3.6419079499128104}. Best is trial 63 with value: -3011649758.4371915.
[I 2024-12-23 09:57:37,273] Trial 75 finished with value: -3023563923.241921 and parameters: {'power': 1.8347431894264792, 'alpha': 4.012771368830858}. Best is trial 63 with value: -3011649758.4371915.
[I 2024-12-23 09:57:37,310] Trial 76 finished with value: -3021239555.5787344 and parameters: {'power': 1.833010952432729, 'alpha': 3.9059363991756904}. Best is trial 63 with value: -3011649758.4371915.
[I 2024-12-23 09:57:37,351] Trial 78 finished with value: -3021358504.8592024 and parameters: {'power': 1.834676761077833, 'alpha': 3.838925678568785}. Best is trial 63 with value: -3011649758.4371915.
[I 2024-12-23 09:57:37,369] Trial 77 finished with value: -3022943868.132524 and parameters: {'power': 1.8316511201068792, 'alpha': 4.113902117492004}. Best is trial 63 with value: -3011649758.4371915.
[I 2024-12-23 09:57:37,549] Trial 79 finished with value: -3016428340.137749 and
```

```
parameters: {'power': 1.8193052755654107, 'alpha': 3.7214655036794957}. Best is trial 63 with value: -3011649758.4371915.  
[I 2024-12-23 09:57:37,689] Trial 80 finished with value: -3015595638.8204885 and parameters: {'power': 1.8034215897374986, 'alpha': 4.516201648842701}. Best is trial 63 with value: -3011649758.4371915.  
[I 2024-12-23 09:57:37,797] Trial 81 finished with value: -3029154864.0450234 and parameters: {'power': 1.8042686316614485, 'alpha': 3.0051733809837113}. Best is trial 63 with value: -3011649758.4371915.  
[I 2024-12-23 09:57:37,878] Trial 84 finished with value: -3207406037.4625545 and parameters: {'power': 1.9304966538478496, 'alpha': 3.944168915591085}. Best is trial 63 with value: -3011649758.4371915.  
[I 2024-12-23 09:57:37,967] Trial 82 finished with value: -3033297914.9837213 and parameters: {'power': 1.8002494246241187, 'alpha': 2.9464600265627725}. Best is trial 63 with value: -3011649758.4371915.  
[I 2024-12-23 09:57:37,980] Trial 89 finished with value: -3151573064.258573 and parameters: {'power': 1.9342951953287768, 'alpha': 3.0330938771932385}. Best is trial 63 with value: -3011649758.4371915.  
[I 2024-12-23 09:57:38,059] Trial 83 finished with value: -3095705993.071565 and parameters: {'power': 1.9131681582289182, 'alpha': 2.9657805627585088}. Best is trial 63 with value: -3011649758.4371915.  
[I 2024-12-23 09:57:38,083] Trial 90 finished with value: -3489468664.8363366 and parameters: {'power': 1.9358932204614705, 'alpha': 9.991667724401315}. Best is trial 63 with value: -3011649758.4371915.  
[I 2024-12-23 09:57:38,130] Trial 95 finished with value: -3140404993.996941 and parameters: {'power': 1.9342642049798073, 'alpha': 2.8927659193915636}. Best is trial 63 with value: -3011649758.4371915.  
[I 2024-12-23 09:57:38,142] Trial 93 finished with value: -3126110695.180768 and parameters: {'power': 1.9285572738739987, 'alpha': 2.8943130415494367}. Best is trial 63 with value: -3011649758.4371915.  
[I 2024-12-23 09:57:38,152] Trial 92 finished with value: -3462895224.893654 and parameters: {'power': 1.9278790555027405, 'alpha': 9.922578541862954}. Best is trial 63 with value: -3011649758.4371915.  
[I 2024-12-23 09:57:38,161] Trial 94 finished with value: -3354659704.5085373 and parameters: {'power': 1.895599626097743, 'alpha': 9.786103661560254}. Best is trial 63 with value: -3011649758.4371915.  
[I 2024-12-23 09:57:38,174] Trial 85 finished with value: -3200334126.3823233 and parameters: {'power': 1.9261693868570438, 'alpha': 4.032481396226298}. Best is trial 63 with value: -3011649758.4371915.  
[I 2024-12-23 09:57:38,178] Trial 96 finished with value: -3164260326.474757 and parameters: {'power': 1.9418509701468598, 'alpha': 2.935736206138543}. Best is trial 63 with value: -3011649758.4371915.  
[I 2024-12-23 09:57:38,190] Trial 88 finished with value: -3151373123.4818153 and parameters: {'power': 1.9368304512920305, 'alpha': 2.9453019562622287}. Best is trial 63 with value: -3011649758.4371915.  
[I 2024-12-23 09:57:38,205] Trial 86 finished with value: -3127733029.3518515 and parameters: {'power': 1.9304003268230532, 'alpha': 2.8559299532640434}. Best is trial 63 with value: -3011649758.4371915.  
[I 2024-12-23 09:57:38,212] Trial 87 finished with value: -3123392162.3583293 and parameters: {'power': 1.9279163555231653, 'alpha': 2.8790548000446425}. Best is trial 63 with value: -3011649758.4371915.  
[I 2024-12-23 09:57:38,212] Trial 97 finished with value: -3149911505.899108 and parameters: {'power': 1.939865950248571, 'alpha': 2.828908617214106}. Best is trial 63 with value: -3011649758.4371915.  
[I 2024-12-23 09:57:38,219] Trial 98 finished with value: -3490314650.8902245 and parameters: {'power': 1.9377178018985943, 'alpha': 9.819295744029017}. Best is trial 63 with value: -3011649758.4371915.  
[I 2024-12-23 09:57:38,230] Trial 99 finished with value: -3135308761.468755 and parameters: {'power': 1.9326777218748856, 'alpha': 2.87980974087606}. Best is trial 63 with value: -3011649758.4371915.  
[I 2024-12-23 09:57:38,243] Trial 91 finished with value: -3472798798.774698 and
```

```
parameters: {'power': 1.932160309828539, 'alpha': 9.801352530509362}. Best is trial 63 with value: -3011649758.4371915.  
Best Hyperparameters: {'power': 1.7224120982555733, 'alpha': 9.832504889426804}
```

The generalized model did not perform well, and the power and alpha hyperparameters haven't lead to significant improvement. Compared with the linear regression we used before this one, even though it handles non gaussian distributions, this model performs worse than we would have expected, because the error measures are worse than before. We think that we should look for other models that could suit better our data.

MODEL EVALUATION

```
In [45]: best_params = study.best_params  
best_model = TweedieRegressor(**best_params, link='log', max_iter=1000)  
best_model.fit(X_train_scaled, y_train)  
  
y_pred = best_model.predict(X_test_scaled)  
  
mse = mean_squared_error(y_test, y_pred)  
mape = mean_absolute_percentage_error(y_test, y_pred)  
rmse = np.sqrt(mse)  
r2 = r2_score(y_test, y_pred)  
  
print(f"Mean Squared Error (MSE): {mse}")  
print(f"Mean Absolute Percentage Error (MAPE): {mape}")  
print(f"Root Mean Squared Error (RMSE): {rmse}")  
print(f"R-squared (R²): {r2}")
```

```
Mean Squared Error (MSE): 3001339254.597195  
Mean Absolute Percentage Error (MAPE): 8.558706163397873e+19  
Root Mean Squared Error (RMSE): 54784.48005226658  
R-squared (R²): 0.22219518417715012
```

Quantile regression

This is a kind of regression that models a specified quantile of the target variable, instead of the mean. This approach can be useful when the distribution of the target variable has outliers. By choosing different quantiles, you can predict the median or any other quantile instead of just the mean. As we have been having issues with outliers in the previous models, we expect this model to perform, not good, but at least better than the rest. For that, we are using the QuantileRegressor library and Optuna for optimizing its hyperparameters, we will make 30 trials:

- Quantile: Defines the quantile to predict (between 0 and 1). A quantile of 0.5 would predict the median, while 0.95 would predict the 95th percentile.
- Alpha: This is the regularization parameter we have been regularly using, as before, the larger the alpha, the more regularization is applied.

```
In [32]: X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_state=42)  
scaler = StandardScaler()  
X_train_scaled = scaler.fit_transform(X_train)
```

```
X_test_scaled = scaler.transform(X_test)

def objective(trial):
    quantile = trial.suggest_float('quantile', 0.05, 0.95)

    alpha = trial.suggest_float('alpha', 1e-5, 10, log=True)

    model = QuantileRegressor(
        quantile=quantile,
        alpha=alpha,
        solver='highs'
    )

    score = cross_val_score(
        model,
        X_train_scaled,
        y_train,
        cv=5,
        scoring='neg_mean_squared_error'
    )

    return score.mean()

study = optuna.create_study(direction='maximize')
study.optimize(objective, n_trials=30, n_jobs=-1)

print(f"Best Hyperparameters: {study.best_params} and Quantile: {study.best_para
```

```
[I 2024-12-23 10:03:37,102] A new study created in memory with name: no-name-1fdc23fb-847b-423c-bbd1-53cdcf475040
[I 2024-12-23 10:05:21,680] Trial 7 finished with value: -3287530411.4596767 and parameters: {'quantile': 0.63169284787652, 'alpha': 0.00041790462238463355}. Best is trial 7 with value: -3287530411.4596767.
[I 2024-12-23 10:05:26,707] Trial 13 finished with value: -6256664793.069834 and parameters: {'quantile': 0.14334496844052627, 'alpha': 0.0014962586374899715}. Best is trial 7 with value: -3287530411.4596767.
[I 2024-12-23 10:05:26,719] Trial 5 finished with value: -3473198706.979766 and parameters: {'quantile': 0.636649644054391, 'alpha': 0.01076668298564191}. Best is trial 7 with value: -3287530411.4596767.
[I 2024-12-23 10:05:26,724] Trial 2 finished with value: -3577551796.69522 and parameters: {'quantile': 0.430980334671708, 'alpha': 0.001188721447428491}. Best is trial 7 with value: -3287530411.4596767.
[I 2024-12-23 10:05:26,732] Trial 4 finished with value: -4850594220.739611 and parameters: {'quantile': 0.5772116822149581, 'alpha': 5.609952413907398}. Best is trial 7 with value: -3287530411.4596767.
[I 2024-12-23 10:05:33,216] Trial 0 finished with value: -3507523561.180787 and parameters: {'quantile': 0.5530480566358059, 'alpha': 0.008685034152655256}. Best is trial 7 with value: -3287530411.4596767.
[I 2024-12-23 10:05:33,224] Trial 3 finished with value: -6316386135.097818 and parameters: {'quantile': 0.1136254431940761, 'alpha': 0.00030403749100075406}. Best is trial 7 with value: -3287530411.4596767.
[I 2024-12-23 10:05:36,550] Trial 15 finished with value: -5973643350.983931 and parameters: {'quantile': 0.7990370022200407, 'alpha': 1.2440455172115998e-05}. Best is trial 7 with value: -3287530411.4596767.
[I 2024-12-23 10:05:37,965] Trial 8 finished with value: -9692425226.550127 and parameters: {'quantile': 0.32510311122806324, 'alpha': 4.149379964247361}. Best is trial 7 with value: -3287530411.4596767.
[I 2024-12-23 10:05:40,003] Trial 14 finished with value: -3559083768.0311446 and parameters: {'quantile': 0.4687849608489395, 'alpha': 0.008464945880063503}. Best is trial 7 with value: -3287530411.4596767.
[I 2024-12-23 10:05:41,054] Trial 1 finished with value: -3548934715.636625 and parameters: {'quantile': 0.4648871263266727, 'alpha': 8.476147048820801e-05}. Best is trial 7 with value: -3287530411.4596767.
[I 2024-12-23 10:05:41,064] Trial 17 finished with value: -6850407188.933542 and parameters: {'quantile': 0.8415558331406767, 'alpha': 1.0717979951982454e-05}. Best is trial 7 with value: -3287530411.4596767.
[I 2024-12-23 10:05:41,068] Trial 16 finished with value: -6381579492.317668 and parameters: {'quantile': 0.09615783208875722, 'alpha': 0.0007611465666827552}. Best is trial 7 with value: -3287530411.4596767.
[I 2024-12-23 10:05:41,071] Trial 10 finished with value: -6407265727.809014 and parameters: {'quantile': 0.08793809903363313, 'alpha': 0.00035887069220878233}. Best is trial 7 with value: -3287530411.4596767.
[I 2024-12-23 10:05:41,082] Trial 6 finished with value: -6148549603.243756 and parameters: {'quantile': 0.24585998169193385, 'alpha': 0.009256589914388425}. Best is trial 7 with value: -3287530411.4596767.
[I 2024-12-23 10:05:42,918] Trial 19 finished with value: -9692425226.550127 and parameters: {'quantile': 0.07476650866015808, 'alpha': 0.42931823617875986}. Best is trial 7 with value: -3287530411.4596767.
[I 2024-12-23 10:05:44,833] Trial 11 finished with value: -3729067189.1616836 and parameters: {'quantile': 0.4345938930437117, 'alpha': 0.06883763918248377}. Best is trial 7 with value: -3287530411.4596767.
[I 2024-12-23 10:05:44,860] Trial 18 finished with value: -9692425226.550127 and parameters: {'quantile': 0.05848622426553658, 'alpha': 7.589634501533174}. Best is trial 7 with value: -3287530411.4596767.
[I 2024-12-23 10:05:45,642] Trial 9 finished with value: -3862560616.0471888 and parameters: {'quantile': 0.6725247040351588, 'alpha': 0.0031151372870730078}. Best is trial 7 with value: -3287530411.4596767.
[I 2024-12-23 10:05:45,651] Trial 12 finished with value: -6271274542.531157 and
```

```
parameters: {'quantile': 0.3158165282679164, 'alpha': 0.10685777839881347}. Best
is trial 7 with value: -3287530411.4596767.
[I 2024-12-23 10:06:32,257] Trial 20 finished with value: -7079619961.680377 and
parameters: {'quantile': 0.8532691736875784, 'alpha': 0.00022853676318303995}. Be
st is trial 7 with value: -3287530411.4596767.
[I 2024-12-23 10:06:34,233] Trial 26 finished with value: -3300470775.159223 and
parameters: {'quantile': 0.6331277462066002, 'alpha': 6.298946715348997e-05}. Bes
t is trial 7 with value: -3287530411.4596767.
[I 2024-12-23 10:06:37,274] Trial 27 finished with value: -11002831600.439985 and
parameters: {'quantile': 0.9430755278626819, 'alpha': 0.18878657618696362}. Best
is trial 7 with value: -3287530411.4596767.
[I 2024-12-23 10:06:37,284] Trial 22 finished with value: -4501166405.187889 and
parameters: {'quantile': 0.5290300756633007, 'alpha': 0.99430817544046}. Best is
trial 7 with value: -3287530411.4596767.
[I 2024-12-23 10:06:39,887] Trial 21 finished with value: -10441014763.209274 and
parameters: {'quantile': 0.9424721598073641, 'alpha': 0.00026898197429871766}. Be
st is trial 7 with value: -3287530411.4596767.
[I 2024-12-23 10:06:40,400] Trial 23 finished with value: -3642971553.1287627 and
parameters: {'quantile': 0.660078047683278, 'alpha': 0.0001281285457136433}. Best
is trial 7 with value: -3287530411.4596767.
[I 2024-12-23 10:06:40,401] Trial 29 finished with value: -9868164362.076529 and
parameters: {'quantile': 0.9192642123343315, 'alpha': 0.26594115233256854}. Best
is trial 7 with value: -3287530411.4596767.
[I 2024-12-23 10:06:40,402] Trial 24 finished with value: -9692425226.550127 and
parameters: {'quantile': 0.28500237135609924, 'alpha': 0.43124662276866205}. Best
is trial 7 with value: -3287530411.4596767.
[I 2024-12-23 10:06:40,907] Trial 28 finished with value: -9987687341.46823 and p
arameters: {'quantile': 0.9223449312489284, 'alpha': 0.1696815012857333}. Best is
trial 7 with value: -3287530411.4596767.
[I 2024-12-23 10:06:41,243] Trial 25 finished with value: -9692425226.550127 and
parameters: {'quantile': 0.05977519407930562, 'alpha': 0.09216785129370332}. Best
is trial 7 with value: -3287530411.4596767.
```

Best Hyperparameters: {'quantile': 0.63169284787652, 'alpha': 0.00041790462238463
355} and Quantile: 0.63169284787652

```
In [33]: best_params = study.best_params
best_quantile = best_params.pop('quantile')

best_model = QuantileRegressor(
    quantile=best_quantile,
    alpha=best_params['alpha'],
    solver='highs'
)
best_model.fit(X_train_scaled, y_train)

y_pred = best_model.predict(X_test_scaled)

mse = mean_squared_error(y_test, y_pred)
mape = mean_absolute_percentage_error(y_test, y_pred)
rmse = np.sqrt(mse)
r2 = r2_score(y_test, y_pred)

print(f"Mean Squared Error (MSE): {mse}")
print(f"Mean Absolute Percentage Error (MAPE): {mape}")
print(f"Root Mean Squared Error (RMSE): {rmse}")
print(f"R-squared (R²): {r2}")
```

```
Mean Squared Error (MSE): 3186170684.674181
Mean Absolute Percentage Error (MAPE): 1.162740024916458e+20
Root Mean Squared Error (RMSE): 56446.1751111077
R-squared (R2): 0.17429564192810243
```

The best hyperparameters we found have been 0.632 for the quantile, and 0.00042 for the alpha regularization. After running the model, we see that both MSE and RMSE are high, indicating that, again, the predictions are far from the actual values, similar to the previous models. The MAPE value is extremely high, possibly due to extreme or outlier values, which we thought that would be managed by this model, but we now see that it hasn't been like that. The R² value is quite low, so the relationship between the selected features and the target variable is not enough for the model to make predictions.

Overall, even optimizing the hyperparameters, we have not been able to handle the target variable, maybe the outliers are so extreme that not even the quantile regression model can handle them.

Polynomial regression

⚠ WE HAVEN'T BEEN ABLE TO RUN THIS REGRESSOR ⚠ :

We have tried to train it in different devices, but when we try to initialize it our PCs explodes, Google Collab is also resilient of helping out.

```
In [1]: '''from sklearn.model_selection import train_test_split, cross_val_score
from sklearn.preprocessing import PolynomialFeatures, StandardScaler
from sklearn.linear_model import Ridge
from sklearn.metrics import mean_squared_error, mean_absolute_percentage_error,
import numpy as np
import optuna

X = dfFeature.drop(['Balance'], axis=1)
y = dfFeature['Balance']

X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_

scaler = StandardScaler()
X_train_scaled = scaler.fit_transform(X_train)
X_test_scaled = scaler.transform(X_test)

def objective(trial):
    degree = trial.suggest_int('degree', 1, 5)
    alpha = trial.suggest_float('alpha', 1e-5, 1000)

    poly = PolynomialFeatures(degree=degree)
    X_train_poly = poly.fit_transform(X_train_scaled)

    model = Ridge(alpha=alpha)

    score = cross_val_score(model, X_train_poly, y_train, cv=5, scoring='neg_mean_squared_error')
    return score.mean()

study = optuna.create_study(direction='minimize')
study.optimize(objective, n_trials=500, n_jobs=-1)
```

```
print(f"Best Hyperparameters: {study.best_params}")'''
```

```
Out[1]: 'from sklearn.model_selection import train_test_split, cross_val_score\nfrom sklearn.preprocessing import PolynomialFeatures, StandardScaler\nfrom sklearn.linear_model import Ridge\nfrom sklearn.metrics import mean_squared_error, mean_absolute_percentage_error, r2_score\nimport numpy as np\nimport optuna\n\nX = dfFeature.drop(['Balance'], axis=1)\ny = dfFeature['Balance']\n\nX_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_state=42)\n\nscaler = StandardScaler()\nX_train_scaled = scaler.fit_transform(X_train)\nX_test_scaled = scaler.transform(X_test)\n\ndef objective(trial):\n    degree = trial.suggest_int('degree', 1, 5)\n    alpha = trial.suggest_float('alpha', 1e-5, 1000)\n    poly = PolynomialFeatures(degree=degree)\n    X_train_poly = poly.fit_transform(X_train_scaled)\n    model = Ridge(alpha=alpha)\n    score = cross_val_score(model, X_train_poly, y_train, cv=5, scoring='neg_mean_squared_error')\n    return score.mean()\nstudy = optuna.create_study(direction='minimize')\nstudy.optimize(objective, n_trials=500, n_jobs=-1)\n\nprint(f"Best Hyperparameters: {study.best_params}")'
```

MODEL EVALUATION

```
In [ ]: best_params = study.best_params\ndegree = best_params['degree']\nalpha = best_params['alpha']\n\npoly = PolynomialFeatures(degree=degree)\nX_train_poly = poly.fit_transform(X_train_scaled)\nX_test_poly = poly.transform(X_test_scaled)\n\nbest_model = Ridge(alpha=alpha)\nbest_model.fit(X_train_poly, y_train)\n\ny_pred = best_model.predict(X_test_poly)\n\nmse = mean_squared_error(y_test, y_pred)\nmape = mean_absolute_percentage_error(y_test, y_pred)\nrmse = np.sqrt(mse)\nr2 = r2_score(y_test, y_pred)\n\nprint(f"Mean Squared Error (MSE): {mse}")\nprint(f"Mean Absolute Percentage Error (MAPE): {mape}")\nprint(f"Root Mean Squared Error (RMSE): {rmse}")\nprint(f"R-squared (R2): {r2}")
```

SVR

Now we are testing the Support Vector Regressor (SVR), using Optuna for hyperparameter tuning. We are expecting from SVR to find a hyperplane that maximizes the margin around the data, focusing on minimizing errors outside that margin rather than fitting every point closely. SVR is more robust to outliers than some of the previous models that we have trained and maybe could do it better, for this the following hyperparameters are being evaluated:

- C: Regularization parameter (ranging from 1e-3 to 1e2). Controls the balance between maximizing the margin and minimizing classification errors.

- Epsilon: This controls the margin of tolerance in the SVC model. A smaller epsilon allows for a narrower margin, while a larger epsilon broadens the margin, impacting the model's ability to fit the data closely. We are tuning epsilon between 0.01 and 1.0.
- kernel: Specifies the type of kernel function used, we have excluded linear as we want to test it separately later.
- max_iter: trial.suggest_int("max_iter", 5000, 20000, step=1000)

Despite the strengths of SVR, we do not anticipate significantly better results, as previous models have underperformed, likely due to the dataset's limitations or inherent noise.

```
In [11]: X = dfFeature.drop(['Balance'], axis=1)
y = dfFeature['Balance']

X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_
scaler = StandardScaler()
X_train_scaled = scaler.fit_transform(X_train)
X_test_scaled = scaler.transform(X_test)

def objective(trial):
    C = trial.suggest_float("C", 0.1, 100.0, log=True)
    epsilon = trial.suggest_float("epsilon", 0.01, 1.0)
    kernel = trial.suggest_categorical("kernel", ["poly", "rbf", "sigmoid"])
    max_iter = trial.suggest_int("max_iter", 5000, 20000, step=1000)

    model = SVR(C=C, epsilon=epsilon, kernel=kernel, max_iter=max_iter)

    score = cross_val_score(model, X_train_scaled, y_train, cv=5, scoring='neg_r
    return score.mean()

study = optuna.create_study(direction='maximize')
study.optimize(objective, n_trials=50, n_jobs=-1)

print(f"Best Hyperparameters: {study.best_params}")
```

[I 2024-12-23 13:16:23,057] A new study created in memory with name: no-name-46f0
450a-52f8-411f-aee7-ba022a222e32

```
[I 2024-12-23 13:18:21,689] Trial 12 finished with value: -4142072390.961608 and parameters: {'C': 69.16669070907534, 'epsilon': 0.3631228281687276, 'kernel': 'poly', 'max_iter': 17000}. Best is trial 12 with value: -4142072390.961608.  
[I 2024-12-23 13:18:22,389] Trial 13 finished with value: -4313592295.318417 and parameters: {'C': 1.559931866458354, 'epsilon': 0.41528330436684896, 'kernel': 'poly', 'max_iter': 5000}. Best is trial 12 with value: -4142072390.961608.  
[I 2024-12-23 13:18:22,674] Trial 5 finished with value: -4267956086.3557463 and parameters: {'C': 17.87177128462009, 'epsilon': 0.6099719874633717, 'kernel': 'poly', 'max_iter': 20000}. Best is trial 12 with value: -4142072390.961608.  
[I 2024-12-23 13:18:22,884] Trial 6 finished with value: -4313876899.425295 and parameters: {'C': 1.4310175654549795, 'epsilon': 0.08111313042334604, 'kernel': 'poly', 'max_iter': 16000}. Best is trial 12 with value: -4142072390.961608.  
[I 2024-12-23 13:18:24,975] Trial 18 finished with value: -4317469835.441419 and parameters: {'C': 0.1672118848913134, 'epsilon': 0.03095078810432618, 'kernel': 'poly', 'max_iter': 7000}. Best is trial 12 with value: -4142072390.961608.  
[I 2024-12-23 13:18:24,976] Trial 15 finished with value: -4282610128.3915215 and parameters: {'C': 12.959163842363148, 'epsilon': 0.9410863729161387, 'kernel': 'poly', 'max_iter': 18000}. Best is trial 12 with value: -4142072390.961608.  
[I 2024-12-23 13:18:26,616] Trial 19 finished with value: -4317305244.823562 and parameters: {'C': 0.2262719395937903, 'epsilon': 0.45806145317961816, 'kernel': 'poly', 'max_iter': 13000}. Best is trial 12 with value: -4142072390.961608.  
[I 2024-12-23 13:18:34,245] Trial 3 finished with value: -4315520514.324798 and parameters: {'C': 0.7668646562309971, 'epsilon': 0.43463944569036334, 'kernel': 'poly', 'max_iter': 15000}. Best is trial 12 with value: -4142072390.961608.  
[I 2024-12-23 13:18:36,918] Trial 7 finished with value: -4260822493.5388894 and parameters: {'C': 12.004341222628227, 'epsilon': 0.6357324470017317, 'kernel': 'rbf', 'max_iter': 17000}. Best is trial 12 with value: -4142072390.961608.  
[I 2024-12-23 13:18:39,072] Trial 9 finished with value: -4193187380.652299 and parameters: {'C': 26.207831460692226, 'epsilon': 0.2916144184876449, 'kernel': 'rbf', 'max_iter': 11000}. Best is trial 12 with value: -4142072390.961608.  
[I 2024-12-23 13:18:39,443] Trial 17 finished with value: -4316772447.452879 and parameters: {'C': 0.23903165043884192, 'epsilon': 0.475795520729515, 'kernel': 'rbf', 'max_iter': 17000}. Best is trial 12 with value: -4142072390.961608.  
[I 2024-12-23 13:18:39,836] Trial 11 finished with value: -4315198820.534472 and parameters: {'C': 0.5469928763119425, 'epsilon': 0.6781044803797964, 'kernel': 'rbf', 'max_iter': 8000}. Best is trial 12 with value: -4142072390.961608.  
[I 2024-12-23 13:18:40,257] Trial 8 finished with value: -4309040596.49835 and parameters: {'C': 1.7811870340938576, 'epsilon': 0.38139024107205616, 'kernel': 'rbf', 'max_iter': 9000}. Best is trial 12 with value: -4142072390.961608.  
[I 2024-12-23 13:18:42,978] Trial 0 finished with value: -4312744339.045965 and parameters: {'C': 0.9936415296550357, 'epsilon': 0.451607628388393, 'kernel': 'rbf', 'max_iter': 12000}. Best is trial 12 with value: -4142072390.961608.  
[I 2024-12-23 13:18:47,002] Trial 2 finished with value: -4317359952.799821 and parameters: {'C': 0.12212067791866801, 'epsilon': 0.40850003038688515, 'kernel': 'rbf', 'max_iter': 16000}. Best is trial 12 with value: -4142072390.961608.  
[I 2024-12-23 13:18:59,972] Trial 10 finished with value: -4310881665.374432 and parameters: {'C': 0.4974942248999957, 'epsilon': 0.4662459287929746, 'kernel': 'sigmoid', 'max_iter': 9000}. Best is trial 12 with value: -4142072390.961608.  
[I 2024-12-23 13:19:00,041] Trial 14 finished with value: -4003247589.4653254 and parameters: {'C': 25.08889331927212, 'epsilon': 0.25168308493346986, 'kernel': 'sigmoid', 'max_iter': 15000}. Best is trial 14 with value: -4003247589.4653254.  
[I 2024-12-23 13:19:01,158] Trial 16 finished with value: -4224737163.941565 and parameters: {'C': 6.769770517274561, 'epsilon': 0.5716161239464811, 'kernel': 'sigmoid', 'max_iter': 13000}. Best is trial 14 with value: -4003247589.4653254.  
[I 2024-12-23 13:19:01,739] Trial 1 finished with value: -3993127612.5224023 and parameters: {'C': 25.907963674093654, 'epsilon': 0.7171248369828918, 'kernel': 'sigmoid', 'max_iter': 17000}. Best is trial 1 with value: -3993127612.5224023.  
[I 2024-12-23 13:19:03,141] Trial 4 finished with value: -4314584840.214392 and parameters: {'C': 0.22453231830680417, 'epsilon': 0.6114676144580112, 'kernel': 'sigmoid', 'max_iter': 6000}. Best is trial 1 with value: -3993127612.5224023.
```

```
[I 2024-12-23 13:20:04,868] Trial 20 finished with value: -4316692345.833468 and parameters: {'C': 0.4316144670830891, 'epsilon': 0.07877803117263908, 'kernel': 'poly', 'max_iter': 20000}. Best is trial 1 with value: -3993127612.5224023.  
[I 2024-12-23 13:20:04,966] Trial 23 finished with value: -4317413167.787482 and parameters: {'C': 0.18754488306930958, 'epsilon': 0.9916932778105253, 'kernel': 'poly', 'max_iter': 9000}. Best is trial 1 with value: -3993127612.5224023.  
[I 2024-12-23 13:20:06,782] Trial 26 finished with value: -4315468255.441885 and parameters: {'C': 0.7876729177388471, 'epsilon': 0.247250853278754, 'kernel': 'poly', 'max_iter': 10000}. Best is trial 1 with value: -3993127612.5224023.  
[I 2024-12-23 13:20:09,840] Trial 25 finished with value: -4021817388.5108023 and parameters: {'C': 64.76152364854093, 'epsilon': 0.9647843081408652, 'kernel': 'rbf', 'max_iter': 16000}. Best is trial 1 with value: -3993127612.5224023.  
[I 2024-12-23 13:20:09,888] Trial 24 finished with value: -4312192608.097178 and parameters: {'C': 1.1062238626671057, 'epsilon': 0.18661736619532188, 'kernel': 'rbf', 'max_iter': 14000}. Best is trial 1 with value: -3993127612.5224023.  
[I 2024-12-23 13:20:09,932] Trial 22 finished with value: -4317098931.187994 and parameters: {'C': 0.1753040490471542, 'epsilon': 0.8377506213590806, 'kernel': 'rbf', 'max_iter': 10000}. Best is trial 1 with value: -3993127612.5224023.  
[I 2024-12-23 13:20:17,490] Trial 21 finished with value: -4287301540.712056 and parameters: {'C': 2.334329215671903, 'epsilon': 0.44855061424581344, 'kernel': 'sigmoid', 'max_iter': 20000}. Best is trial 1 with value: -3993127612.5224023.  
[I 2024-12-23 13:20:25,281] Trial 29 finished with value: -3500295697.711006 and parameters: {'C': 94.5976499059167, 'epsilon': 0.8430315509867022, 'kernel': 'sigmoid', 'max_iter': 11000}. Best is trial 29 with value: -3500295697.711006.  
[I 2024-12-23 13:20:26,884] Trial 27 finished with value: -4132091026.5278883 and parameters: {'C': 14.08901634442699, 'epsilon': 0.27701531428162424, 'kernel': 'sigmoid', 'max_iter': 15000}. Best is trial 29 with value: -3500295697.711006.  
[I 2024-12-23 13:20:27,607] Trial 28 finished with value: -4304403949.7133255 and parameters: {'C': 1.0090211134730418, 'epsilon': 0.3211672126888584, 'kernel': 'sigmoid', 'max_iter': 6000}. Best is trial 29 with value: -3500295697.711006.  
[I 2024-12-23 13:20:28,099] Trial 30 finished with value: -3511735917.128717 and parameters: {'C': 92.27882231487177, 'epsilon': 0.23263716331016432, 'kernel': 'sigmoid', 'max_iter': 10000}. Best is trial 29 with value: -3500295697.711006.  
[I 2024-12-23 13:20:28,885] Trial 31 finished with value: -3517374444.91751 and parameters: {'C': 91.1002669818664, 'epsilon': 0.2395874777293135, 'kernel': 'sigmoid', 'max_iter': 11000}. Best is trial 29 with value: -3500295697.711006.  
[I 2024-12-23 13:20:29,737] Trial 32 finished with value: -3531895835.1685653 and parameters: {'C': 88.24916462346721, 'epsilon': 0.2715304417252804, 'kernel': 'sigmoid', 'max_iter': 11000}. Best is trial 29 with value: -3500295697.711006.  
[I 2024-12-23 13:20:32,724] Trial 33 finished with value: -3482222351.602628 and parameters: {'C': 98.0814335861046, 'epsilon': 0.21473897962008082, 'kernel': 'sigmoid', 'max_iter': 11000}. Best is trial 33 with value: -3482222351.602628.  
[I 2024-12-23 13:20:33,349] Trial 34 finished with value: -3605029847.6029387 and parameters: {'C': 75.42468485444192, 'epsilon': 0.25134654228631353, 'kernel': 'sigmoid', 'max_iter': 12000}. Best is trial 33 with value: -3482222351.602628.  
[I 2024-12-23 13:20:34,992] Trial 36 finished with value: -3503010052.635415 and parameters: {'C': 94.02591138134457, 'epsilon': 0.23026636089051378, 'kernel': 'sigmoid', 'max_iter': 20000}. Best is trial 33 with value: -3482222351.602628.  
[I 2024-12-23 13:20:36,534] Trial 35 finished with value: -3589372971.634444 and parameters: {'C': 78.31006285771188, 'epsilon': 0.21979931190660695, 'kernel': 'sigmoid', 'max_iter': 12000}. Best is trial 33 with value: -3482222351.602628.  
[I 2024-12-23 13:20:36,872] Trial 37 finished with value: -3562783970.4386215 and parameters: {'C': 82.88377734232576, 'epsilon': 0.20232679514215784, 'kernel': 'sigmoid', 'max_iter': 14000}. Best is trial 33 with value: -3482222351.602628.  
[I 2024-12-23 13:20:40,767] Trial 38 finished with value: -3573859050.97023 and parameters: {'C': 80.94253824494767, 'epsilon': 0.7694523315078692, 'kernel': 'sigmoid', 'max_iter': 20000}. Best is trial 33 with value: -3482222351.602628.  
[I 2024-12-23 13:20:45,859] Trial 39 finished with value: -3645127713.4329286 and parameters: {'C': 68.38873881104975, 'epsilon': 0.7985768078888951, 'kernel': 'sigmoid', 'max_iter': 20000}. Best is trial 33 with value: -3482222351.602628.
```

```
[I 2024-12-23 13:20:58,710] Trial 41 finished with value: -3567744763.3059607 and
parameters: {'C': 81.90565723688472, 'epsilon': 0.21948945424669217, 'kernel': 'si
igmoid', 'max_iter': 14000}. Best is trial 33 with value: -3482222351.602628.
[I 2024-12-23 13:20:59,240] Trial 40 finished with value: -3484223916.351743 and
parameters: {'C': 97.66881368453946, 'epsilon': 0.2315634918085109, 'kernel': 'si
igmoid', 'max_iter': 14000}. Best is trial 33 with value: -3482222351.602628.
[I 2024-12-23 13:21:00,233] Trial 42 finished with value: -3505432161.069213 and
parameters: {'C': 93.49985851452578, 'epsilon': 0.7904467810736178, 'kernel': 'si
igmoid', 'max_iter': 14000}. Best is trial 33 with value: -3482222351.602628.
[I 2024-12-23 13:21:00,283] Trial 44 finished with value: -3513586572.2899537 and
parameters: {'C': 91.89180315316652, 'epsilon': 0.7679599226565951, 'kernel': 'si
igmoid', 'max_iter': 19000}. Best is trial 33 with value: -3482222351.602628.
[I 2024-12-23 13:21:02,987] Trial 43 finished with value: -3759635105.3048487 and
parameters: {'C': 50.75334298454545, 'epsilon': 0.7582562066638742, 'kernel': 'si
igmoid', 'max_iter': 19000}. Best is trial 33 with value: -3482222351.602628.
[I 2024-12-23 13:21:03,006] Trial 45 finished with value: -3559331113.311301 and
parameters: {'C': 83.40978198274027, 'epsilon': 0.8191835597053807, 'kernel': 'si
igmoid', 'max_iter': 19000}. Best is trial 33 with value: -3482222351.602628.
[I 2024-12-23 13:21:04,184] Trial 46 finished with value: -3613929555.155257 and
parameters: {'C': 74.06834768904653, 'epsilon': 0.7623591835571141, 'kernel': 'si
igmoid', 'max_iter': 15000}. Best is trial 33 with value: -3482222351.602628.
[I 2024-12-23 13:21:04,608] Trial 49 finished with value: -3810050535.4168334 and
parameters: {'C': 44.43668734152692, 'epsilon': 0.7593788619875907, 'kernel': 'si
igmoid', 'max_iter': 12000}. Best is trial 33 with value: -3482222351.602628.
[I 2024-12-23 13:21:04,976] Trial 47 finished with value: -3475063254.5612516 and
parameters: {'C': 99.45090965342551, 'epsilon': 0.7596566508764838, 'kernel': 'si
igmoid', 'max_iter': 14000}. Best is trial 47 with value: -3475063254.5612516.
[I 2024-12-23 13:21:05,542] Trial 48 finished with value: -3857712548.5367 and pa
rameters: {'C': 39.22639881453886, 'epsilon': 0.7516810632280843, 'kernel': 'sigm
oid', 'max_iter': 12000}. Best is trial 47 with value: -3475063254.5612516.
Best Hyperparameters: {'C': 99.45090965342551, 'epsilon': 0.7596566508764838, 'ke
rnel': 'sigmoid', 'max_iter': 14000}
```

MODEL EVALUATION

```
In [12]: best_model = SVR(**study.best_params)
best_model.fit(X_train_scaled, y_train)

y_pred = best_model.predict(X_test_scaled)

mse = mean_squared_error(y_test, y_pred)
rmse = np.sqrt(mse)
mape = mean_absolute_percentage_error(y_test, y_pred)
r2 = r2_score(y_test, y_pred)

print(f"Mean Squared Error (MSE): {mse}")
print(f"Mean Absolute Percentage Error (MAPE): {mape}")
print(f"Root Mean Squared Error (RMSE): {rmse}")
print(f"R-squared (R²): {r2}")
```

```
Mean Squared Error (MSE): 3291894311.649197
Mean Absolute Percentage Error (MAPE): 1.2280332448673364e+20
Root Mean Squared Error (RMSE): 57375.032127652856
R-squared (R²): 0.14689709107069115
```

for {'C': 99.45090965342551, 'epsilon': 0.7596566508764838, 'kernel': 'sigmoid', 'max_iter': 14000} hyperparameters. The MSE and RMSE suggest moderate prediction errors, with an RMSE of around 57,375. The extremely high MAPE indicates a large deviation between predictions and actual values, while the R² value of 0.15 shows that the model explains

only a small portion of the variance. Then even being more robust to outliers it didn't perform as expected.

LinearSVR

Now we are testing Linear Support Vector Regressor model, we are using Optuna for hyperparameter tuning. The following hyperparameters are being evaluated:

- C: Regularization parameter (ranging from 1e-3 to 1e2). Controls the balance between maximizing the margin and minimizing classification errors.
- Epsilon: This controls the margin of tolerance in the SVC model. A smaller epsilon allows for a narrower margin, while a larger epsilon broadens the margin, impacting the model's ability to fit the data closely. We are tuning epsilon between 0.01 and 1.0.
- Max Iter: Maximum number of iterations for the solver. We are tuning this between 1000 and 10000.

With the Linear SVR, we expect to achieve the better performance from all the possible kernels for SVR, because it is the simpler, more efficient, and it could have a good performance in our data

```
In [46]: X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_state=42)

scaler = StandardScaler()
X_train_scaled = scaler.fit_transform(X_train)
X_test_scaled = scaler.transform(X_test)

def objective(trial):
    C = trial.suggest_float("C", 0.1, 10.0, log=True)
    epsilon = trial.suggest_float("epsilon", 0.01, 1.0)
    max_iter = trial.suggest_int("max_iter", 1000, 10000, step=1000)

    model = LinearSVR(C=C, epsilon=epsilon, max_iter=max_iter, random_state=42)

    score = cross_val_score(model, X_train_scaled, y_train, cv=5, scoring="neg_mean_squared_error")
    return score

study = optuna.create_study(direction="maximize")
study.optimize(objective, n_trials=50, n_jobs=-1)

print("Best hyperparameters:", study.best_params)
```

```
[I 2024-12-22 21:03:46,555] A new study created in memory with name: no-name-e178bc21-0987-4db8-8c45-a73cf4feb3b6
[I 2024-12-22 21:03:46,761] Trial 1 finished with value: -9517146483.32661 and parameters: {'C': 0.2727994881080792, 'epsilon': 0.6103289182407792, 'max_iter': 1000}. Best is trial 1 with value: -9517146483.32661.
[I 2024-12-22 21:03:46,772] Trial 3 finished with value: -9020358006.945807 and parameters: {'C': 1.0710178253052376, 'epsilon': 0.32227690923397645, 'max_iter': 2000}. Best is trial 3 with value: -9020358006.945807.
[I 2024-12-22 21:03:46,777] Trial 0 finished with value: -8392693553.181727 and parameters: {'C': 2.139980507166145, 'epsilon': 0.7958586577911217, 'max_iter': 7000}. Best is trial 0 with value: -8392693553.181727.
[I 2024-12-22 21:03:46,792] Trial 5 finished with value: -9523139144.143867 and parameters: {'C': 0.2633973337119978, 'epsilon': 0.1822773064704562, 'max_iter': 1000}. Best is trial 0 with value: -8392693553.181727.
[I 2024-12-22 21:03:46,796] Trial 2 finished with value: -9218685231.165339 and parameters: {'C': 0.7477161837062379, 'epsilon': 0.3539553207549934, 'max_iter': 2000}. Best is trial 0 with value: -8392693553.181727.
[I 2024-12-22 21:03:46,798] Trial 12 finished with value: -8069112824.389742 and parameters: {'C': 2.7219089062080504, 'epsilon': 0.19516111433834893, 'max_iter': 2000}. Best is trial 12 with value: -8069112824.389742.
[I 2024-12-22 21:03:46,813] Trial 4 finished with value: -8882450577.006784 and parameters: {'C': 1.2997482154301347, 'epsilon': 0.966765477260588, 'max_iter': 5000}. Best is trial 12 with value: -8069112824.389742.
[I 2024-12-22 21:03:46,819] Trial 10 finished with value: -5732151310.478379 and parameters: {'C': 8.188633314335144, 'epsilon': 0.9510663508651312, 'max_iter': 9000}. Best is trial 10 with value: -5732151310.478379.
[I 2024-12-22 21:03:46,827] Trial 9 finished with value: -5482022959.727126 and parameters: {'C': 9.168753602321173, 'epsilon': 0.08329208273102827, 'max_iter': 1000}. Best is trial 9 with value: -5482022959.727126.
[I 2024-12-22 21:03:46,831] Trial 8 finished with value: -9312760724.232334 and parameters: {'C': 0.5965464353901695, 'epsilon': 0.7459100122643081, 'max_iter': 5000}. Best is trial 9 with value: -5482022959.727126.
[I 2024-12-22 21:03:46,832] Trial 6 finished with value: -9550619542.031927 and parameters: {'C': 0.2203599009139698, 'epsilon': 0.5509186395276106, 'max_iter': 5000}. Best is trial 9 with value: -5482022959.727126.
[I 2024-12-22 21:03:46,874] Trial 7 finished with value: -5911106520.436472 and parameters: {'C': 7.628072409770887, 'epsilon': 0.9704677635828152, 'max_iter': 1000}. Best is trial 9 with value: -5482022959.727126.
[I 2024-12-22 21:03:46,888] Trial 18 finished with value: -8042163617.435905 and parameters: {'C': 2.7714041665549884, 'epsilon': 0.7962096841866287, 'max_iter': 8000}. Best is trial 9 with value: -5482022959.727126.
[I 2024-12-22 21:03:46,901] Trial 16 finished with value: -9576680364.12527 and parameters: {'C': 0.1796402436465689, 'epsilon': 0.9253320656888728, 'max_iter': 3000}. Best is trial 9 with value: -5482022959.727126.
[I 2024-12-22 21:03:46,903] Trial 19 finished with value: -8192855301.506714 and parameters: {'C': 2.496649090809741, 'epsilon': 0.10203717789229365, 'max_iter': 6000}. Best is trial 9 with value: -5482022959.727126.
[I 2024-12-22 21:03:46,908] Trial 13 finished with value: -9227486450.317846 and parameters: {'C': 0.7335152167497777, 'epsilon': 0.518191852936401, 'max_iter': 3000}. Best is trial 9 with value: -5482022959.727126.
[I 2024-12-22 21:03:46,909] Trial 11 finished with value: -8650774788.867422 and parameters: {'C': 1.691522279900354, 'epsilon': 0.34628463827072203, 'max_iter': 1000}. Best is trial 9 with value: -5482022959.727126.
[I 2024-12-22 21:03:46,915] Trial 14 finished with value: -5574769517.466896 and parameters: {'C': 8.781599384771129, 'epsilon': 0.058988049097410726, 'max_iter': 3000}. Best is trial 9 with value: -5482022959.727126.
[I 2024-12-22 21:03:46,920] Trial 15 finished with value: -7255157948.214193 and parameters: {'C': 4.316635545041303, 'epsilon': 0.08020111804112678, 'max_iter': 3000}. Best is trial 9 with value: -5482022959.727126.
[I 2024-12-22 21:03:46,923] Trial 17 finished with value: -5863741964.506172 and
```

```
parameters: {'C': 7.7758059382899125, 'epsilon': 0.7531607576097246, 'max_iter': 3000}. Best is trial 9 with value: -5482022959.727126.
[I 2024-12-22 21:03:47,064] Trial 20 finished with value: -8042131255.210551 and parameters: {'C': 2.771487519346391, 'epsilon': 0.3190121846097587, 'max_iter': 10000}. Best is trial 9 with value: -5482022959.727126.
[I 2024-12-22 21:03:47,130] Trial 21 finished with value: -9356272913.793097 and parameters: {'C': 0.5271042656027578, 'epsilon': 0.7552051557290426, 'max_iter': 2000}. Best is trial 9 with value: -5482022959.727126.
[I 2024-12-22 21:03:47,135] Trial 22 finished with value: -9354803470.066484 and parameters: {'C': 0.529446944776401, 'epsilon': 0.7696681170135834, 'max_iter': 8000}. Best is trial 9 with value: -5482022959.727126.
[I 2024-12-22 21:03:47,148] Trial 23 finished with value: -6143184823.79965 and parameters: {'C': 6.935719513343974, 'epsilon': 0.08232262378370685, 'max_iter': 10000}. Best is trial 9 with value: -5482022959.727126.
[I 2024-12-22 21:03:47,167] Trial 24 finished with value: -5335986202.597931 and parameters: {'C': 9.808268895562904, 'epsilon': 0.019234680792785452, 'max_iter': 10000}. Best is trial 24 with value: -5335986202.597931.
[I 2024-12-22 21:03:47,210] Trial 28 finished with value: -7070058030.96716 and parameters: {'C': 4.71218817160886, 'epsilon': 0.011731899840430098, 'max_iter': 4000}. Best is trial 24 with value: -5335986202.597931.
[I 2024-12-22 21:03:47,214] Trial 25 finished with value: -5345650918.742726 and parameters: {'C': 9.763058939694602, 'epsilon': 0.08603769333674569, 'max_iter': 10000}. Best is trial 24 with value: -5335986202.597931.
[I 2024-12-22 21:03:47,230] Trial 26 finished with value: -5316529929.304403 and parameters: {'C': 9.894845401995912, 'epsilon': 0.41090369313792746, 'max_iter': 10000}. Best is trial 26 with value: -5316529929.304403.
[I 2024-12-22 21:03:47,269] Trial 29 finished with value: -7128751856.648491 and parameters: {'C': 4.585754441930163, 'epsilon': 0.01802470239301953, 'max_iter': 4000}. Best is trial 26 with value: -5316529929.304403.
[I 2024-12-22 21:03:47,298] Trial 27 finished with value: -7031893038.751314 and parameters: {'C': 4.794004384904663, 'epsilon': 0.038903026903493, 'max_iter': 4000}. Best is trial 26 with value: -5316529929.304403.
[I 2024-12-22 21:03:47,314] Trial 32 finished with value: -6917808061.390909 and parameters: {'C': 5.041456538332483, 'epsilon': 0.05613788628319347, 'max_iter': 4000}. Best is trial 26 with value: -5316529929.304403.
[I 2024-12-22 21:03:47,333] Trial 30 finished with value: -7102194188.767023 and parameters: {'C': 4.642917799053576, 'epsilon': 0.01068332444343384, 'max_iter': 4000}. Best is trial 26 with value: -5316529929.304403.
[I 2024-12-22 21:03:47,357] Trial 31 finished with value: -7109274886.198626 and parameters: {'C': 4.626943811296015, 'epsilon': 0.25105464100661745, 'max_iter': 4000}. Best is trial 26 with value: -5316529929.304403.
[I 2024-12-22 21:03:47,414] Trial 34 finished with value: -7398866244.294644 and parameters: {'C': 4.014720842636496, 'epsilon': 0.2368863519387682, 'max_iter': 4000}. Best is trial 26 with value: -5316529929.304403.
[I 2024-12-22 21:03:47,427] Trial 33 finished with value: -6786651706.968242 and parameters: {'C': 5.333433833776075, 'epsilon': 0.027226359619183127, 'max_iter': 4000}. Best is trial 26 with value: -5316529929.304403.
[I 2024-12-22 21:03:47,452] Trial 35 finished with value: -5473291047.21646 and parameters: {'C': 9.205043253923465, 'epsilon': 0.024154336448257346, 'max_iter': 8000}. Best is trial 26 with value: -5316529929.304403.
[I 2024-12-22 21:03:47,524] Trial 38 finished with value: -6821859453.752382 and parameters: {'C': 5.254139775021045, 'epsilon': 0.23384953847784276, 'max_iter': 4000}. Best is trial 26 with value: -5316529929.304403.
[I 2024-12-22 21:03:47,525] Trial 39 finished with value: -7061693527.196625 and parameters: {'C': 4.730165460004301, 'epsilon': 0.1850690259397246, 'max_iter': 4000}. Best is trial 26 with value: -5316529929.304403.
[I 2024-12-22 21:03:47,532] Trial 36 finished with value: -6733338344.971961 and parameters: {'C': 5.454171764608352, 'epsilon': 0.011202838696863233, 'max_iter': 4000}. Best is trial 26 with value: -5316529929.304403.
[I 2024-12-22 21:03:47,537] Trial 37 finished with value: -5305000311.537096 and
```

```

parameters: {'C': 9.960797228575068, 'epsilon': 0.011270017942272094, 'max_iter': 4000}. Best is trial 37 with value: -5305000311.537096.
[I 2024-12-22 21:03:47,565] Trial 40 finished with value: -6928286912.538698 and parameters: {'C': 5.018518027500013, 'epsilon': 0.20922740182225658, 'max_iter': 4000}. Best is trial 37 with value: -5305000311.537096.
[I 2024-12-22 21:03:47,569] Trial 42 finished with value: -6795231623.852233 and parameters: {'C': 5.3137476395051095, 'epsilon': 0.24658394821204713, 'max_iter': 9000}. Best is trial 37 with value: -5305000311.537096.
[I 2024-12-22 21:03:47,575] Trial 41 finished with value: -7244039872.14829 and parameters: {'C': 4.3396164781850475, 'epsilon': 0.20934668459332018, 'max_iter': 9000}. Best is trial 37 with value: -5305000311.537096.
[I 2024-12-22 21:03:47,589] Trial 43 finished with value: -9620324752.032894 and parameters: {'C': 0.11168659125955625, 'epsilon': 0.21928722253409824, 'max_iter': 9000}. Best is trial 37 with value: -5305000311.537096.
[I 2024-12-22 21:03:47,610] Trial 44 finished with value: -5307095093.002396 and parameters: {'C': 9.948054798387282, 'epsilon': 0.18689411315870116, 'max_iter': 9000}. Best is trial 37 with value: -5305000311.537096.
[I 2024-12-22 21:03:47,617] Trial 45 finished with value: -5464194603.413203 and parameters: {'C': 9.239627194220581, 'epsilon': 0.1471226948745203, 'max_iter': 9000}. Best is trial 37 with value: -5305000311.537096.
[I 2024-12-22 21:03:47,623] Trial 46 finished with value: -5463711174.630527 and parameters: {'C': 9.242223804000547, 'epsilon': 0.14946879513688272, 'max_iter': 9000}. Best is trial 37 with value: -5305000311.537096.
[I 2024-12-22 21:03:47,630] Trial 47 finished with value: -5373515442.838908 and parameters: {'C': 9.62088378637131, 'epsilon': 0.41317026637585985, 'max_iter': 9000}. Best is trial 37 with value: -5305000311.537096.
[I 2024-12-22 21:03:47,631] Trial 49 finished with value: -6347898362.042506 and parameters: {'C': 6.38340297728059, 'epsilon': 0.42647937450442597, 'max_iter': 9000}. Best is trial 37 with value: -5305000311.537096.
[I 2024-12-22 21:03:47,636] Trial 48 finished with value: -5370429144.189099 and parameters: {'C': 9.633108709826647, 'epsilon': 0.4376983618019127, 'max_iter': 9000}. Best is trial 37 with value: -5305000311.537096.

Best hyperparameters: {'C': 9.960797228575068, 'epsilon': 0.011270017942272094, 'max_iter': 4000}

```

MODEL EVALUATION

```

In [47]: best_model = LinearSVR(**study.best_params, random_state=42)
best_model.fit(X_train_scaled, y_train)

y_pred = best_model.predict(X_test_scaled)

mse = mean_squared_error(y_test, y_pred)
rmse = np.sqrt(mse)
mape = mean_absolute_percentage_error(y_test, y_pred)
r2 = r2_score(y_test, y_pred)

print(f"Mean Squared Error (MSE): {mse}")
print(f"Mean Absolute Percentage Error (MAPE): {mape}")
print(f"Root Mean Squared Error (RMSE): {rmse}")
print(f"R-squared (R²): {r2}")

```

Mean Squared Error (MSE): 5108027618.897247
 Mean Absolute Percentage Error (MAPE): 1.1513973628318943e+19
 Root Mean Squared Error (RMSE): 71470.46676003486
 R-squared (R²): -0.32375854387298175

Model Evaluation Summary:

For {'C': 9.960797228575068, 'epsilon': 0.011270017942272094, 'max_iter': 4000} hyperparameters. The MSE and RMSE indicate significant error in the model's predictions, with an RMSE over 71,000. The extremely high MAPE suggests the predictions are far from the actual values. This model performed the worst, with a negative R², indicating it couldn't find a suitable linear relationship between the variables. This suggests the data doesn't fit well with a linear model.

NuSVR

```
In [21]: X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_
scaler = StandardScaler()
X_train_scaled = scaler.fit_transform(X_train)
X_test_scaled = scaler.transform(X_test)

def objective(trial):
    C = trial.suggest_float("C", 0.1, 10.0, log=True)
    nu = trial.suggest_float("nu", 0.01, 1.0)
    max_iter = trial.suggest_int("max_iter", 7000, 30000, step=1000)

    model = NuSVR(C=C, nu=nu, max_iter=max_iter)

    score = cross_val_score(model, X_train_scaled, y_train, cv=5, scoring="neg_r
    return score

study = optuna.create_study(direction="maximize")
study.optimize(objective, n_trials=50, n_jobs=-1)

print("Best hyperparameters:", study.best_params)
```

```
[I 2024-12-23 10:25:27,210] A new study created in memory with name: no-name-5594
1e88-d9d1-4ab7-bbe7-bc8871c80db1
```

```
[I 2024-12-23 10:25:37,199] Trial 18 finished with value: -3967441167.218882 and parameters: {'C': 0.16310191192844276, 'nu': 0.06999868608030786, 'max_iter': 2200}. Best is trial 18 with value: -3967441167.218882.
[I 2024-12-23 10:25:37,982] Trial 5 finished with value: -3942708300.86189 and parameters: {'C': 0.12894942738261583, 'nu': 0.08876983485650145, 'max_iter': 21000}. Best is trial 5 with value: -3942708300.86189.
[I 2024-12-23 10:25:39,282] Trial 17 finished with value: -3931714813.067441 and parameters: {'C': 1.6972394572426766, 'nu': 0.09788258738504656, 'max_iter': 14000}. Best is trial 17 with value: -3931714813.067441.
[I 2024-12-23 10:25:40,198] Trial 0 finished with value: -3910488551.658507 and parameters: {'C': 1.8919108781844876, 'nu': 0.1222725616120193, 'max_iter': 13000}. Best is trial 0 with value: -3910488551.658507.
[I 2024-12-23 10:25:41,864] Trial 10 finished with value: -3900978398.491342 and parameters: {'C': 0.8308876091622519, 'nu': 0.16192734373333872, 'max_iter': 20000}. Best is trial 10 with value: -3900978398.491342.
[I 2024-12-23 10:25:48,502] Trial 12 finished with value: -3941189361.0961404 and parameters: {'C': 0.2674931376105432, 'nu': 0.3191662821696147, 'max_iter': 10000}. Best is trial 10 with value: -3900978398.491342.
[I 2024-12-23 10:25:49,502] Trial 8 finished with value: -3935063729.789824 and parameters: {'C': 0.12982935642314689, 'nu': 0.3053441532379354, 'max_iter': 29000}. Best is trial 10 with value: -3900978398.491342.
[I 2024-12-23 10:25:52,856] Trial 1 finished with value: -3960319158.905336 and parameters: {'C': 8.950451750015674, 'nu': 0.3732841014343935, 'max_iter': 9000}. Best is trial 10 with value: -3900978398.491342.
[I 2024-12-23 10:25:54,458] Trial 13 finished with value: -3994052140.6421065 and parameters: {'C': 0.37449156914015325, 'nu': 0.41105313679573824, 'max_iter': 25000}. Best is trial 10 with value: -3900978398.491342.
[I 2024-12-23 10:25:56,411] Trial 15 finished with value: -4034166383.0641885 and parameters: {'C': 0.35201579614274536, 'nu': 0.4714039940013766, 'max_iter': 17000}. Best is trial 10 with value: -3900978398.491342.
[I 2024-12-23 10:25:58,388] Trial 7 finished with value: -4034501475.8286195 and parameters: {'C': 0.7000051139138105, 'nu': 0.47299287071603985, 'max_iter': 28000}. Best is trial 10 with value: -3900978398.491342.
[I 2024-12-23 10:26:00,939] Trial 14 finished with value: -4077365963.6466913 and parameters: {'C': 0.21458041686249316, 'nu': 0.5318411291143007, 'max_iter': 19000}. Best is trial 10 with value: -3900978398.491342.
[I 2024-12-23 10:26:01,936] Trial 16 finished with value: -4085755333.1412673 and parameters: {'C': 1.7122949658426223, 'nu': 0.5475932653050516, 'max_iter': 14000}. Best is trial 10 with value: -3900978398.491342.
[I 2024-12-23 10:26:02,603] Trial 9 finished with value: -4075343008.443148 and parameters: {'C': 0.19394471009185488, 'nu': 0.5294509272014217, 'max_iter': 27000}. Best is trial 10 with value: -3900978398.491342.
[I 2024-12-23 10:26:04,709] Trial 2 finished with value: -4150551845.896907 and parameters: {'C': 0.8791996681687385, 'nu': 0.6255471112519442, 'max_iter': 8000}. Best is trial 10 with value: -3900978398.491342.
[I 2024-12-23 10:26:06,205] Trial 11 finished with value: -4138063401.54208 and parameters: {'C': 5.882416376130862, 'nu': 0.6301191316881581, 'max_iter': 18000}. Best is trial 10 with value: -3900978398.491342.
[I 2024-12-23 10:26:06,328] Trial 3 finished with value: -4201782569.4490614 and parameters: {'C': 0.7942653518400269, 'nu': 0.6758681925508904, 'max_iter': 7000}. Best is trial 10 with value: -3900978398.491342.
[I 2024-12-23 10:26:09,040] Trial 19 finished with value: -4175242628.3709044 and parameters: {'C': 4.321256205256322, 'nu': 0.7240724776648217, 'max_iter': 12000}. Best is trial 10 with value: -3900978398.491342.
[I 2024-12-23 10:26:13,530] Trial 21 finished with value: -4056484958.808419 and parameters: {'C': 0.34654422986863104, 'nu': 0.5077862403149586, 'max_iter': 17000}. Best is trial 10 with value: -3900978398.491342.
[I 2024-12-23 10:26:14,251] Trial 25 finished with value: -3915173609.156255 and parameters: {'C': 0.32229973125481576, 'nu': 0.25325414799039714, 'max_iter': 22000}. Best is trial 10 with value: -3900978398.491342.
```

```
[I 2024-12-23 10:26:14,300] Trial 22 finished with value: -4044489597.1512957 and parameters: {'C': 0.6562380337258532, 'nu': 0.48835606800131914, 'max_iter': 24000}. Best is trial 10 with value: -3900978398.491342.  
[I 2024-12-23 10:26:15,061] Trial 20 finished with value: -4133289965.131851 and parameters: {'C': 0.277763261780427, 'nu': 0.6013568930507588, 'max_iter': 10000}. Best is trial 10 with value: -3900978398.491342.  
[I 2024-12-23 10:26:15,525] Trial 4 finished with value: -4210054244.734922 and parameters: {'C': 0.25819466516691414, 'nu': 0.8528365901302145, 'max_iter': 23000}. Best is trial 10 with value: -3900978398.491342.  
[I 2024-12-23 10:26:17,322] Trial 6 finished with value: -4294994724.758412 and parameters: {'C': 2.0986590983457973, 'nu': 0.9626156316957797, 'max_iter': 11000}. Best is trial 10 with value: -3900978398.491342.  
[I 2024-12-23 10:26:19,040] Trial 23 finished with value: -4039546045.4419327 and parameters: {'C': 7.632914278931806, 'nu': 0.5045400294194741, 'max_iter': 15000}. Best is trial 10 with value: -3900978398.491342.  
[I 2024-12-23 10:26:22,339] Trial 28 finished with value: -3909897344.5561547 and parameters: {'C': 3.297145013724077, 'nu': 0.24061228292043832, 'max_iter': 24000}. Best is trial 10 with value: -3900978398.491342.  
[I 2024-12-23 10:26:36,552] Trial 24 finished with value: -4080878141.4497275 and parameters: {'C': 0.3753529391450946, 'nu': 0.782489575113266, 'max_iter': 29000}. Best is trial 10 with value: -3900978398.491342.  
[I 2024-12-23 10:26:41,801] Trial 42 finished with value: -3900835209.7525024 and parameters: {'C': 1.5672229546933742, 'nu': 0.18643948951919231, 'max_iter': 20000}. Best is trial 42 with value: -3900835209.7525024.  
[I 2024-12-23 10:26:42,248] Trial 40 finished with value: -3903085761.7133636 and parameters: {'C': 1.4978842481940142, 'nu': 0.2047053962338235, 'max_iter': 20000}. Best is trial 42 with value: -3900835209.7525024.  
[I 2024-12-23 10:26:42,975] Trial 41 finished with value: -3906423777.65565 and parameters: {'C': 1.6302174994121594, 'nu': 0.22210171005755114, 'max_iter': 21000}. Best is trial 42 with value: -3900835209.7525024.  
[I 2024-12-23 10:26:46,391] Trial 26 finished with value: -4055551278.1359367 and parameters: {'C': 1.194210844271386, 'nu': 0.7756173403353888, 'max_iter': 25000}. Best is trial 42 with value: -3900835209.7525024.  
[I 2024-12-23 10:26:46,847] Trial 43 finished with value: -3904974890.396164 and parameters: {'C': 1.3097314497821115, 'nu': 0.21581287280701378, 'max_iter': 20000}. Best is trial 42 with value: -3900835209.7525024.  
[I 2024-12-23 10:26:46,893] Trial 45 finished with value: -3900070749.271015 and parameters: {'C': 3.036661923945966, 'nu': 0.18431142562716707, 'max_iter': 20000}. Best is trial 45 with value: -3900070749.271015.  
[I 2024-12-23 10:26:48,523] Trial 44 finished with value: -3914102056.4999437 and parameters: {'C': 0.505646861930903, 'nu': 0.24993588818420776, 'max_iter': 20000}. Best is trial 45 with value: -3900070749.271015.  
[I 2024-12-23 10:26:48,523] Trial 49 finished with value: -4220889487.998749 and parameters: {'C': 1.1726760846116326, 'nu': 0.0165166727206128, 'max_iter': 19000}. Best is trial 45 with value: -3900070749.271015.  
[I 2024-12-23 10:26:49,991] Trial 27 finished with value: -4034932632.021451 and parameters: {'C': 1.3092861789360595, 'nu': 0.7696339066910508, 'max_iter': 15000}. Best is trial 45 with value: -3900070749.271015.  
[I 2024-12-23 10:26:51,898] Trial 31 finished with value: -4201275279.916066 and parameters: {'C': 2.0682685509722902, 'nu': 0.6806115397912985, 'max_iter': 14000}. Best is trial 45 with value: -3900070749.271015.  
[I 2024-12-23 10:26:52,944] Trial 29 finished with value: -4092359922.1858506 and parameters: {'C': 0.8701307862589779, 'nu': 0.7876637247557091, 'max_iter': 29000}. Best is trial 45 with value: -3900070749.271015.  
[I 2024-12-23 10:26:54,757] Trial 33 finished with value: -3908136561.113784 and parameters: {'C': 4.507907105572252, 'nu': 0.7358021523552918, 'max_iter': 14000}. Best is trial 45 with value: -3900070749.271015.  
[I 2024-12-23 10:26:55,682] Trial 46 finished with value: -3902469285.2077117 and parameters: {'C': 3.386665218063059, 'nu': 0.20662327757009097, 'max_iter': 20000}. Best is trial 45 with value: -3900070749.271015.
```

```
[I 2024-12-23 10:26:55,711] Trial 30 finished with value: -4225239180.431222 and
parameters: {'C': 2.079287331825513, 'nu': 0.8784349882420518, 'max_iter': 1500
0}. Best is trial 45 with value: -3900070749.271015.
[I 2024-12-23 10:26:56,464] Trial 32 finished with value: -4112508569.82782 and p
arameters: {'C': 3.8694034942379862, 'nu': 0.8042867221616322, 'max_iter': 1400
0}. Best is trial 45 with value: -3900070749.271015.
[I 2024-12-23 10:26:56,809] Trial 48 finished with value: -3900469969.690099 and
parameters: {'C': 1.3706213600530313, 'nu': 0.17692873436860101, 'max_iter': 2000
0}. Best is trial 45 with value: -3900070749.271015.
[I 2024-12-23 10:26:56,959] Trial 47 finished with value: -3900434976.9241424 and
parameters: {'C': 3.0409668252670974, 'nu': 0.1907450274303094, 'max_iter': 2000
0}. Best is trial 45 with value: -3900070749.271015.
[I 2024-12-23 10:26:57,785] Trial 34 finished with value: -4253730086.751251 and
parameters: {'C': 3.97494468622137, 'nu': 0.9096701367412388, 'max_iter': 14000}.
Best is trial 45 with value: -3900070749.271015.
[I 2024-12-23 10:26:58,478] Trial 36 finished with value: -4285377476.556357 and
parameters: {'C': 2.5975172070034684, 'nu': 0.9440330878181431, 'max_iter': 1300
0}. Best is trial 45 with value: -3900070749.271015.
[I 2024-12-23 10:26:58,566] Trial 35 finished with value: -4265647723.5168953 and
parameters: {'C': 3.065703286116959, 'nu': 0.9155387592782673, 'max_iter': 1400
0}. Best is trial 45 with value: -3900070749.271015.
[I 2024-12-23 10:26:58,995] Trial 37 finished with value: -4292930620.6092987 and
parameters: {'C': 1.8774681742568893, 'nu': 0.9523893797378195, 'max_iter': 1500
0}. Best is trial 45 with value: -3900070749.271015.
[I 2024-12-23 10:26:59,842] Trial 39 finished with value: -4210773310.8306084 and
parameters: {'C': 2.5624123219779786, 'nu': 0.864633359082447, 'max_iter': 1300
0}. Best is trial 45 with value: -3900070749.271015.
[I 2024-12-23 10:26:59,871] Trial 38 finished with value: -4246769338.326304 and
parameters: {'C': 2.3137800191763507, 'nu': 0.8965452663726055, 'max_iter': 2400
0}. Best is trial 45 with value: -3900070749.271015.
Best hyperparameters: {'C': 3.036661923945966, 'nu': 0.18431142562716707, 'max_it
er': 20000}
```

MODEL EVALUATION

```
In [23]: best_model = NuSVR(**study.best_params)
best_model.fit(X_train_scaled, y_train)

y_pred = best_model.predict(X_test_scaled)

mse = mean_squared_error(y_test, y_pred)
rmse = np.sqrt(mse)
mape = mean_absolute_percentage_error(y_test, y_pred)
r2 = r2_score(y_test, y_pred)

print(f"Mean Squared Error (MSE): {mse}")
print(f"Mean Absolute Percentage Error (MAPE): {mape}")
print(f"Root Mean Squared Error (RMSE): {rmse}")
print(f"R-squared (R2): {r2}")
```

```
Mean Squared Error (MSE): 3863678742.929842
Mean Absolute Percentage Error (MAPE): 1.1880377202283718e+20
Root Mean Squared Error (RMSE): 62158.496948766726
R-squared (R2): -0.0012823203641891823
```

Model Evaluation Summary

The MSE and RMSE indicate significant prediction errors, with an RMSE of about 62,158. The extremely high MAPE suggests that the model's predictions are far off from the

actual values. The negative R^2 value shows that the model fails to capture the underlying patterns in the data, performing worse than a simple mean-based model. NuSVR showed intermediate performance compare to the other SVRs. While it didn't perform as well as the RBF kernel SVR, it handled the dataset's complexity better than the Linear SVR, but still failed to capture much of the data's variability.

SGDRegressor

Now we are testing the SGDRegressor model, using Optuna for hyperparameter tuning. The following hyperparameters are being evaluated:

- Alpha: Regularization strength (ranging from 1e-5 to 300). It controls the penalty applied to the model to prevent overfitting, with larger values leading to stronger regularization.
- Eta0: Initial learning rate (ranging from 1e-5 to 1e-1). This parameter influences how much the model weights the updates to the parameters in each iteration. A smaller eta0 allows for slower but potentially more precise learning, while a larger value speeds up convergence.
- Max Iter: Maximum number of iterations for the solver (ranging from 100 to 1000). This parameter controls the maximum number of passes over the training data. Higher values allow the model more time to optimize.

With the SGDRegressor, we expect to achieve good performance, as it is an efficient, flexible model capable of working well with our dataset through proper tuning of these key hyperparameters.

```
In [25]: X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_state=42)

scaler = StandardScaler()
X_train_scaled = scaler.fit_transform(X_train)
X_test_scaled = scaler.transform(X_test)

def objective(trial):
    alpha = trial.suggest_float('alpha', 1e-5, 300)
    eta0 = trial.suggest_float('eta0', 1e-5, 1e-1)
    max_iter = trial.suggest_int('max_iter', 100, 1000)

    model = SGDRegressor(alpha=alpha, eta0=eta0, max_iter=max_iter, random_state=42)

    score = cross_val_score(model, X_train_scaled, y_train, cv=5, scoring='neg_mean_squared_error')
    return score.mean()

study = optuna.create_study(direction='maximize')
study.optimize(objective, n_trials=500, n_jobs=-1)

print(f"Best Hyperparameters: {study.best_params}")
```

```
[I 2024-12-23 10:27:50,349] A new study created in memory with name: no-name-26d04b9e-3f3c-47e3-bd25-66491c3231b9
[I 2024-12-23 10:27:50,491] Trial 0 finished with value: -3884741486.926847 and parameters: {'alpha': 167.4481891529173, 'eta0': 0.008798808372885073, 'max_iter': 234}. Best is trial 0 with value: -3884741486.926847.
[I 2024-12-23 10:27:50,501] Trial 3 finished with value: -3860764686.8043594 and parameters: {'alpha': 73.31014299624223, 'eta0': 0.004956848305779043, 'max_iter': 725}. Best is trial 3 with value: -3860764686.8043594.
[I 2024-12-23 10:27:50,520] Trial 1 finished with value: -3491028859.7735915 and parameters: {'alpha': 5.018958922371419, 'eta0': 0.0012021952710893394, 'max_iter': 553}. Best is trial 1 with value: -3491028859.7735915.
[I 2024-12-23 10:27:50,534] Trial 5 finished with value: -3915970328.3606315 and parameters: {'alpha': 248.49552628539257, 'eta0': 0.05983418790729203, 'max_iter': 879}. Best is trial 1 with value: -3491028859.7735915.
[I 2024-12-23 10:27:50,545] Trial 9 finished with value: -3887592441.7967787 and parameters: {'alpha': 119.32220736198599, 'eta0': 0.09809169547906973, 'max_iter': 206}. Best is trial 1 with value: -3491028859.7735915.
[I 2024-12-23 10:27:50,551] Trial 4 finished with value: -3913365220.8711486 and parameters: {'alpha': 246.7553579935957, 'eta0': 0.079397338310522, 'max_iter': 830}. Best is trial 1 with value: -3491028859.7735915.
[I 2024-12-23 10:27:50,577] Trial 2 finished with value: -3795362416.196313 and parameters: {'alpha': 26.665348311078606, 'eta0': 0.0029124225640589905, 'max_iter': 173}. Best is trial 1 with value: -3491028859.7735915.
[I 2024-12-23 10:27:50,585] Trial 7 finished with value: -3913350945.1508346 and parameters: {'alpha': 241.34767895119288, 'eta0': 0.07722147740634985, 'max_iter': 921}. Best is trial 1 with value: -3491028859.7735915.
[I 2024-12-23 10:27:50,637] Trial 10 finished with value: -3892072250.8709993 and parameters: {'alpha': 166.13552068651538, 'eta0': 0.03617368231812425, 'max_iter': 360}. Best is trial 1 with value: -3491028859.7735915.
[I 2024-12-23 10:27:50,641] Trial 11 finished with value: -3876801236.0968146 and parameters: {'alpha': 91.51523413204369, 'eta0': 0.020886509010020232, 'max_iter': 915}. Best is trial 1 with value: -3491028859.7735915.
[I 2024-12-23 10:27:50,644] Trial 6 finished with value: -3892126519.877945 and parameters: {'alpha': 169.28224258857117, 'eta0': 0.035162552557002076, 'max_iter': 764}. Best is trial 1 with value: -3491028859.7735915.
[I 2024-12-23 10:27:50,648] Trial 8 finished with value: -3878496956.640519 and parameters: {'alpha': 142.88231825339673, 'eta0': 0.0012299759982609259, 'max_iter': 968}. Best is trial 1 with value: -3491028859.7735915.
[I 2024-12-23 10:27:50,680] Trial 12 finished with value: -3913246296.227816 and parameters: {'alpha': 284.5941125452536, 'eta0': 0.09675223846431627, 'max_iter': 207}. Best is trial 1 with value: -3491028859.7735915.
[I 2024-12-23 10:27:50,695] Trial 14 finished with value: -3891028883.7302384 and parameters: {'alpha': 234.504707549028, 'eta0': 0.013735225498891335, 'max_iter': 584}. Best is trial 1 with value: -3491028859.7735915.
[I 2024-12-23 10:27:50,697] Trial 13 finished with value: -3893504988.1117187 and parameters: {'alpha': 159.55634028004454, 'eta0': 0.0506493392353308, 'max_iter': 382}. Best is trial 1 with value: -3491028859.7735915.
[I 2024-12-23 10:27:50,711] Trial 15 finished with value: -3897529481.7966194 and parameters: {'alpha': 260.34207860818213, 'eta0': 0.03245631613849392, 'max_iter': 799}. Best is trial 1 with value: -3491028859.7735915.
[I 2024-12-23 10:27:50,762] Trial 16 finished with value: -3893899058.4781823 and parameters: {'alpha': 178.8558655786368, 'eta0': 0.04089544561405824, 'max_iter': 375}. Best is trial 1 with value: -3491028859.7735915.
[I 2024-12-23 10:27:50,770] Trial 19 finished with value: -3891278858.461693 and parameters: {'alpha': 273.63177788678104, 'eta0': 0.01033184543499419, 'max_iter': 635}. Best is trial 1 with value: -3491028859.7735915.
[I 2024-12-23 10:27:50,783] Trial 18 finished with value: -3878819342.307714 and parameters: {'alpha': 50.97484341940718, 'eta0': 0.06847578885932849, 'max_iter': 916}. Best is trial 1 with value: -3491028859.7735915.
[I 2024-12-23 10:27:50,850] Trial 17 finished with value: -3878106875.7963424 and
```

```
parameters: {'alpha': 132.28843735139407, 'eta0': 0.0003464696329505272, 'max_iter': 407}. Best is trial 1 with value: -3491028859.7735915.
[I 2024-12-23 10:27:50,857] Trial 20 finished with value: -3894086621.0322876 and parameters: {'alpha': 169.20832647102526, 'eta0': 0.04860720704656565, 'max_iter': 862}. Best is trial 1 with value: -3491028859.7735915.
[I 2024-12-23 10:27:50,858] Trial 21 finished with value: -3854037992.5845194 and parameters: {'alpha': 69.07946643397489, 'eta0': 0.0029932272731259192, 'max_iter': 349}. Best is trial 1 with value: -3491028859.7735915.
[I 2024-12-23 10:27:50,896] Trial 22 finished with value: -3896033058.937271 and parameters: {'alpha': 220.55611829087107, 'eta0': 0.05577525449040471, 'max_iter': 562}. Best is trial 1 with value: -3491028859.7735915.
[I 2024-12-23 10:27:50,933] Trial 23 finished with value: -3879369143.8914046 and parameters: {'alpha': 92.26092660487907, 'eta0': 0.034324720043647394, 'max_iter': 612}. Best is trial 1 with value: -3491028859.7735915.
[I 2024-12-23 10:27:50,946] Trial 27 finished with value: -3888689731.118061 and parameters: {'alpha': 122.18754973323817, 'eta0': 0.0911884641895219, 'max_iter': 212}. Best is trial 1 with value: -3491028859.7735915.
[I 2024-12-23 10:27:50,949] Trial 24 finished with value: -3891267606.8383284 and parameters: {'alpha': 215.7639839511828, 'eta0': 0.01893051163074721, 'max_iter': 984}. Best is trial 1 with value: -3491028859.7735915.
[I 2024-12-23 10:27:50,954] Trial 26 finished with value: -3884053241.6401443 and parameters: {'alpha': 89.46887379420538, 'eta0': 0.08461032023041763, 'max_iter': 288}. Best is trial 1 with value: -3491028859.7735915.
[I 2024-12-23 10:27:50,994] Trial 25 finished with value: -3880795734.236557 and parameters: {'alpha': 85.7274102354444, 'eta0': 0.056376961416283046, 'max_iter': 723}. Best is trial 1 with value: -3491028859.7735915.
[I 2024-12-23 10:27:51,076] Trial 29 finished with value: -3332882920.113015 and parameters: {'alpha': 2.8002983966419315, 'eta0': 0.02380111442724269, 'max_iter': 538}. Best is trial 29 with value: -3332882920.113015.
[I 2024-12-23 10:27:51,078] Trial 30 finished with value: -3728197794.906568 and parameters: {'alpha': 16.10971648578098, 'eta0': 0.021686876990300828, 'max_iter': 544}. Best is trial 29 with value: -3332882920.113015.
[I 2024-12-23 10:27:51,089] Trial 28 finished with value: -3146142936.0238233 and parameters: {'alpha': 1.3753126737601469, 'eta0': 0.022762471811245306, 'max_iter': 473}. Best is trial 28 with value: -3146142936.0238233.
[I 2024-12-23 10:27:51,092] Trial 33 finished with value: -3475674444.936054 and parameters: {'alpha': 4.33649580550912, 'eta0': 0.022356301307165163, 'max_iter': 563}. Best is trial 28 with value: -3146142936.0238233.
[I 2024-12-23 10:27:51,101] Trial 32 finished with value: -3314865509.6106067 and parameters: {'alpha': 2.522145915840973, 'eta0': 0.019132710799534516, 'max_iter': 578}. Best is trial 28 with value: -3146142936.0238233.
[I 2024-12-23 10:27:51,106] Trial 31 finished with value: -3015233028.347834 and parameters: {'alpha': 0.7561468580238042, 'eta0': 0.02417171747414469, 'max_iter': 506}. Best is trial 31 with value: -3015233028.347834.
[I 2024-12-23 10:27:51,148] Trial 35 finished with value: -3300181543.255859 and parameters: {'alpha': 2.48368370456204, 'eta0': 0.022414023040226674, 'max_iter': 114}. Best is trial 31 with value: -3015233028.347834.
[I 2024-12-23 10:27:51,174] Trial 34 finished with value: -3597822758.314248 and parameters: {'alpha': 7.345781375958757, 'eta0': 0.022872615581923585, 'max_iter': 115}. Best is trial 31 with value: -3015233028.347834.
[I 2024-12-23 10:27:51,175] Trial 38 finished with value: -3530933441.130641 and parameters: {'alpha': 5.4333370575579725, 'eta0': 0.022848107158747948, 'max_iter': 120}. Best is trial 31 with value: -3015233028.347834.
[I 2024-12-23 10:27:51,187] Trial 36 finished with value: -2955747532.339892 and parameters: {'alpha': 0.5875190980447371, 'eta0': 0.02152968950685413, 'max_iter': 506}. Best is trial 36 with value: -2955747532.339892.
[I 2024-12-23 10:27:51,187] Trial 37 finished with value: -3068304451.0430174 and parameters: {'alpha': 0.9937723195383983, 'eta0': 0.024847377315895487, 'max_iter': 419}. Best is trial 36 with value: -2955747532.339892.
[I 2024-12-23 10:27:51,203] Trial 39 finished with value: -2966344930.190599 and
```

```
parameters: {'alpha': 0.6308184201125471, 'eta0': 0.022070654360469243, 'max_iter': 126}. Best is trial 36 with value: -2955747532.339892.
[I 2024-12-23 10:27:51,337] Trial 44 finished with value: -3746616593.8718567 and parameters: {'alpha': 18.078794724120947, 'eta0': 0.0253033494486233, 'max_iter': 466}. Best is trial 36 with value: -2955747532.339892.
[I 2024-12-23 10:27:51,341] Trial 41 finished with value: -3402900105.451799 and parameters: {'alpha': 3.447706511866972, 'eta0': 0.017505597458742653, 'max_iter': 109}. Best is trial 36 with value: -2955747532.339892.
[I 2024-12-23 10:27:51,350] Trial 42 finished with value: -3464493948.291365 and parameters: {'alpha': 4.157762264145959, 'eta0': 0.02425848005748572, 'max_iter': 121}. Best is trial 36 with value: -2955747532.339892.
[I 2024-12-23 10:27:51,367] Trial 43 finished with value: -3328418015.9381776 and parameters: {'alpha': 2.755218273951741, 'eta0': 0.02386902156736588, 'max_iter': 112}. Best is trial 36 with value: -2955747532.339892.
[I 2024-12-23 10:27:51,367] Trial 40 finished with value: -3467070215.9700117 and parameters: {'alpha': 4.190445544616029, 'eta0': 0.021441563198344414, 'max_iter': 122}. Best is trial 36 with value: -2955747532.339892.
[I 2024-12-23 10:27:51,403] Trial 45 finished with value: -3326797249.9604445 and parameters: {'alpha': 2.741261236983359, 'eta0': 0.024795445562337568, 'max_iter': 125}. Best is trial 36 with value: -2955747532.339892.
[I 2024-12-23 10:27:51,434] Trial 48 finished with value: -3819031742.489952 and parameters: {'alpha': 34.41614634570814, 'eta0': 0.026539521639938102, 'max_iter': 464}. Best is trial 36 with value: -2955747532.339892.
[I 2024-12-23 10:27:51,449] Trial 46 finished with value: -3239032763.140836 and parameters: {'alpha': 1.9844496866516113, 'eta0': 0.02418061149763569, 'max_iter': 479}. Best is trial 36 with value: -2955747532.339892.
[I 2024-12-23 10:27:51,460] Trial 47 finished with value: -3551813691.1535096 and parameters: {'alpha': 5.950920160690863, 'eta0': 0.023335997856288957, 'max_iter': 485}. Best is trial 36 with value: -2955747532.339892.
[I 2024-12-23 10:27:51,517] Trial 49 finished with value: -3845541358.0038047 and parameters: {'alpha': 38.778164547750876, 'eta0': 0.029740282680991364, 'max_iter': 473}. Best is trial 36 with value: -2955747532.339892.
[I 2024-12-23 10:27:51,538] Trial 50 finished with value: -3815001397.8167048 and parameters: {'alpha': 32.627977677087145, 'eta0': 0.02763198479743331, 'max_iter': 455}. Best is trial 36 with value: -2955747532.339892.
[I 2024-12-23 10:27:51,556] Trial 51 finished with value: -3812099221.45497 and parameters: {'alpha': 31.41226908306325, 'eta0': 0.028785818951039675, 'max_iter': 449}. Best is trial 36 with value: -2955747532.339892.
[I 2024-12-23 10:27:51,590] Trial 54 finished with value: -3839669893.3139358 and parameters: {'alpha': 35.53685616956004, 'eta0': 0.029823119939943576, 'max_iter': 472}. Best is trial 36 with value: -2955747532.339892.
[I 2024-12-23 10:27:51,593] Trial 53 finished with value: -3844784521.7004037 and parameters: {'alpha': 38.06538938836332, 'eta0': 0.030498631516415867, 'max_iter': 456}. Best is trial 36 with value: -2955747532.339892.
[I 2024-12-23 10:27:51,606] Trial 52 finished with value: -3841611925.993721 and parameters: {'alpha': 36.698311880646514, 'eta0': 0.029344928037748432, 'max_iter': 476}. Best is trial 36 with value: -2955747532.339892.
[I 2024-12-23 10:27:51,635] Trial 55 finished with value: -3839616369.7631197 and parameters: {'alpha': 35.828726709408606, 'eta0': 0.02881834808635785, 'max_iter': 479}. Best is trial 36 with value: -2955747532.339892.
[I 2024-12-23 10:27:51,722] Trial 56 finished with value: -3844338741.193597 and parameters: {'alpha': 38.31315893168404, 'eta0': 0.02906500739287384, 'max_iter': 482}. Best is trial 36 with value: -2955747532.339892.
[I 2024-12-23 10:27:51,762] Trial 57 finished with value: -3841852470.344938 and parameters: {'alpha': 36.67706153005871, 'eta0': 0.02979704184469209, 'max_iter': 470}. Best is trial 36 with value: -2955747532.339892.
[I 2024-12-23 10:27:51,764] Trial 61 finished with value: -3840731052.153861 and parameters: {'alpha': 36.11867317955777, 'eta0': 0.02969855681071431, 'max_iter': 451}. Best is trial 36 with value: -2955747532.339892.
[I 2024-12-23 10:27:51,794] Trial 58 finished with value: -3835861235.24549 and p
```

arameters: {'alpha': 33.81158391856302, 'eta0': 0.029492270608952747, 'max_iter': 477}. Best is trial 36 with value: -2955747532.339892.

[I 2024-12-23 10:27:51,809] Trial 60 finished with value: -3839677063.6077185 and parameters: {'alpha': 35.56763532192179, 'eta0': 0.029736873232671567, 'max_iter': 475}. Best is trial 36 with value: -2955747532.339892.

[I 2024-12-23 10:27:51,820] Trial 62 finished with value: -3840462561.918908 and parameters: {'alpha': 35.915610818398186, 'eta0': 0.029899087277237595, 'max_iter': 440}. Best is trial 36 with value: -2955747532.339892.

[I 2024-12-23 10:27:51,824] Trial 59 finished with value: -3850431156.494282 and parameters: {'alpha': 41.92711303555178, 'eta0': 0.02972737774516501, 'max_iter': 486}. Best is trial 36 with value: -2955747532.339892.

[I 2024-12-23 10:27:51,877] Trial 63 finished with value: -3847510242.6523232 and parameters: {'alpha': 39.774083891865914, 'eta0': 0.03030416850084224, 'max_iter': 466}. Best is trial 36 with value: -2955747532.339892.

[I 2024-12-23 10:27:51,921] Trial 64 finished with value: -3831367105.7743607 and parameters: {'alpha': 41.06513097676667, 'eta0': 0.008708585428712667, 'max_iter': 284}. Best is trial 36 with value: -2955747532.339892.

[I 2024-12-23 10:27:51,926] Trial 69 finished with value: -3868637517.2765703 and parameters: {'alpha': 52.21356505169221, 'eta0': 0.03990134274188998, 'max_iter': 300}. Best is trial 36 with value: -2955747532.339892.

[I 2024-12-23 10:27:51,928] Trial 65 finished with value: -3843375406.476014 and parameters: {'alpha': 37.393490245081374, 'eta0': 0.030135469038909454, 'max_iter': 258}. Best is trial 36 with value: -2955747532.339892.

[I 2024-12-23 10:27:51,940] Trial 67 finished with value: -3843683708.0705824 and parameters: {'alpha': 50.316025853837594, 'eta0': 0.009535126945056965, 'max_iter': 680}. Best is trial 36 with value: -2955747532.339892.

[I 2024-12-23 10:27:51,943] Trial 66 finished with value: -3851363398.491229 and parameters: {'alpha': 42.49353793834266, 'eta0': 0.029945208384209568, 'max_iter': 662}. Best is trial 36 with value: -2955747532.339892.

[I 2024-12-23 10:27:51,978] Trial 68 finished with value: -3843606409.1918693 and parameters: {'alpha': 50.31712696417569, 'eta0': 0.00910074057198305, 'max_iter': 286}. Best is trial 36 with value: -2955747532.339892.

[I 2024-12-23 10:27:52,027] Trial 70 finished with value: -3841182827.135936 and parameters: {'alpha': 48.144857596729445, 'eta0': 0.00951254803395538, 'max_iter': 293}. Best is trial 36 with value: -2955747532.339892.

[I 2024-12-23 10:27:52,061] Trial 73 finished with value: -3851799932.6834817 and parameters: {'alpha': 59.302383768229426, 'eta0': 0.00745222104474445, 'max_iter': 318}. Best is trial 36 with value: -2955747532.339892.

[I 2024-12-23 10:27:52,070] Trial 71 finished with value: -3872641028.431633 and parameters: {'alpha': 57.13208454852423, 'eta0': 0.040373226207322595, 'max_iter': 295}. Best is trial 36 with value: -2955747532.339892.

[I 2024-12-23 10:27:52,090] Trial 76 finished with value: -3748584788.3575044 and parameters: {'alpha': 17.390683441854478, 'eta0': 0.00991023238169074, 'max_iter': 669}. Best is trial 36 with value: -2955747532.339892.

[I 2024-12-23 10:27:52,145] Trial 72 finished with value: -3868521583.7697525 and parameters: {'alpha': 52.54115739405382, 'eta0': 0.03908665883955413, 'max_iter': 308}. Best is trial 36 with value: -2955747532.339892.

[I 2024-12-23 10:27:52,149] Trial 75 finished with value: -3872048928.2340546 and parameters: {'alpha': 57.35212054912313, 'eta0': 0.03871419610090866, 'max_iter': 292}. Best is trial 36 with value: -2955747532.339892.

[I 2024-12-23 10:27:52,161] Trial 74 finished with value: -3870925644.544931 and parameters: {'alpha': 55.40347909216449, 'eta0': 0.03934123119441055, 'max_iter': 313}. Best is trial 36 with value: -2955747532.339892.

[I 2024-12-23 10:27:52,191] Trial 79 finished with value: -3769996288.3139663 and parameters: {'alpha': 20.436163521505378, 'eta0': 0.013935558929057042, 'max_iter': 319}. Best is trial 36 with value: -2955747532.339892.

[I 2024-12-23 10:27:52,207] Trial 77 finished with value: -3844855593.596486 and parameters: {'alpha': 54.509918718920794, 'eta0': 0.010649440895464202, 'max_iter': 293}. Best is trial 36 with value: -2955747532.339892.

[I 2024-12-23 10:27:52,216] Trial 78 finished with value: -3768751596.110961 and

parameters: {'alpha': 19.991476611769546, 'eta0': 0.007944223472546275, 'max_iter': 279}. Best is trial 36 with value: -2955747532.339892.

[I 2024-12-23 10:27:52,259] Trial 82 finished with value: -3755783783.283036 and parameters: {'alpha': 19.701062530945045, 'eta0': 0.03961264903942905, 'max_iter': 311}. Best is trial 36 with value: -2955747532.339892.

[I 2024-12-23 10:27:52,281] Trial 81 finished with value: -3869375918.290142 and parameters: {'alpha': 53.60227490528526, 'eta0': 0.03903601596669629, 'max_iter': 314}. Best is trial 36 with value: -2955747532.339892.

[I 2024-12-23 10:27:52,282] Trial 80 finished with value: -3870068578.5443716 and parameters: {'alpha': 54.546353850494995, 'eta0': 0.03891418174532115, 'max_iter': 321}. Best is trial 36 with value: -2955747532.339892.

[I 2024-12-23 10:27:52,330] Trial 83 finished with value: -3768605209.5885744 and parameters: {'alpha': 19.948677430077794, 'eta0': 0.007820600214558921, 'max_iter': 290}. Best is trial 36 with value: -2955747532.339892.

[I 2024-12-23 10:27:52,411] Trial 84 finished with value: -3750519070.2538633 and parameters: {'alpha': 17.41119403693564, 'eta0': 0.015022257354203674, 'max_iter': 520}. Best is trial 36 with value: -2955747532.339892.

[I 2024-12-23 10:27:52,425] Trial 88 finished with value: -3762321097.904147 and parameters: {'alpha': 19.149233910458882, 'eta0': 0.015065970830496794, 'max_iter': 521}. Best is trial 36 with value: -2955747532.339892.

[I 2024-12-23 10:27:52,436] Trial 87 finished with value: -3763093165.2165937 and parameters: {'alpha': 19.268808188721785, 'eta0': 0.014574271326510449, 'max_iter': 516}. Best is trial 36 with value: -2955747532.339892.

[I 2024-12-23 10:27:52,466] Trial 85 finished with value: -3766344440.3987284 and parameters: {'alpha': 19.810718368460766, 'eta0': 0.015219654428339755, 'max_iter': 171}. Best is trial 36 with value: -2955747532.339892.

[I 2024-12-23 10:27:52,467] Trial 86 finished with value: -3768307573.3836813 and parameters: {'alpha': 20.141038628758587, 'eta0': 0.014254205733784464, 'max_iter': 402}. Best is trial 36 with value: -2955747532.339892.

[I 2024-12-23 10:27:52,471] Trial 89 finished with value: -3762230436.4942675 and parameters: {'alpha': 19.121582749701396, 'eta0': 0.013907092936300462, 'max_iter': 158}. Best is trial 36 with value: -2955747532.339892.

[I 2024-12-23 10:27:52,527] Trial 90 finished with value: -3743851801.8536315 and parameters: {'alpha': 16.56309921485091, 'eta0': 0.01724455252268256, 'max_iter': 515}. Best is trial 36 with value: -2955747532.339892.

[I 2024-12-23 10:27:52,564] Trial 92 finished with value: -3771566913.9140425 and parameters: {'alpha': 22.67432383992425, 'eta0': 0.018050870094245306, 'max_iter': 510}. Best is trial 36 with value: -2955747532.339892.

[I 2024-12-23 10:27:52,569] Trial 91 finished with value: -3785447631.2234063 and parameters: {'alpha': 23.564118869756225, 'eta0': 0.014244415014280273, 'max_iter': 528}. Best is trial 36 with value: -2955747532.339892.

[I 2024-12-23 10:27:52,600] Trial 95 finished with value: -3696328509.264109 and parameters: {'alpha': 12.374120178046068, 'eta0': 0.01646613853803814, 'max_iter': 520}. Best is trial 36 with value: -2955747532.339892.

[I 2024-12-23 10:27:52,600] Trial 94 finished with value: -3783774783.9187117 and parameters: {'alpha': 25.4116138376833, 'eta0': 0.016933841835929768, 'max_iter': 176}. Best is trial 36 with value: -2955747532.339892.

[I 2024-12-23 10:27:52,631] Trial 93 finished with value: -3783606092.066569 and parameters: {'alpha': 23.14603233729071, 'eta0': 0.014872283904642004, 'max_iter': 515}. Best is trial 36 with value: -2955747532.339892.

[I 2024-12-23 10:27:52,655] Trial 98 finished with value: -3660931350.4429817 and parameters: {'alpha': 10.061267502423743, 'eta0': 0.018127596376763686, 'max_iter': 156}. Best is trial 36 with value: -2955747532.339892.

[I 2024-12-23 10:27:52,672] Trial 96 finished with value: -3780076231.6301146 and parameters: {'alpha': 24.499299883303998, 'eta0': 0.016976594540638396, 'max_iter': 517}. Best is trial 36 with value: -2955747532.339892.

[I 2024-12-23 10:27:52,721] Trial 97 finished with value: -3709139442.8620934 and parameters: {'alpha': 13.032697229977932, 'eta0': 0.017452348556210025, 'max_iter': 166}. Best is trial 36 with value: -2955747532.339892.

[I 2024-12-23 10:27:52,794] Trial 99 finished with value: -3705863060.771182 and

```
parameters: {'alpha': 13.06701497158601, 'eta0': 0.01473707164586657, 'max_iter': 170}. Best is trial 36 with value: -2955747532.339892.
[I 2024-12-23 10:27:52,800] Trial 101 finished with value: -3681660293.4653063 and parameters: {'alpha': 11.322155329230773, 'eta0': 0.017157923730656534, 'max_iter': 154}. Best is trial 36 with value: -2955747532.339892.
[I 2024-12-23 10:27:52,801] Trial 102 finished with value: -3687472287.556447 and parameters: {'alpha': 11.420571337127031, 'eta0': 0.018697663794866606, 'max_iter': 162}. Best is trial 36 with value: -2955747532.339892.
[I 2024-12-23 10:27:52,802] Trial 100 finished with value: -3707240534.0892706 and parameters: {'alpha': 12.879571836697405, 'eta0': 0.017881294222486202, 'max_iter': 515}. Best is trial 36 with value: -2955747532.339892.
[I 2024-12-23 10:27:52,841] Trial 104 finished with value: -3670986341.9352365 and parameters: {'alpha': 10.703483960990427, 'eta0': 0.019154009817136372, 'max_iter': 162}. Best is trial 36 with value: -2955747532.339892.
[I 2024-12-23 10:27:52,874] Trial 105 finished with value: -3676994187.121999 and parameters: {'alpha': 11.007324777738008, 'eta0': 0.01714963609129658, 'max_iter': 602}. Best is trial 36 with value: -2955747532.339892.
[I 2024-12-23 10:27:52,882] Trial 103 finished with value: -3688173809.9590673 and parameters: {'alpha': 11.741495039424816, 'eta0': 0.016264095630290923, 'max_iter': 160}. Best is trial 36 with value: -2955747532.339892.
[I 2024-12-23 10:27:52,963] Trial 107 finished with value: -3685101035.229439 and parameters: {'alpha': 11.267543472739906, 'eta0': 0.019414197791715007, 'max_iter': 575}. Best is trial 36 with value: -2955747532.339892.
[I 2024-12-23 10:27:53,002] Trial 106 finished with value: -3649882829.763335 and parameters: {'alpha': 9.477053832451467, 'eta0': 0.018648359200860463, 'max_iter': 154}. Best is trial 36 with value: -2955747532.339892.
[I 2024-12-23 10:27:53,007] Trial 108 finished with value: -3691945121.915698 and parameters: {'alpha': 11.728585068173938, 'eta0': 0.01883898959920869, 'max_iter': 587}. Best is trial 36 with value: -2955747532.339892.
[I 2024-12-23 10:27:53,014] Trial 109 finished with value: -2883600333.496223 and parameters: {'alpha': 0.33282258893702893, 'eta0': 0.018798544322780143, 'max_iter': 581}. Best is trial 109 with value: -2883600333.496223.
[I 2024-12-23 10:27:53,035] Trial 111 finished with value: -3677126543.6056 and parameters: {'alpha': 10.763582431076204, 'eta0': 0.01963226888993102, 'max_iter': 145}. Best is trial 109 with value: -2883600333.496223.
[I 2024-12-23 10:27:53,115] Trial 110 finished with value: -3667596253.517186 and parameters: {'alpha': 10.502758480448474, 'eta0': 0.01940536246702988, 'max_iter': 149}. Best is trial 109 with value: -2883600333.496223.
[I 2024-12-23 10:27:53,120] Trial 114 finished with value: -3010257859.328322 and parameters: {'alpha': 0.6702323157852823, 'eta0': 0.033672556246142474, 'max_iter': 587}. Best is trial 109 with value: -2883600333.496223.
[I 2024-12-23 10:27:53,132] Trial 113 finished with value: -3100043923.354783 and parameters: {'alpha': 1.1737830822711381, 'eta0': 0.020186150709765434, 'max_iter': 576}. Best is trial 109 with value: -2883600333.496223.
[I 2024-12-23 10:27:53,145] Trial 112 finished with value: -3672144505.050502 and parameters: {'alpha': 11.08429880945557, 'eta0': 0.03324523855884078, 'max_iter': 604}. Best is trial 109 with value: -2883600333.496223.
[I 2024-12-23 10:27:53,149] Trial 115 finished with value: -3144606556.132758 and parameters: {'alpha': 1.3841894585117926, 'eta0': 0.034357144026111265, 'max_iter': 613}. Best is trial 109 with value: -2883600333.496223.
[I 2024-12-23 10:27:53,150] Trial 117 finished with value: -3063258133.84682 and parameters: {'alpha': 0.9135885472876402, 'eta0': 0.03375291980425152, 'max_iter': 593}. Best is trial 109 with value: -2883600333.496223.
[I 2024-12-23 10:27:53,206] Trial 116 finished with value: -3058880452.907745 and parameters: {'alpha': 0.8930463598198745, 'eta0': 0.03369637459837726, 'max_iter': 612}. Best is trial 109 with value: -2883600333.496223.
[I 2024-12-23 10:27:53,276] Trial 119 finished with value: -2881159527.5576296 and parameters: {'alpha': 0.18447760744323904, 'eta0': 0.02583433076401141, 'max_iter': 622}. Best is trial 119 with value: -2881159527.5576296.
[I 2024-12-23 10:27:53,282] Trial 118 finished with value: -2858374118.683107 and
```

```
parameters: {'alpha': 0.08280900003574732, 'eta0': 0.025826924571308987, 'max_iter': 583}. Best is trial 118 with value: -2858374118.683107.
[I 2024-12-23 10:27:53,312] Trial 120 finished with value: -2997984950.0485754 and parameters: {'alpha': 0.7782436499729339, 'eta0': 0.020519189298435946, 'max_iter': 602}. Best is trial 118 with value: -2858374118.683107.
[I 2024-12-23 10:27:53,341] Trial 122 finished with value: -2861650294.6779222 and parameters: {'alpha': 0.060772474424232836, 'eta0': 0.033117436945962996, 'max_iter': 587}. Best is trial 118 with value: -2858374118.683107.
[I 2024-12-23 10:27:53,348] Trial 121 finished with value: -2925070804.890938 and parameters: {'alpha': 0.42359074817116327, 'eta0': 0.025613763044970227, 'max_iter': 587}. Best is trial 118 with value: -2858374118.683107.
[I 2024-12-23 10:27:53,351] Trial 124 finished with value: -3237783462.6714196 and parameters: {'alpha': 1.9710251180898366, 'eta0': 0.033839323009516496, 'max_iter': 569}. Best is trial 118 with value: -2858374118.683107.
[I 2024-12-23 10:27:53,407] Trial 123 finished with value: -3044239943.5766435 and parameters: {'alpha': 0.8260441537686309, 'eta0': 0.03336130086969255, 'max_iter': 554}. Best is trial 118 with value: -2858374118.683107.
[I 2024-12-23 10:27:53,419] Trial 125 finished with value: -3116485061.1352153 and parameters: {'alpha': 1.1865560820521504, 'eta0': 0.026298523322383114, 'max_iter': 579}. Best is trial 118 with value: -2858374118.683107.
[I 2024-12-23 10:27:53,441] Trial 126 finished with value: -3353709737.559158 and parameters: {'alpha': 3.0556965982282414, 'eta0': 0.0333810914150582, 'max_iter': 423}. Best is trial 118 with value: -2858374118.683107.
[I 2024-12-23 10:27:53,495] Trial 127 finished with value: -2928041750.781062 and parameters: {'alpha': 0.4362046652016769, 'eta0': 0.025799818352373535, 'max_iter': 418}. Best is trial 118 with value: -2858374118.683107.
[I 2024-12-23 10:27:53,528] Trial 128 finished with value: -2976323247.900102 and parameters: {'alpha': 0.5420964518397042, 'eta0': 0.032728333199179914, 'max_iter': 221}. Best is trial 118 with value: -2858374118.683107.
[I 2024-12-23 10:27:53,567] Trial 129 finished with value: -3155400882.4825606 and parameters: {'alpha': 1.3973296411611225, 'eta0': 0.025602002338137496, 'max_iter': 432}. Best is trial 118 with value: -2858374118.683107.
[I 2024-12-23 10:27:53,581] Trial 132 finished with value: -3210871471.5240088 and parameters: {'alpha': 1.7532722757220713, 'eta0': 0.04708906889346627, 'max_iter': 638}. Best is trial 118 with value: -2858374118.683107.
[I 2024-12-23 10:27:53,594] Trial 130 finished with value: -3020278685.6255784 and parameters: {'alpha': 0.7707559347105875, 'eta0': 0.025390446692005197, 'max_iter': 430}. Best is trial 118 with value: -2858374118.683107.
[I 2024-12-23 10:27:53,696] Trial 134 finished with value: -3220318199.6260314 and parameters: {'alpha': 1.824542937170432, 'eta0': 0.04624549867470796, 'max_iter': 634}. Best is trial 118 with value: -2858374118.683107.
[I 2024-12-23 10:27:53,710] Trial 131 finished with value: -2926017947.611327 and parameters: {'alpha': 0.38737237911239286, 'eta0': 0.0334923974096515, 'max_iter': 555}. Best is trial 118 with value: -2858374118.683107.
[I 2024-12-23 10:27:53,739] Trial 135 finished with value: -3121618081.015753 and parameters: {'alpha': 1.2246923546708897, 'eta0': 0.044388795178211815, 'max_iter': 637}. Best is trial 118 with value: -2858374118.683107.
[I 2024-12-23 10:27:53,745] Trial 133 finished with value: -3000493112.782679 and parameters: {'alpha': 0.6120515150014304, 'eta0': 0.03651835054499555, 'max_iter': 629}. Best is trial 118 with value: -2858374118.683107.
[I 2024-12-23 10:27:53,749] Trial 138 finished with value: -3125469921.1711006 and parameters: {'alpha': 1.2670521901364178, 'eta0': 0.03693785925313291, 'max_iter': 633}. Best is trial 118 with value: -2858374118.683107.
[I 2024-12-23 10:27:53,750] Trial 136 finished with value: -3108874284.0519 and parameters: {'alpha': 1.1782369766855132, 'eta0': 0.03533810733866803, 'max_iter': 623}. Best is trial 118 with value: -2858374118.683107.
[I 2024-12-23 10:27:53,812] Trial 137 finished with value: -2947665114.643567 and parameters: {'alpha': 0.29620559369439414, 'eta0': 0.04706530188535102, 'max_iter': 642}. Best is trial 118 with value: -2858374118.683107.
[I 2024-12-23 10:27:53,851] Trial 142 finished with value: -3914257561.3836846 an
```

d parameters: {'alpha': 299.7375873103555, 'eta0': 0.04723794736655239, 'max_iter': 640}. Best is trial 118 with value: -2858374118.683107.

[I 2024-12-23 10:27:53,855] Trial 141 finished with value: -3896701841.6896324 and parameters: {'alpha': 299.4509150932744, 'eta0': 0.026728538225380363, 'max_iter': 638}. Best is trial 118 with value: -2858374118.683107.

[I 2024-12-23 10:27:53,865] Trial 140 finished with value: -3834429854.7745104 and parameters: {'alpha': 28.918378637044825, 'eta0': 0.044023543612657506, 'max_iter': 640}. Best is trial 118 with value: -2858374118.683107.

[I 2024-12-23 10:27:53,883] Trial 139 finished with value: -3800968494.505974 and parameters: {'alpha': 27.787102540730054, 'eta0': 0.026148459112691157, 'max_iter': 631}. Best is trial 118 with value: -2858374118.683107.

[I 2024-12-23 10:27:53,901] Trial 143 finished with value: -3826278498.6226625 and parameters: {'alpha': 28.34111555985712, 'eta0': 0.03644101316712141, 'max_iter': 651}. Best is trial 118 with value: -2858374118.683107.

[I 2024-12-23 10:27:53,925] Trial 144 finished with value: -2897218279.327516 and parameters: {'alpha': 0.18831583163626098, 'eta0': 0.03681994439520355, 'max_iter': 638}. Best is trial 118 with value: -2858374118.683107.

[I 2024-12-23 10:27:53,945] Trial 145 finished with value: -3824758914.112981 and parameters: {'alpha': 27.945228600472156, 'eta0': 0.03595668303546276, 'max_iter': 648}. Best is trial 118 with value: -2858374118.683107.

[I 2024-12-23 10:27:53,968] Trial 147 finished with value: -3896656862.1189804 and parameters: {'alpha': 299.41263411361024, 'eta0': 0.026268010042244803, 'max_iter': 632}. Best is trial 118 with value: -2858374118.683107.

[I 2024-12-23 10:27:53,972] Trial 146 finished with value: -3895650505.8979135 and parameters: {'alpha': 203.9333279617605, 'eta0': 0.03560071649343398, 'max_iter': 634}. Best is trial 118 with value: -2858374118.683107.

[I 2024-12-23 10:27:54,065] Trial 151 finished with value: -3826470236.1323633 and parameters: {'alpha': 28.496211628063172, 'eta0': 0.0360171584222896, 'max_iter': 555}. Best is trial 118 with value: -2858374118.683107.

[I 2024-12-23 10:27:54,071] Trial 148 finished with value: -3834719128.810238 and parameters: {'alpha': 29.07346923387675, 'eta0': 0.04379264469618687, 'max_iter': 547}. Best is trial 118 with value: -2858374118.683107.

[I 2024-12-23 10:27:54,088] Trial 150 finished with value: -3830766486.887601 and parameters: {'alpha': 29.96223537321348, 'eta0': 0.03622646364921846, 'max_iter': 650}. Best is trial 118 with value: -2858374118.683107.

[I 2024-12-23 10:27:54,108] Trial 149 finished with value: -3826481869.8882036 and parameters: {'alpha': 28.24926055792198, 'eta0': 0.03719041210580129, 'max_iter': 550}. Best is trial 118 with value: -2858374118.683107.

[I 2024-12-23 10:27:54,171] Trial 152 finished with value: -3799758922.2809577 and parameters: {'alpha': 27.387497283839185, 'eta0': 0.027037412577494636, 'max_iter': 551}. Best is trial 118 with value: -2858374118.683107.

[I 2024-12-23 10:27:54,266] Trial 153 finished with value: -3826248943.2542343 and parameters: {'alpha': 28.33696109886492, 'eta0': 0.03641445448901532, 'max_iter': 713}. Best is trial 118 with value: -2858374118.683107.

[I 2024-12-23 10:27:54,267] Trial 155 finished with value: -3883317124.403867 and parameters: {'alpha': 110.20683595589706, 'eta0': 0.03670525251732558, 'max_iter': 692}. Best is trial 118 with value: -2858374118.683107.

[I 2024-12-23 10:27:54,270] Trial 154 finished with value: -3898378462.300061 and parameters: {'alpha': 183.2797337284732, 'eta0': 0.026974365501648397, 'max_iter': 729}. Best is trial 118 with value: -2858374118.683107.

[I 2024-12-23 10:27:54,334] Trial 156 finished with value: -3833791829.415612 and parameters: {'alpha': 26.717209793809413, 'eta0': 0.05391755717363004, 'max_iter': 686}. Best is trial 118 with value: -2858374118.683107.

[I 2024-12-23 10:27:54,401] Trial 157 finished with value: -3842794902.511716 and parameters: {'alpha': 29.28245206919446, 'eta0': 0.056842169170411044, 'max_iter': 684}. Best is trial 118 with value: -2858374118.683107.

[I 2024-12-23 10:27:54,468] Trial 160 finished with value: -3624403626.8620253 and parameters: {'alpha': 8.360356648795948, 'eta0': 0.021783221812646344, 'max_iter': 697}. Best is trial 118 with value: -2858374118.683107.

[I 2024-12-23 10:27:54,470] Trial 161 finished with value: -3899722020.8053703 an

d parameters: {'alpha': 98.61724575763034, 'eta0': 0.054440748523748604, 'max_iter': 681}. Best is trial 118 with value: -2858374118.683107.

[I 2024-12-23 10:27:54,481] Trial 159 finished with value: -3880031538.2430573 and parameters: {'alpha': 101.30732008855625, 'eta0': 0.022077191289345828, 'max_iter': 699}. Best is trial 118 with value: -2858374118.683107.

[I 2024-12-23 10:27:54,540] Trial 162 finished with value: -3580566211.6939025 and parameters: {'alpha': 6.95238710654577, 'eta0': 0.055854671204963395, 'max_iter': 714}. Best is trial 118 with value: -2858374118.683107.

[I 2024-12-23 10:27:54,541] Trial 158 finished with value: -3891300711.657088 and parameters: {'alpha': 178.40919129700615, 'eta0': 0.022057749191650954, 'max_iter': 547}. Best is trial 118 with value: -2858374118.683107.

[I 2024-12-23 10:27:54,579] Trial 163 finished with value: -3592310817.0718536 and parameters: {'alpha': 7.358498460123841, 'eta0': 0.050714668599995474, 'max_iter': 704}. Best is trial 118 with value: -2858374118.683107.

[I 2024-12-23 10:27:54,600] Trial 165 finished with value: -3889727554.955303 and parameters: {'alpha': 120.18816541831895, 'eta0': 0.06077761034088237, 'max_iter': 723}. Best is trial 118 with value: -2858374118.683107.

[I 2024-12-23 10:27:54,622] Trial 164 finished with value: -3885884782.1100492 and parameters: {'alpha': 102.03769988906527, 'eta0': 0.05425149916803151, 'max_iter': 695}. Best is trial 118 with value: -2858374118.683107.

[I 2024-12-23 10:27:54,677] Trial 168 finished with value: -3604580255.5829253 and parameters: {'alpha': 7.802177055714121, 'eta0': 0.051809391592089, 'max_iter': 700}. Best is trial 118 with value: -2858374118.683107.

[I 2024-12-23 10:27:54,681] Trial 166 finished with value: -3624101386.682605 and parameters: {'alpha': 8.591506646433427, 'eta0': 0.05385322332085436, 'max_iter': 706}. Best is trial 118 with value: -2858374118.683107.

[I 2024-12-23 10:27:54,687] Trial 170 finished with value: -3594430966.582751 and parameters: {'alpha': 7.2120614804574465, 'eta0': 0.022040495610133017, 'max_iter': 702}. Best is trial 118 with value: -2858374118.683107.

[I 2024-12-23 10:27:54,698] Trial 169 finished with value: -3573978865.6261606 and parameters: {'alpha': 6.72840460031955, 'eta0': 0.06022717584531904, 'max_iter': 769}. Best is trial 118 with value: -2858374118.683107.

[I 2024-12-23 10:27:54,723] Trial 171 finished with value: -3585705176.001597 and parameters: {'alpha': 7.132906889648035, 'eta0': 0.0510771336793911, 'max_iter': 714}. Best is trial 118 with value: -2858374118.683107.

[I 2024-12-23 10:27:54,727] Trial 167 finished with value: -3886662287.9798975 and parameters: {'alpha': 105.89387707579823, 'eta0': 0.05372303125104122, 'max_iter': 541}. Best is trial 118 with value: -2858374118.683107.

[I 2024-12-23 10:27:54,745] Trial 172 finished with value: -3599574605.4440002 and parameters: {'alpha': 7.617659771395871, 'eta0': 0.05075154277130747, 'max_iter': 697}. Best is trial 118 with value: -2858374118.683107.

[I 2024-12-23 10:27:54,799] Trial 175 finished with value: -3605058126.5343313 and parameters: {'alpha': 7.606777582433912, 'eta0': 0.02275864656554568, 'max_iter': 199}. Best is trial 118 with value: -2858374118.683107.

[I 2024-12-23 10:27:54,844] Trial 173 finished with value: -3598529062.9001837 and parameters: {'alpha': 7.5670371365012254, 'eta0': 0.05598106965648827, 'max_iter': 215}. Best is trial 118 with value: -2858374118.683107.

[I 2024-12-23 10:27:54,851] Trial 174 finished with value: -3610829875.039792 and parameters: {'alpha': 8.045911620122443, 'eta0': 0.04174553401120622, 'max_iter': 220}. Best is trial 118 with value: -2858374118.683107.

[I 2024-12-23 10:27:54,885] Trial 176 finished with value: -3603532095.247463 and parameters: {'alpha': 7.730372995339985, 'eta0': 0.06150230931101165, 'max_iter': 599}. Best is trial 118 with value: -2858374118.683107.

[I 2024-12-23 10:27:54,959] Trial 177 finished with value: -3553688757.7890115 and parameters: {'alpha': 6.1247021480147295, 'eta0': 0.06345402585279045, 'max_iter': 204}. Best is trial 118 with value: -2858374118.683107.

[I 2024-12-23 10:27:54,995] Trial 179 finished with value: -3591310344.5501084 and parameters: {'alpha': 7.12725343233942, 'eta0': 0.023283670198188975, 'max_iter': 227}. Best is trial 118 with value: -2858374118.683107.

[I 2024-12-23 10:27:55,026] Trial 178 finished with value: -3597733547.624177 and

```
parameters: {'alpha': 7.511140609921315, 'eta0': 0.06268807916949436, 'max_iter': 602}. Best is trial 118 with value: -2858374118.683107.
[I 2024-12-23 10:27:55,070] Trial 182 finished with value: -3605564335.048639 and parameters: {'alpha': 7.647626300437388, 'eta0': 0.02388901625924745, 'max_iter': 232}. Best is trial 118 with value: -2858374118.683107.
[I 2024-12-23 10:27:55,072] Trial 180 finished with value: -3892294678.385745 and parameters: {'alpha': 141.31573630054507, 'eta0': 0.0631747875102042, 'max_iter': 195}. Best is trial 118 with value: -2858374118.683107.
[I 2024-12-23 10:27:55,077] Trial 181 finished with value: -3595844639.719392 and parameters: {'alpha': 7.4291145015567945, 'eta0': 0.06543003761617694, 'max_iter': 590}. Best is trial 118 with value: -2858374118.683107.
[I 2024-12-23 10:27:55,125] Trial 184 finished with value: -3596234688.603987 and parameters: {'alpha': 7.322375574751557, 'eta0': 0.024719911774683502, 'max_iter': 353}. Best is trial 118 with value: -2858374118.683107.
[I 2024-12-23 10:27:55,135] Trial 185 finished with value: -3564226440.119963 and parameters: {'alpha': 6.808205446060695, 'eta0': 0.03209370764933095, 'max_iter': 345}. Best is trial 118 with value: -2858374118.683107.
[I 2024-12-23 10:27:55,203] Trial 183 finished with value: -3570126996.3898315 and parameters: {'alpha': 6.983905006124754, 'eta0': 0.03189923336897222, 'max_iter': 228}. Best is trial 118 with value: -2858374118.683107.
[I 2024-12-23 10:27:55,214] Trial 186 finished with value: -3733241183.952386 and parameters: {'alpha': 16.47424340474228, 'eta0': 0.032111253751221876, 'max_iter': 237}. Best is trial 118 with value: -2858374118.683107.
[I 2024-12-23 10:27:55,261] Trial 188 finished with value: -3719541553.112851 and parameters: {'alpha': 14.917048509537699, 'eta0': 0.030982747159841614, 'max_iter': 592}. Best is trial 118 with value: -2858374118.683107.
[I 2024-12-23 10:27:55,279] Trial 189 finished with value: -3713943195.0240707 and parameters: {'alpha': 14.367719789412032, 'eta0': 0.03174381555077663, 'max_iter': 234}. Best is trial 118 with value: -2858374118.683107.
[I 2024-12-23 10:27:55,287] Trial 187 finished with value: -3888326739.6491904 and parameters: {'alpha': 138.0864799154681, 'eta0': 0.03171396811083992, 'max_iter': 358}. Best is trial 118 with value: -2858374118.683107.
[I 2024-12-23 10:27:55,298] Trial 191 finished with value: -3716631909.3951545 and parameters: {'alpha': 14.62106302303095, 'eta0': 0.030999586562138283, 'max_iter': 359}. Best is trial 118 with value: -2858374118.683107.
[I 2024-12-23 10:27:55,332] Trial 190 finished with value: -3723186030.395152 and parameters: {'alpha': 15.310273739815639, 'eta0': 0.03144662634544639, 'max_iter': 590}. Best is trial 118 with value: -2858374118.683107.
[I 2024-12-23 10:27:55,358] Trial 192 finished with value: -3723515110.6002975 and parameters: {'alpha': 15.328882287455745, 'eta0': 0.030485778902676626, 'max_iter': 383}. Best is trial 118 with value: -2858374118.683107.
[I 2024-12-23 10:27:55,386] Trial 193 finished with value: -3722400719.9704237 and parameters: {'alpha': 15.545620304251319, 'eta0': 0.024260023118158343, 'max_iter': 594}. Best is trial 118 with value: -2858374118.683107.
[I 2024-12-23 10:27:55,420] Trial 196 finished with value: -3741497716.52386 and parameters: {'alpha': 17.522160784203507, 'eta0': 0.03152875307975011, 'max_iter': 397}. Best is trial 118 with value: -2858374118.683107.
[I 2024-12-23 10:27:55,424] Trial 194 finished with value: -3729466138.766449 and parameters: {'alpha': 16.029907637820493, 'eta0': 0.03241160509722874, 'max_iter': 498}. Best is trial 118 with value: -2858374118.683107.
[I 2024-12-23 10:27:55,432] Trial 195 finished with value: -3744517965.6320753 and parameters: {'alpha': 17.94418944353022, 'eta0': 0.031912148449148095, 'max_iter': 372}. Best is trial 118 with value: -2858374118.683107.
[I 2024-12-23 10:27:55,478] Trial 198 finished with value: -3889096502.917507 and parameters: {'alpha': 143.47928960378894, 'eta0': 0.03188314061947135, 'max_iter': 587}. Best is trial 118 with value: -2858374118.683107.
[I 2024-12-23 10:27:55,518] Trial 197 finished with value: -3722449386.033683 and parameters: {'alpha': 15.238776365205553, 'eta0': 0.03191481056625127, 'max_iter': 370}. Best is trial 118 with value: -2858374118.683107.
[I 2024-12-23 10:27:55,529] Trial 199 finished with value: -3730280413.5946455 an
```

d parameters: {'alpha': 16.10253193568071, 'eta0': 0.031080178110426633, 'max_iter': 585}. Best is trial 118 with value: -2858374118.683107.

[I 2024-12-23 10:27:55,584] Trial 202 finished with value: -3729342084.36652 and parameters: {'alpha': 16.009980772331502, 'eta0': 0.03206784016747561, 'max_iter': 564}. Best is trial 118 with value: -2858374118.683107.

[I 2024-12-23 10:27:55,587] Trial 200 finished with value: -3743133520.4360785 and parameters: {'alpha': 17.763864144991004, 'eta0': 0.0326553164995256, 'max_iter': 608}. Best is trial 118 with value: -2858374118.683107.

[I 2024-12-23 10:27:55,619] Trial 201 finished with value: -3742491915.313095 and parameters: {'alpha': 17.660369749627378, 'eta0': 0.03171359020364777, 'max_iter': 376}. Best is trial 118 with value: -2858374118.683107.

[I 2024-12-23 10:27:55,625] Trial 204 finished with value: -3723584320.171321 and parameters: {'alpha': 15.350975106200025, 'eta0': 0.031305507566516136, 'max_iter': 497}. Best is trial 118 with value: -2858374118.683107.

[I 2024-12-23 10:27:55,630] Trial 203 finished with value: -3727776617.3755736 and parameters: {'alpha': 15.820211186949678, 'eta0': 0.03148972414662761, 'max_iter': 496}. Best is trial 118 with value: -2858374118.683107.

[I 2024-12-23 10:27:55,679] Trial 206 finished with value: -3711702694.099824 and parameters: {'alpha': 14.073378597037687, 'eta0': 0.02740707488254414, 'max_iter': 615}. Best is trial 118 with value: -2858374118.683107.

[I 2024-12-23 10:27:55,701] Trial 205 finished with value: -2892860092.5807905 and parameters: {'alpha': 0.230932929355683, 'eta0': 0.028270398068912586, 'max_iter': 498}. Best is trial 118 with value: -2858374118.683107.

[I 2024-12-23 10:27:55,768] Trial 207 finished with value: -3095317710.793186 and parameters: {'alpha': 1.0383917506304938, 'eta0': 0.04184180541433178, 'max_iter': 611}. Best is trial 118 with value: -2858374118.683107.

[I 2024-12-23 10:27:55,881] Trial 209 finished with value: -2916850145.4258513 and parameters: {'alpha': 0.36245197986299527, 'eta0': 0.028432801733212963, 'max_iter': 609}. Best is trial 118 with value: -2858374118.683107.

[I 2024-12-23 10:27:55,891] Trial 211 finished with value: -2897231271.0926905 and parameters: {'alpha': 0.2621910581817811, 'eta0': 0.027846934636978304, 'max_iter': 615}. Best is trial 118 with value: -2858374118.683107.

[I 2024-12-23 10:27:55,913] Trial 210 finished with value: -2856280620.4484844 and parameters: {'alpha': 0.0005416734087628772, 'eta0': 0.028041306776507832, 'max_iter': 615}. Best is trial 210 with value: -2856280620.4484844.

[I 2024-12-23 10:27:55,920] Trial 212 finished with value: -2980932511.1662803 and parameters: {'alpha': 0.5856211720570758, 'eta0': 0.027473854110072148, 'max_iter': 618}. Best is trial 210 with value: -2856280620.4484844.

[I 2024-12-23 10:27:55,921] Trial 208 finished with value: -3049220346.727519 and parameters: {'alpha': 0.8718987829610014, 'eta0': 0.028486650893353907, 'max_iter': 615}. Best is trial 210 with value: -2856280620.4484844.

[I 2024-12-23 10:27:55,930] Trial 213 finished with value: -2892461620.183562 and parameters: {'alpha': 0.2356028823160325, 'eta0': 0.027658745933037427, 'max_iter': 570}. Best is trial 210 with value: -2856280620.4484844.

[I 2024-12-23 10:27:55,934] Trial 214 finished with value: -2916699554.4742346 and parameters: {'alpha': 0.36405605885813364, 'eta0': 0.028135125515975613, 'max_iter': 615}. Best is trial 210 with value: -2856280620.4484844.

[I 2024-12-23 10:27:55,973] Trial 215 finished with value: -2891291569.9302397 and parameters: {'alpha': 0.22376463853695538, 'eta0': 0.028032293676605778, 'max_iter': 608}. Best is trial 210 with value: -2856280620.4484844.

[I 2024-12-23 10:27:56,024] Trial 217 finished with value: -3873315232.551346 and parameters: {'alpha': 77.44095654326301, 'eta0': 0.027205484973617043, 'max_iter': 615}. Best is trial 210 with value: -2856280620.4484844.

[I 2024-12-23 10:27:56,050] Trial 218 finished with value: -3043707958.660187 and parameters: {'alpha': 0.8689920004467855, 'eta0': 0.026648511428985975, 'max_iter': 615}. Best is trial 210 with value: -2856280620.4484844.

[I 2024-12-23 10:27:56,080] Trial 216 finished with value: -3158125311.4127936 and parameters: {'alpha': 1.47704102445902, 'eta0': 0.028120121107014624, 'max_iter': 567}. Best is trial 210 with value: -2856280620.4484844.

[I 2024-12-23 10:27:56,121] Trial 219 finished with value: -2981636488.0275545 an

d parameters: {'alpha': 0.5585375666369142, 'eta0': 0.03411113590690397, 'max_iter': 615}. Best is trial 210 with value: -2856280620.4484844.

[I 2024-12-23 10:27:56,122] Trial 222 finished with value: -2959012826.0725794 and parameters: {'alpha': 0.5678761061140041, 'eta0': 0.027552741657281457, 'max_iter': 618}. Best is trial 210 with value: -2856280620.4484844.

[I 2024-12-23 10:27:56,153] Trial 220 finished with value: -2891822100.211044 and parameters: {'alpha': 0.2287950041345799, 'eta0': 0.027896494700244787, 'max_iter': 618}. Best is trial 210 with value: -2856280620.4484844.

[I 2024-12-23 10:27:56,205] Trial 224 finished with value: -3012150797.845845 and parameters: {'alpha': 0.7229312425163984, 'eta0': 0.028735697589501313, 'max_iter': 612}. Best is trial 210 with value: -2856280620.4484844.

[I 2024-12-23 10:27:56,215] Trial 225 finished with value: -2913928154.9212565 and parameters: {'alpha': 0.35028048712966253, 'eta0': 0.028100157590410228, 'max_iter': 662}. Best is trial 210 with value: -2856280620.4484844.

[I 2024-12-23 10:27:56,219] Trial 227 finished with value: -2933031091.8360624 and parameters: {'alpha': 0.4463780063546876, 'eta0': 0.027742947573901604, 'max_iter': 569}. Best is trial 210 with value: -2856280620.4484844.

[I 2024-12-23 10:27:56,241] Trial 221 finished with value: -2858869933.9539948 and parameters: {'alpha': 0.03530201425283386, 'eta0': 0.028604466183204724, 'max_iter': 615}. Best is trial 210 with value: -2856280620.4484844.

[I 2024-12-23 10:27:56,256] Trial 223 finished with value: -2999801092.312636 and parameters: {'alpha': 0.39956774605735335, 'eta0': 0.07331215191493809, 'max_iter': 667}. Best is trial 210 with value: -2856280620.4484844.

[I 2024-12-23 10:27:56,274] Trial 226 finished with value: -3171242824.829561 and parameters: {'alpha': 1.556870267252824, 'eta0': 0.028608657006082863, 'max_iter': 564}. Best is trial 210 with value: -2856280620.4484844.

[I 2024-12-23 10:27:56,435] Trial 231 finished with value: -2934915093.978748 and parameters: {'alpha': 0.45319562211597364, 'eta0': 0.028056632233224542, 'max_iter': 663}. Best is trial 210 with value: -2856280620.4484844.

[I 2024-12-23 10:27:56,482] Trial 230 finished with value: -2910080843.016835 and parameters: {'alpha': 0.33675140349787297, 'eta0': 0.027357485600443234, 'max_iter': 568}. Best is trial 210 with value: -2856280620.4484844.

[I 2024-12-23 10:27:56,512] Trial 229 finished with value: -2923541965.3034024 and parameters: {'alpha': 0.3960529230093803, 'eta0': 0.028399717721273907, 'max_iter': 536}. Best is trial 210 with value: -2856280620.4484844.

[I 2024-12-23 10:27:56,513] Trial 232 finished with value: -3012385581.958139 and parameters: {'alpha': 0.718865301456405, 'eta0': 0.028176970130282933, 'max_iter': 664}. Best is trial 210 with value: -2856280620.4484844.

[I 2024-12-23 10:27:56,518] Trial 228 finished with value: -3239623051.375787 and parameters: {'alpha': 1.9871197089521613, 'eta0': 0.028177951547509357, 'max_iter': 569}. Best is trial 210 with value: -2856280620.4484844.

[I 2024-12-23 10:27:56,519] Trial 234 finished with value: -2858192748.210845 and parameters: {'alpha': 0.03141706673261249, 'eta0': 0.028164799885783395, 'max_iter': 664}. Best is trial 210 with value: -2856280620.4484844.

[I 2024-12-23 10:27:56,555] Trial 233 finished with value: -3120232636.8312426 and parameters: {'alpha': 1.2218185662413252, 'eta0': 0.02812078123134159, 'max_iter': 569}. Best is trial 210 with value: -2856280620.4484844.

[I 2024-12-23 10:27:56,611] Trial 236 finished with value: -2928560693.022723 and parameters: {'alpha': 0.42821049227676, 'eta0': 0.027298451046953446, 'max_iter': 660}. Best is trial 210 with value: -2856280620.4484844.

[I 2024-12-23 10:27:56,620] Trial 235 finished with value: -2900687344.5146475 and parameters: {'alpha': 0.27932271152469385, 'eta0': 0.028113421769805125, 'max_iter': 616}. Best is trial 210 with value: -2856280620.4484844.

[I 2024-12-23 10:27:56,631] Trial 239 finished with value: -3896686877.8413024 and parameters: {'alpha': 254.77681675870505, 'eta0': 0.029024011292109058, 'max_iter': 657}. Best is trial 210 with value: -2856280620.4484844.

[I 2024-12-23 10:27:56,632] Trial 237 finished with value: -3005105305.454341 and parameters: {'alpha': 0.7082359448532036, 'eta0': 0.02476597425673646, 'max_iter': 669}. Best is trial 210 with value: -2856280620.4484844.

[I 2024-12-23 10:27:56,688] Trial 238 finished with value: -2907122057.3467207 an

d parameters: {'alpha': 0.3118707803251114, 'eta0': 0.02842246019652912, 'max_iter': 663}. Best is trial 210 with value: -2856280620.4484844.

[I 2024-12-23 10:27:56,698] Trial 240 finished with value: -3142151980.0567636 and parameters: {'alpha': 1.3814946771535468, 'eta0': 0.028574908683570006, 'max_iter': 668}. Best is trial 210 with value: -2856280620.4484844.

[I 2024-12-23 10:27:56,744] Trial 244 finished with value: -3555276335.8255835 and parameters: {'alpha': 6.061213009684881, 'eta0': 0.02490817348558043, 'max_iter': 658}. Best is trial 210 with value: -2856280620.4484844.

[I 2024-12-23 10:27:56,833] Trial 243 finished with value: -2860903539.4166393 and parameters: {'alpha': 0.12934250724788804, 'eta0': 0.025150220595990116, 'max_iter': 666}. Best is trial 210 with value: -2856280620.4484844.

[I 2024-12-23 10:27:56,848] Trial 241 finished with value: -3072273414.1512423 and parameters: {'alpha': 0.980360160775314, 'eta0': 0.028404648369345815, 'max_iter': 665}. Best is trial 210 with value: -2856280620.4484844.

[I 2024-12-23 10:27:56,861] Trial 242 finished with value: -3523138918.927668 and parameters: {'alpha': 5.275012095562776, 'eta0': 0.0249080752511584, 'max_iter': 662}. Best is trial 210 with value: -2856280620.4484844.

[I 2024-12-23 10:27:56,905] Trial 246 finished with value: -3586724010.5800505 and parameters: {'alpha': 6.996862748515803, 'eta0': 0.024693185999173334, 'max_iter': 670}. Best is trial 210 with value: -2856280620.4484844.

[I 2024-12-23 10:27:56,925] Trial 245 finished with value: -3566465364.836014 and parameters: {'alpha': 6.374347456664183, 'eta0': 0.024974684544280444, 'max_iter': 655}. Best is trial 210 with value: -2856280620.4484844.

[I 2024-12-23 10:27:56,977] Trial 247 finished with value: -3573104141.2195067 and parameters: {'alpha': 6.567712054315125, 'eta0': 0.024768083298291728, 'max_iter': 653}. Best is trial 210 with value: -2856280620.4484844.

[I 2024-12-23 10:27:57,012] Trial 248 finished with value: -3560231955.3782845 and parameters: {'alpha': 6.201540585736998, 'eta0': 0.02529583092485166, 'max_iter': 650}. Best is trial 210 with value: -2856280620.4484844.

[I 2024-12-23 10:27:57,054] Trial 249 finished with value: -3593350536.222721 and parameters: {'alpha': 7.221484483913698, 'eta0': 0.024718780218375192, 'max_iter': 656}. Best is trial 210 with value: -2856280620.4484844.

[I 2024-12-23 10:27:57,078] Trial 250 finished with value: -3631231025.342986 and parameters: {'alpha': 8.456043737834621, 'eta0': 0.025228637108439922, 'max_iter': 661}. Best is trial 210 with value: -2856280620.4484844.

[I 2024-12-23 10:27:57,117] Trial 251 finished with value: -3614472812.561362 and parameters: {'alpha': 7.795889742615566, 'eta0': 0.025225990773453798, 'max_iter': 657}. Best is trial 210 with value: -2856280620.4484844.

[I 2024-12-23 10:27:57,139] Trial 252 finished with value: -3622139415.4921236 and parameters: {'alpha': 8.087985377476292, 'eta0': 0.02532328704994787, 'max_iter': 658}. Best is trial 210 with value: -2856280620.4484844.

[I 2024-12-23 10:27:57,180] Trial 254 finished with value: -3605877525.3201494 and parameters: {'alpha': 7.683668929856626, 'eta0': 0.025190280257100687, 'max_iter': 653}. Best is trial 210 with value: -2856280620.4484844.

[I 2024-12-23 10:27:57,193] Trial 256 finished with value: -3634798581.710491 and parameters: {'alpha': 8.6073651613864, 'eta0': 0.025329294312303647, 'max_iter': 533}. Best is trial 210 with value: -2856280620.4484844.

[I 2024-12-23 10:27:57,203] Trial 255 finished with value: -3634723028.0532556 and parameters: {'alpha': 8.604136973829464, 'eta0': 0.024969507250502787, 'max_iter': 538}. Best is trial 210 with value: -2856280620.4484844.

[I 2024-12-23 10:27:57,245] Trial 257 finished with value: -3652206725.6358247 and parameters: {'alpha': 9.407723674250292, 'eta0': 0.02565393561728774, 'max_iter': 534}. Best is trial 210 with value: -2856280620.4484844.

[I 2024-12-23 10:27:57,307] Trial 253 finished with value: -3616555731.8629785 and parameters: {'alpha': 7.873578387662965, 'eta0': 0.02494208715765559, 'max_iter': 657}. Best is trial 210 with value: -2856280620.4484844.

[I 2024-12-23 10:27:57,330] Trial 259 finished with value: -3574884137.6777396 and parameters: {'alpha': 6.633721395092777, 'eta0': 0.025621158358612155, 'max_iter': 585}. Best is trial 210 with value: -2856280620.4484844.

[I 2024-12-23 10:27:57,361] Trial 258 finished with value: -3636193400.3902855 an

d parameters: {'alpha': 8.667606795715688, 'eta0': 0.025443076078815692, 'max_iter': 536}. Best is trial 210 with value: -2856280620.4484844.

[I 2024-12-23 10:27:57,369] Trial 261 finished with value: -3667988902.8894067 and parameters: {'alpha': 10.236613381636733, 'eta0': 0.02548660111281479, 'max_iter': 535}. Best is trial 210 with value: -2856280620.4484844.

[I 2024-12-23 10:27:57,434] Trial 260 finished with value: -3621210093.671365 and parameters: {'alpha': 8.051673693801405, 'eta0': 0.025820659438144374, 'max_iter': 538}. Best is trial 210 with value: -2856280620.4484844.

[I 2024-12-23 10:27:57,460] Trial 263 finished with value: -3662522326.309948 and parameters: {'alpha': 9.937560107501836, 'eta0': 0.02534238941326636, 'max_iter': 537}. Best is trial 210 with value: -2856280620.4484844.

[I 2024-12-23 10:27:57,463] Trial 262 finished with value: -3646644836.9675217 and parameters: {'alpha': 9.14003512773063, 'eta0': 0.02570193959962684, 'max_iter': 540}. Best is trial 210 with value: -2856280620.4484844.

[I 2024-12-23 10:27:57,493] Trial 266 finished with value: -3644526990.3294435 and parameters: {'alpha': 9.040622367846066, 'eta0': 0.02614868798219585, 'max_iter': 537}. Best is trial 210 with value: -2856280620.4484844.

[I 2024-12-23 10:27:57,497] Trial 264 finished with value: -3663681431.922179 and parameters: {'alpha': 9.999639987301814, 'eta0': 0.025473915021124366, 'max_iter': 646}. Best is trial 210 with value: -2856280620.4484844.

[I 2024-12-23 10:27:57,544] Trial 265 finished with value: -3657886303.8551764 and parameters: {'alpha': 10.484129992185128, 'eta0': 0.02619157752130472, 'max_iter': 533}. Best is trial 210 with value: -2856280620.4484844.

[I 2024-12-23 10:27:57,572] Trial 268 finished with value: -3667715823.632289 and parameters: {'alpha': 11.071671574664965, 'eta0': 0.02607795314071672, 'max_iter': 538}. Best is trial 210 with value: -2856280620.4484844.

[I 2024-12-23 10:27:57,577] Trial 267 finished with value: -3655084103.9731965 and parameters: {'alpha': 10.322770526025888, 'eta0': 0.026046212207831577, 'max_iter': 580}. Best is trial 210 with value: -2856280620.4484844.

[I 2024-12-23 10:27:57,612] Trial 269 finished with value: -3668783244.5392504 and parameters: {'alpha': 11.198896541408262, 'eta0': 0.02975725889544846, 'max_iter': 583}. Best is trial 210 with value: -2856280620.4484844.

[I 2024-12-23 10:27:57,640] Trial 270 finished with value: -3653190799.984945 and parameters: {'alpha': 10.229070866649069, 'eta0': 0.026794826017748387, 'max_iter': 581}. Best is trial 210 with value: -2856280620.4484844.

[I 2024-12-23 10:27:57,659] Trial 271 finished with value: -3667791899.759134 and parameters: {'alpha': 11.135066035534628, 'eta0': 0.02969099980110291, 'max_iter': 579}. Best is trial 210 with value: -2856280620.4484844.

[I 2024-12-23 10:27:57,675] Trial 272 finished with value: -3668051334.9526124 and parameters: {'alpha': 11.10859180789457, 'eta0': 0.026988187836469398, 'max_iter': 530}. Best is trial 210 with value: -2856280620.4484844.

[I 2024-12-23 10:27:57,709] Trial 273 finished with value: -3673608201.9269767 and parameters: {'alpha': 11.506862540855524, 'eta0': 0.029358969429077786, 'max_iter': 583}. Best is trial 210 with value: -2856280620.4484844.

[I 2024-12-23 10:27:57,770] Trial 274 finished with value: -3667059505.073007 and parameters: {'alpha': 11.089289261873187, 'eta0': 0.02971175245595376, 'max_iter': 589}. Best is trial 210 with value: -2856280620.4484844.

[I 2024-12-23 10:27:57,796] Trial 275 finished with value: -3672117759.2232695 and parameters: {'alpha': 11.4038693332822, 'eta0': 0.02906638910121259, 'max_iter': 591}. Best is trial 210 with value: -2856280620.4484844.

[I 2024-12-23 10:27:57,819] Trial 277 finished with value: -3686692172.6054535 and parameters: {'alpha': 12.038254819282292, 'eta0': 0.029758235817385226, 'max_iter': 581}. Best is trial 210 with value: -2856280620.4484844.

[I 2024-12-23 10:27:57,825] Trial 276 finished with value: -3686190291.7412705 and parameters: {'alpha': 11.994233454104076, 'eta0': 0.02924513819137898, 'max_iter': 583}. Best is trial 210 with value: -2856280620.4484844.

[I 2024-12-23 10:27:57,874] Trial 278 finished with value: -3679443075.7236633 and parameters: {'alpha': 11.900643070155045, 'eta0': 0.029063217941913126, 'max_iter': 631}. Best is trial 210 with value: -2856280620.4484844.

[I 2024-12-23 10:27:57,959] Trial 280 finished with value: -3690651473.684705 and

```
parameters: {'alpha': 12.332376251779653, 'eta0': 0.029695197438305797, 'max_iter': 634}. Best is trial 210 with value: -2856280620.4484844.  
[I 2024-12-23 10:27:57,969] Trial 279 finished with value: -3692958107.5694075 and parameters: {'alpha': 12.505775037382158, 'eta0': 0.029442392356461358, 'max_iter': 629}. Best is trial 210 with value: -2856280620.4484844.  
[I 2024-12-23 10:27:57,990] Trial 281 finished with value: -2850975295.824206 and parameters: {'alpha': 0.07684844102544672, 'eta0': 0.022042912167604168, 'max_iter': 626}. Best is trial 281 with value: -2850975295.824206.  
[I 2024-12-23 10:27:57,996] Trial 283 finished with value: -2995877894.2016234 and parameters: {'alpha': 0.6448854188035231, 'eta0': 0.02981521606324691, 'max_iter': 629}. Best is trial 281 with value: -2850975295.824206.  
[I 2024-12-23 10:27:58,062] Trial 282 finished with value: -2898487423.601967 and parameters: {'alpha': 0.24952623075512798, 'eta0': 0.029720659410335838, 'max_iter': 601}. Best is trial 281 with value: -2850975295.824206.  
[I 2024-12-23 10:27:58,067] Trial 285 finished with value: -3704720735.437358 and parameters: {'alpha': 13.471222308717566, 'eta0': 0.029097285428088624, 'max_iter': 628}. Best is trial 281 with value: -2850975295.824206.  
[I 2024-12-23 10:27:58,089] Trial 284 finished with value: -2997424207.7274666 and parameters: {'alpha': 0.6541410692804417, 'eta0': 0.029358294337836648, 'max_iter': 631}. Best is trial 281 with value: -2850975295.824206.  
[I 2024-12-23 10:27:58,132] Trial 286 finished with value: -2891104032.590689 and parameters: {'alpha': 0.21790660723459712, 'eta0': 0.029879510251887426, 'max_iter': 631}. Best is trial 281 with value: -2850975295.824206.  
[I 2024-12-23 10:27:58,197] Trial 287 finished with value: -3113292370.295075 and parameters: {'alpha': 1.1789223570479952, 'eta0': 0.02974112965853799, 'max_iter': 601}. Best is trial 281 with value: -2850975295.824206.  
[I 2024-12-23 10:27:58,208] Trial 289 finished with value: -2861702589.420773 and parameters: {'alpha': 0.08062618699800456, 'eta0': 0.02922828701140187, 'max_iter': 597}. Best is trial 281 with value: -2850975295.824206.  
[I 2024-12-23 10:27:58,221] Trial 288 finished with value: -2972488680.097281 and parameters: {'alpha': 0.5348758868723764, 'eta0': 0.029477896739369226, 'max_iter': 626}. Best is trial 281 with value: -2850975295.824206.  
[I 2024-12-23 10:27:58,255] Trial 291 finished with value: -2862275244.952962 and parameters: {'alpha': 0.18711540131047472, 'eta0': 0.02199444508484576, 'max_iter': 631}. Best is trial 281 with value: -2850975295.824206.  
[I 2024-12-23 10:27:58,275] Trial 290 finished with value: -3083948628.9485855 and parameters: {'alpha': 1.0320715994226424, 'eta0': 0.029468716054492562, 'max_iter': 627}. Best is trial 281 with value: -2850975295.824206.  
[I 2024-12-23 10:27:58,297] Trial 292 finished with value: -3061699159.1478834 and parameters: {'alpha': 0.9829760958374381, 'eta0': 0.021249157816320044, 'max_iter': 628}. Best is trial 281 with value: -2850975295.824206.  
[I 2024-12-23 10:27:58,298] Trial 293 finished with value: -2940337490.625777 and parameters: {'alpha': 0.5256034111074275, 'eta0': 0.02067385469089894, 'max_iter': 625}. Best is trial 281 with value: -2850975295.824206.  
[I 2024-12-23 10:27:58,314] Trial 296 finished with value: -3436227258.5938478 and parameters: {'alpha': 3.7266930193558077, 'eta0': 0.022700246706565407, 'max_iter': 626}. Best is trial 281 with value: -2850975295.824206.  
[I 2024-12-23 10:27:58,372] Trial 294 finished with value: -2851851416.3430586 and parameters: {'alpha': 0.06576175559448402, 'eta0': 0.02278294947492115, 'max_iter': 632}. Best is trial 281 with value: -2850975295.824206.  
[I 2024-12-23 10:27:58,384] Trial 295 finished with value: -3082581332.286491 and parameters: {'alpha': 1.0712422763993734, 'eta0': 0.02320458412449972, 'max_iter': 605}. Best is trial 281 with value: -2850975295.824206.  
[I 2024-12-23 10:27:58,423] Trial 297 finished with value: -2873675936.5935717 and parameters: {'alpha': 0.25567797358409966, 'eta0': 0.021982625519558034, 'max_iter': 628}. Best is trial 281 with value: -2850975295.824206.  
[I 2024-12-23 10:27:58,458] Trial 298 finished with value: -3016354312.9643393 and parameters: {'alpha': 0.7769377826349313, 'eta0': 0.02172525278215187, 'max_iter': 627}. Best is trial 281 with value: -2850975295.824206.  
[I 2024-12-23 10:27:58,485] Trial 299 finished with value: -3899174607.2651544 an
```

d parameters: {'alpha': 229.44703714106726, 'eta0': 0.02286392526247874, 'max_iter': 608}. Best is trial 281 with value: -2850975295.824206.

[I 2024-12-23 10:27:58,554] Trial 300 finished with value: -3888818481.533381 and parameters: {'alpha': 155.4723538365105, 'eta0': 0.020719123015261943, 'max_iter': 598}. Best is trial 281 with value: -2850975295.824206.

[I 2024-12-23 10:27:58,575] Trial 302 finished with value: -2940300059.7701974 and parameters: {'alpha': 0.5225246777753285, 'eta0': 0.021127229644469323, 'max_iter': 608}. Best is trial 281 with value: -2850975295.824206.

[I 2024-12-23 10:27:58,584] Trial 301 finished with value: -2926751113.6486077 and parameters: {'alpha': 0.4506171591481938, 'eta0': 0.022878979493667177, 'max_iter': 604}. Best is trial 281 with value: -2850975295.824206.

[I 2024-12-23 10:27:58,602] Trial 303 finished with value: -2964980146.402275 and parameters: {'alpha': 0.6242180020948516, 'eta0': 0.022181249477231182, 'max_iter': 599}. Best is trial 281 with value: -2850975295.824206.

[I 2024-12-23 10:27:58,619] Trial 304 finished with value: -2848057453.3819666 and parameters: {'alpha': 0.022941436469636672, 'eta0': 0.021211574128194476, 'max_iter': 604}. Best is trial 304 with value: -2848057453.3819666.

[I 2024-12-23 10:27:58,670] Trial 307 finished with value: -3775113910.8825045 and parameters: {'alpha': 22.898973621075548, 'eta0': 0.02073813625026979, 'max_iter': 604}. Best is trial 304 with value: -2848057453.3819666.

[I 2024-12-23 10:27:58,682] Trial 305 finished with value: -2873026862.584045 and parameters: {'alpha': 0.2592396423366559, 'eta0': 0.02122298785420061, 'max_iter': 608}. Best is trial 304 with value: -2848057453.3819666.

[I 2024-12-23 10:27:58,712] Trial 306 finished with value: -3775532789.4162965 and parameters: {'alpha': 23.077312775898978, 'eta0': 0.02232880388173924, 'max_iter': 605}. Best is trial 304 with value: -2848057453.3819666.

[I 2024-12-23 10:27:58,774] Trial 310 finished with value: -3465742765.293353 and parameters: {'alpha': 4.168741485619551, 'eta0': 0.0213581560798344, 'max_iter': 605}. Best is trial 304 with value: -2848057453.3819666.

[I 2024-12-23 10:27:58,780] Trial 313 finished with value: -3889664505.761316 and parameters: {'alpha': 155.44922271608363, 'eta0': 0.023152418322846265, 'max_iter': 609}. Best is trial 304 with value: -2848057453.3819666.

[I 2024-12-23 10:27:58,847] Trial 312 finished with value: -3500994120.308178 and parameters: {'alpha': 4.799622327884428, 'eta0': 0.022850947701272564, 'max_iter': 599}. Best is trial 304 with value: -2848057453.3819666.

[I 2024-12-23 10:27:58,852] Trial 309 finished with value: -3769059397.084788 and parameters: {'alpha': 21.74031847805178, 'eta0': 0.02247436000865875, 'max_iter': 601}. Best is trial 304 with value: -2848057453.3819666.

[I 2024-12-23 10:27:58,866] Trial 311 finished with value: -3889439298.60353 and parameters: {'alpha': 155.23693253901263, 'eta0': 0.022558210108262918, 'max_iter': 603}. Best is trial 304 with value: -2848057453.3819666.

[I 2024-12-23 10:27:58,895] Trial 308 finished with value: -2852537998.250779 and parameters: {'alpha': 0.11989420616900462, 'eta0': 0.021460676227690025, 'max_iter': 607}. Best is trial 304 with value: -2848057453.3819666.

[I 2024-12-23 10:27:58,907] Trial 315 finished with value: -3897897609.2527246 and parameters: {'alpha': 223.28791925283798, 'eta0': 0.02072151212478529, 'max_iter': 602}. Best is trial 304 with value: -2848057453.3819666.

[I 2024-12-23 10:27:58,922] Trial 316 finished with value: -3765311784.873332 and parameters: {'alpha': 21.602640014860114, 'eta0': 0.020996717065025657, 'max_iter': 601}. Best is trial 304 with value: -2848057453.3819666.

[I 2024-12-23 10:27:58,932] Trial 314 finished with value: -3898938650.349823 and parameters: {'alpha': 224.16842650170594, 'eta0': 0.022792838997244044, 'max_iter': 607}. Best is trial 304 with value: -2848057453.3819666.

[I 2024-12-23 10:27:58,990] Trial 317 finished with value: -3913355258.3785143 and parameters: {'alpha': 226.67690480597685, 'eta0': 0.08639708202847249, 'max_iter': 600}. Best is trial 304 with value: -2848057453.3819666.

[I 2024-12-23 10:27:59,000] Trial 319 finished with value: -3899355162.950601 and parameters: {'alpha': 271.34391716393424, 'eta0': 0.020402270062124587, 'max_iter': 602}. Best is trial 304 with value: -2848057453.3819666.

[I 2024-12-23 10:27:59,062] Trial 320 finished with value: -3754913374.767235 and

parameters: {'alpha': 19.240047464642608, 'eta0': 0.022750461376387775, 'max_iter': 605}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:27:59,064] Trial 318 finished with value: -3772295613.125478 and parameters: {'alpha': 22.968750044878053, 'eta0': 0.0202545591003297, 'max_iter': 607}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:27:59,145] Trial 324 finished with value: -3806432796.2858915 and parameters: {'alpha': 20.614558517579738, 'eta0': 0.09988803742566862, 'max_iter': 839}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:27:59,160] Trial 321 finished with value: -3764186469.2996864 and parameters: {'alpha': 21.30569398895391, 'eta0': 0.01948243962973562, 'max_iter': 678}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:27:59,175] Trial 323 finished with value: -3764417829.062471 and parameters: {'alpha': 21.340269055803798, 'eta0': 0.01933276165080963, 'max_iter': 565}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:27:59,194] Trial 327 finished with value: -3553934674.717847 and parameters: {'alpha': 5.958126888699207, 'eta0': 0.01916675586157786, 'max_iter': 681}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:27:59,201] Trial 322 finished with value: -3761286238.843798 and parameters: {'alpha': 20.84096618691711, 'eta0': 0.020694626429044953, 'max_iter': 567}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:27:59,221] Trial 325 finished with value: -3554562103.4658422 and parameters: {'alpha': 5.974206063906179, 'eta0': 0.01914662991008501, 'max_iter': 640}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:27:59,246] Trial 326 finished with value: -3764609234.813066 and parameters: {'alpha': 21.316692009409305, 'eta0': 0.01835632703481813, 'max_iter': 644}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:27:59,331] Trial 328 finished with value: -3764449775.9598618 and parameters: {'alpha': 21.337036902902437, 'eta0': 0.0191770349232512, 'max_iter': 680}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:27:59,368] Trial 329 finished with value: -3584720258.92702 and parameters: {'alpha': 6.840045421980947, 'eta0': 0.019109083407213994, 'max_iter': 641}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:27:59,423] Trial 331 finished with value: -3752942075.2409925 and parameters: {'alpha': 19.325269174571716, 'eta0': 0.01869261743309705, 'max_iter': 998}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:27:59,431] Trial 333 finished with value: -3551943802.8551 and parameters: {'alpha': 5.903776986916721, 'eta0': 0.01888589177560671, 'max_iter': 566}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:27:59,461] Trial 332 finished with value: -3562748418.0557275 and parameters: {'alpha': 6.185029217942992, 'eta0': 0.018509254884876182, 'max_iter': 963}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:27:59,467] Trial 330 finished with value: -3757301136.155558 and parameters: {'alpha': 20.08962204290535, 'eta0': 0.019627500567556234, 'max_iter': 685}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:27:59,489] Trial 334 finished with value: -3594894920.397952 and parameters: {'alpha': 7.218939848203869, 'eta0': 0.08820142803729739, 'max_iter': 642}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:27:59,533] Trial 338 finished with value: -3566285887.314227 and parameters: {'alpha': 6.280516827139952, 'eta0': 0.018334762642378977, 'max_iter': 883}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:27:59,539] Trial 335 finished with value: -3569042410.731678 and parameters: {'alpha': 6.364029345447333, 'eta0': 0.018777741489591132, 'max_iter': 641}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:27:59,567] Trial 337 finished with value: -3579641932.8061805 and parameters: {'alpha': 6.672884659762697, 'eta0': 0.01852374968692385, 'max_iter': 643}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:27:59,598] Trial 340 finished with value: -3859907757.482084 and parameters: {'alpha': 66.11100401257207, 'eta0': 0.017046061399805183, 'max_iter': 559}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:27:59,599] Trial 339 finished with value: -3890760454.8399873 an

d parameters: {'alpha': 209.7211856792769, 'eta0': 0.018411151363523233, 'max_iter': 645}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:27:59,603] Trial 336 finished with value: -3603971496.965486 and parameters: {'alpha': 7.4203754783206595, 'eta0': 0.01541636735974156, 'max_iter': 637}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:27:59,660] Trial 342 finished with value: -3563548340.028454 and parameters: {'alpha': 6.190680304149325, 'eta0': 0.017147188970609375, 'max_iter': 641}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:27:59,694] Trial 341 finished with value: -3561079328.7079453 and parameters: {'alpha': 6.13013488523998, 'eta0': 0.017693292744846833, 'max_iter': 559}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:27:59,719] Trial 347 finished with value: -3557221094.689379 and parameters: {'alpha': 6.033638023005171, 'eta0': 0.01823824359052724, 'max_iter': 638}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:27:59,751] Trial 343 finished with value: -3550314327.8919883 and parameters: {'alpha': 5.844619931701048, 'eta0': 0.017103399149920206, 'max_iter': 638}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:27:59,765] Trial 344 finished with value: -3535331072.186319 and parameters: {'alpha': 6.032025249560487, 'eta0': 0.033921112237815215, 'max_iter': 636}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:27:59,806] Trial 345 finished with value: -3556812350.7433486 and parameters: {'alpha': 6.009195387595687, 'eta0': 0.01695388726900729, 'max_iter': 628}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:27:59,807] Trial 346 finished with value: -3898326404.968291 and parameters: {'alpha': 203.31610781053445, 'eta0': 0.023459428320503864, 'max_iter': 637}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:27:59,839] Trial 349 finished with value: -3545461744.88429 and parameters: {'alpha': 5.714242795135655, 'eta0': 0.015761092620277306, 'max_iter': 894}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:27:59,932] Trial 348 finished with value: -3540270511.617011 and parameters: {'alpha': 6.157282064289798, 'eta0': 0.03470785011539689, 'max_iter': 641}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:00,006] Trial 351 finished with value: -3546276647.775172 and parameters: {'alpha': 5.74091462842502, 'eta0': 0.01665612249736477, 'max_iter': 640}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:00,045] Trial 350 finished with value: -3574228895.7111177 and parameters: {'alpha': 6.590455906106399, 'eta0': 0.0239733000476531, 'max_iter': 644}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:00,109] Trial 353 finished with value: -3888103852.0331674 and parameters: {'alpha': 204.65251846155644, 'eta0': 0.012566430560167544, 'max_iter': 625}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:00,117] Trial 357 finished with value: -3716726623.1391907 and parameters: {'alpha': 13.680932404050203, 'eta0': 0.01639142352156519, 'max_iter': 626}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:00,120] Trial 352 finished with value: -3555803962.403327 and parameters: {'alpha': 5.975859211207851, 'eta0': 0.016213552096339214, 'max_iter': 622}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:00,132] Trial 354 finished with value: -3493520797.187748 and parameters: {'alpha': 5.199513920613781, 'eta0': 0.03442391672290768, 'max_iter': 625}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:00,137] Trial 359 finished with value: -3709480054.0737343 and parameters: {'alpha': 13.976606322672419, 'eta0': 0.03414445535103959, 'max_iter': 620}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:00,145] Trial 356 finished with value: -3723133393.9783287 and parameters: {'alpha': 15.354889794638295, 'eta0': 0.035008364791010174, 'max_iter': 623}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:00,162] Trial 355 finished with value: -3869473589.9204764 and parameters: {'alpha': 64.35694573334185, 'eta0': 0.034305984363782814, 'max_iter': 627}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:00,178] Trial 358 finished with value: -3728533602.9629507 an

d parameters: {'alpha': 15.923877618160219, 'eta0': 0.03252946310617595, 'max_iter': 623}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:00,217] Trial 362 finished with value: -3716122565.012736 and parameters: {'alpha': 14.61977120142564, 'eta0': 0.034435467301513145, 'max_iter': 617}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:00,289] Trial 361 finished with value: -3723470190.725918 and parameters: {'alpha': 15.391543136213421, 'eta0': 0.03502426203748439, 'max_iter': 622}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:00,326] Trial 360 finished with value: -3725911819.8767 and parameters: {'alpha': 15.649259162060249, 'eta0': 0.0341180798969448, 'max_iter': 621}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:00,328] Trial 364 finished with value: -3710110138.308078 and parameters: {'alpha': 13.2814866482934, 'eta0': 0.012303453765488304, 'max_iter': 622}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:00,336] Trial 365 finished with value: -3719056904.589836 and parameters: {'alpha': 14.916566031034016, 'eta0': 0.0343487776308851, 'max_iter': 621}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:00,347] Trial 363 finished with value: -3893556976.50796 and parameters: {'alpha': 192.84468696075007, 'eta0': 0.03388509460398802, 'max_iter': 627}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:00,376] Trial 367 finished with value: -3706112939.2112527 and parameters: {'alpha': 12.894415063162779, 'eta0': 0.011720107425676654, 'max_iter': 580}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:00,419] Trial 366 finished with value: -3694531728.397832 and parameters: {'alpha': 12.92226407009914, 'eta0': 0.023664035360336712, 'max_iter': 620}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:00,458] Trial 368 finished with value: -2865222744.2648325 and parameters: {'alpha': 0.18565167005864736, 'eta0': 0.0236991284545006, 'max_iter': 619}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:00,483] Trial 369 finished with value: -3714193758.207429 and parameters: {'alpha': 14.67295594800605, 'eta0': 0.02356762055900275, 'max_iter': 617}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:00,559] Trial 370 finished with value: -3716116356.4556603 and parameters: {'alpha': 13.805693970820096, 'eta0': 0.011877711376769358, 'max_iter': 617}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:00,614] Trial 371 finished with value: -3722167434.904107 and parameters: {'alpha': 15.113328306482325, 'eta0': 0.027110632727065903, 'max_iter': 578}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:00,630] Trial 373 finished with value: -3716913632.7477427 and parameters: {'alpha': 14.572518977008192, 'eta0': 0.027108820772642803, 'max_iter': 582}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:00,658] Trial 374 finished with value: -3712748339.947333 and parameters: {'alpha': 14.166071223741403, 'eta0': 0.02710651212321147, 'max_iter': 584}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:00,680] Trial 375 finished with value: -3715285120.319915 and parameters: {'alpha': 14.414309567988926, 'eta0': 0.02724189770107694, 'max_iter': 579}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:00,711] Trial 372 finished with value: -3685275111.4304237 and parameters: {'alpha': 12.285030251918476, 'eta0': 0.027088359307679447, 'max_iter': 581}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:00,730] Trial 376 finished with value: -2910530280.891656 and parameters: {'alpha': 0.3411076611562268, 'eta0': 0.027114566253158938, 'max_iter': 583}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:00,742] Trial 379 finished with value: -3696684618.4331055 and parameters: {'alpha': 13.176393605083208, 'eta0': 0.027047722597795327, 'max_iter': 577}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:00,766] Trial 378 finished with value: -3874938239.595684 and parameters: {'alpha': 82.3524728285075, 'eta0': 0.02678399135186285, 'max_iter': 582}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:00,795] Trial 377 finished with value: -3895741293.2430296 an

d parameters: {'alpha': 241.04894234411015, 'eta0': 0.027183783014077288, 'max_iter': 582}. Best is trial 304 with value: -2848057453.3819666.

[I 2024-12-23 10:28:00,826] Trial 380 finished with value: -3042597925.557448 and parameters: {'alpha': 0.8606623158650922, 'eta0': 0.027228817392636467, 'max_iter': 579}. Best is trial 304 with value: -2848057453.3819666.

[I 2024-12-23 10:28:00,827] Trial 381 finished with value: -2891365934.233613 and parameters: {'alpha': 0.2343089324121563, 'eta0': 0.02718645330816758, 'max_iter': 581}. Best is trial 304 with value: -2848057453.3819666.

[I 2024-12-23 10:28:00,872] Trial 384 finished with value: -3143406485.0778227 and parameters: {'alpha': 1.322430838399854, 'eta0': 0.027132866451100343, 'max_iter': 584}. Best is trial 304 with value: -2848057453.3819666.

[I 2024-12-23 10:28:00,916] Trial 382 finished with value: -3890392665.5164504 and parameters: {'alpha': 128.2716143192556, 'eta0': 0.07912488868918807, 'max_iter': 581}. Best is trial 304 with value: -2848057453.3819666.

[I 2024-12-23 10:28:00,959] Trial 385 finished with value: -2861890012.971925 and parameters: {'alpha': 0.08716737673155345, 'eta0': 0.02739445576521963, 'max_iter': 591}. Best is trial 304 with value: -2848057453.3819666.

[I 2024-12-23 10:28:00,978] Trial 383 finished with value: -2857456283.2110496 and parameters: {'alpha': 0.055216940676486664, 'eta0': 0.02755511513163649, 'max_iter': 582}. Best is trial 304 with value: -2848057453.3819666.

[I 2024-12-23 10:28:01,017] Trial 388 finished with value: -3105566372.897602 and parameters: {'alpha': 1.130731021841805, 'eta0': 0.0264476354130785, 'max_iter': 584}. Best is trial 304 with value: -2848057453.3819666.

[I 2024-12-23 10:28:01,020] Trial 386 finished with value: -2926736280.9030466 and parameters: {'alpha': 0.4172454157160538, 'eta0': 0.027616503494291005, 'max_iter': 582}. Best is trial 304 with value: -2848057453.3819666.

[I 2024-12-23 10:28:01,031] Trial 387 finished with value: -3884513486.4949975 and parameters: {'alpha': 130.40264347392275, 'eta0': 0.026757991968537446, 'max_iter': 576}. Best is trial 304 with value: -2848057453.3819666.

[I 2024-12-23 10:28:01,118] Trial 389 finished with value: -2886047977.164408 and parameters: {'alpha': 0.20200320466062766, 'eta0': 0.027018212479683276, 'max_iter': 572}. Best is trial 304 with value: -2848057453.3819666.

[I 2024-12-23 10:28:01,121] Trial 390 finished with value: -2856563353.632135 and parameters: {'alpha': 0.035053151903546374, 'eta0': 0.02715675652294004, 'max_iter': 582}. Best is trial 304 with value: -2848057453.3819666.

[I 2024-12-23 10:28:01,222] Trial 391 finished with value: -3078785803.722603 and parameters: {'alpha': 1.0178382409612383, 'eta0': 0.027063077880939618, 'max_iter': 573}. Best is trial 304 with value: -2848057453.3819666.

[I 2024-12-23 10:28:01,238] Trial 392 finished with value: -2855161926.9615364 and parameters: {'alpha': 0.09642815410129735, 'eta0': 0.023628585186822967, 'max_iter': 585}. Best is trial 304 with value: -2848057453.3819666.

[I 2024-12-23 10:28:01,247] Trial 394 finished with value: -2964072564.4389563 and parameters: {'alpha': 0.4982395495262929, 'eta0': 0.030840407947875847, 'max_iter': 588}. Best is trial 304 with value: -2848057453.3819666.

[I 2024-12-23 10:28:01,311] Trial 395 finished with value: -2935839090.8441176 and parameters: {'alpha': 0.4492999630133709, 'eta0': 0.031095247344302322, 'max_iter': 591}. Best is trial 304 with value: -2848057453.3819666.

[I 2024-12-23 10:28:01,319] Trial 393 finished with value: -3111014021.655529 and parameters: {'alpha': 1.1854852094198536, 'eta0': 0.02371998062614673, 'max_iter': 590}. Best is trial 304 with value: -2848057453.3819666.

[I 2024-12-23 10:28:01,334] Trial 398 finished with value: -2893772150.73695 and parameters: {'alpha': 0.28520203961546603, 'eta0': 0.023690109027302002, 'max_iter': 558}. Best is trial 304 with value: -2848057453.3819666.

[I 2024-12-23 10:28:01,338] Trial 396 finished with value: -3457727291.444444 and parameters: {'alpha': 4.5543313828276055, 'eta0': 0.03133101562887591, 'max_iter': 555}. Best is trial 304 with value: -2848057453.3819666.

[I 2024-12-23 10:28:01,377] Trial 401 finished with value: -3883190243.1694465 and parameters: {'alpha': 113.9258412688667, 'eta0': 0.02344049670246626, 'max_iter': 556}. Best is trial 304 with value: -2848057453.3819666.

[I 2024-12-23 10:28:01,382] Trial 400 finished with value: -2861323907.62999 and

```
parameters: {'alpha': 0.1559603111689573, 'eta0': 0.023779177665809167, 'max_iter': 556}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:01,385] Trial 397 finished with value: -2908015415.7186384 and parameters: {'alpha': 0.309543954122274, 'eta0': 0.030829680515329676, 'max_iter': 554}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:01,428] Trial 399 finished with value: -2859241653.9451 and parameters: {'alpha': 0.13220398121941937, 'eta0': 0.024153803244395807, 'max_iter': 558}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:01,447] Trial 402 finished with value: -2871318690.4785557 and parameters: {'alpha': 0.22945459145964398, 'eta0': 0.023265094387797728, 'max_iter': 562}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:01,501] Trial 404 finished with value: -2856652467.991517 and parameters: {'alpha': 0.1175708360030593, 'eta0': 0.023620729491637446, 'max_iter': 554}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:01,543] Trial 403 finished with value: -2864851590.454939 and parameters: {'alpha': 0.18357245860433594, 'eta0': 0.02366124599832553, 'max_iter': 746}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:01,561] Trial 405 finished with value: -2950025099.155086 and parameters: {'alpha': 0.554193943087201, 'eta0': 0.022914033011555, 'max_iter': 554}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:01,586] Trial 406 finished with value: -3563337513.3013816 and parameters: {'alpha': 6.266753528311181, 'eta0': 0.02357381485716422, 'max_iter': 551}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:01,610] Trial 407 finished with value: -2881238557.850502 and parameters: {'alpha': 0.21043471203920625, 'eta0': 0.023958042030996753, 'max_iter': 558}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:01,652] Trial 408 finished with value: -3530861791.3992295 and parameters: {'alpha': 5.809683985270926, 'eta0': 0.001237138052989896, 'max_iter': 551}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:01,677] Trial 410 finished with value: -3542164048.055918 and parameters: {'alpha': 5.71121437553523, 'eta0': 0.02386314481717624, 'max_iter': 749}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:01,694] Trial 409 finished with value: -3547440304.7807007 and parameters: {'alpha': 5.841281303401623, 'eta0': 0.02363352946121957, 'max_iter': 549}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:01,787] Trial 411 finished with value: -3544749243.4642906 and parameters: {'alpha': 5.772010094937297, 'eta0': 0.02352257253373358, 'max_iter': 600}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:01,792] Trial 413 finished with value: -3561819824.866275 and parameters: {'alpha': 6.223630551012463, 'eta0': 0.023529208779512603, 'max_iter': 555}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:01,870] Trial 412 finished with value: -3575473570.7087374 and parameters: {'alpha': 6.623967335221692, 'eta0': 0.023674718476935665, 'max_iter': 547}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:01,887] Trial 415 finished with value: -3571741335.9937897 and parameters: {'alpha': 6.479083694579227, 'eta0': 0.021410826028534734, 'max_iter': 548}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:01,955] Trial 416 finished with value: -3571417596.496629 and parameters: {'alpha': 6.500369469806258, 'eta0': 0.0235684962512619, 'max_iter': 558}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:01,955] Trial 414 finished with value: -3580862787.09628 and parameters: {'alpha': 6.787831705305695, 'eta0': 0.023444574452647002, 'max_iter': 560}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:01,983] Trial 417 finished with value: -3600854413.441514 and parameters: {'alpha': 7.427235086341631, 'eta0': 0.02145460375203049, 'max_iter': 560}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:02,004] Trial 420 finished with value: -3587009924.8279176 and parameters: {'alpha': 6.953528174115368, 'eta0': 0.021489100243316274, 'max_iter': 745}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:02,021] Trial 419 finished with value: -3625274636.753582 and
```

```
parameters: {'alpha': 8.375619530832216, 'eta0': 0.02087047827289359, 'max_iter': 555}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:02,028] Trial 421 finished with value: -3599919865.295981 and parameters: {'alpha': 7.713135015514336, 'eta0': 0.0017289517868417092, 'max_iter': 551}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:02,051] Trial 418 finished with value: -3610240321.437133 and parameters: {'alpha': 7.77127561996899, 'eta0': 0.021203295424796372, 'max_iter': 556}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:02,069] Trial 423 finished with value: -3609408196.694744 and parameters: {'alpha': 7.766953553285782, 'eta0': 0.022524889458235525, 'max_iter': 753}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:02,112] Trial 422 finished with value: -3597711744.9188128 and parameters: {'alpha': 7.315680971811169, 'eta0': 0.021466228091335974, 'max_iter': 548}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:02,120] Trial 425 finished with value: -3616737102.2449293 and parameters: {'alpha': 8.02685786789806, 'eta0': 0.021179344521622175, 'max_iter': 512}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:02,167] Trial 426 finished with value: -3631095422.7565393 and parameters: {'alpha': 8.636632188134673, 'eta0': 0.021043792940923553, 'max_iter': 515}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:02,167] Trial 427 finished with value: -3569952898.8755875 and parameters: {'alpha': 6.417967259321343, 'eta0': 0.020788646720343064, 'max_iter': 770}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:02,172] Trial 424 finished with value: -3616916667.709895 and parameters: {'alpha': 8.04316768883311, 'eta0': 0.021579357536944666, 'max_iter': 547}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:02,281] Trial 429 finished with value: -3644421251.791304 and parameters: {'alpha': 9.282605521615706, 'eta0': 0.021422615251559772, 'max_iter': 516}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:02,290] Trial 428 finished with value: -3620761395.211127 and parameters: {'alpha': 8.192799013740347, 'eta0': 0.021216593037354677, 'max_iter': 754}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:02,331] Trial 430 finished with value: -3646494324.080945 and parameters: {'alpha': 9.363747932901854, 'eta0': 0.020602273680741915, 'max_iter': 784}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:02,346] Trial 431 finished with value: -3678674137.8988914 and parameters: {'alpha': 10.865734249541072, 'eta0': 0.021282222607811874, 'max_iter': 733}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:02,373] Trial 432 finished with value: -3651961743.560857 and parameters: {'alpha': 9.393153184769128, 'eta0': 0.0220081455562346, 'max_iter': 749}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:02,458] Trial 434 finished with value: -3659213074.2045984 and parameters: {'alpha': 9.759514979616997, 'eta0': 0.02150001034938689, 'max_iter': 564}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:02,486] Trial 433 finished with value: -3702829253.7633348 and parameters: {'alpha': 10.043202173115997, 'eta0': 0.09432375093955919, 'max_iter': 597}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:02,556] Trial 435 finished with value: -3670292794.595163 and parameters: {'alpha': 10.366342477449036, 'eta0': 0.02139121251234761, 'max_iter': 746}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:02,578] Trial 436 finished with value: -3677636252.3557725 and parameters: {'alpha': 10.802685175459853, 'eta0': 0.02160618392615625, 'max_iter': 599}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:02,616] Trial 437 finished with value: -3672540648.8506365 and parameters: {'alpha': 10.495518409480544, 'eta0': 0.021017581433535912, 'max_iter': 514}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:02,624] Trial 440 finished with value: -3689204199.2786546 and parameters: {'alpha': 11.550469064511015, 'eta0': 0.021775966309585584, 'max_iter': 733}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:02,625] Trial 438 finished with value: -3679599324.099101 and
```

```
parameters: {'alpha': 10.923639340406245, 'eta0': 0.021435851229538234, 'max_iter': 518}. Best is trial 304 with value: -2848057453.3819666.  
[I 2024-12-23 10:28:02,666] Trial 439 finished with value: -3681035166.5171633 and parameters: {'alpha': 11.009838766889956, 'eta0': 0.02029036971927686, 'max_iter': 518}. Best is trial 304 with value: -2848057453.3819666.  
[I 2024-12-23 10:28:02,707] Trial 441 finished with value: -3681313102.3612 and parameters: {'alpha': 11.030647581870443, 'eta0': 0.021162404310892054, 'max_iter': 837}. Best is trial 304 with value: -2848057453.3819666.  
[I 2024-12-23 10:28:02,754] Trial 444 finished with value: -3725381856.9977036 and parameters: {'alpha': 14.518633283165636, 'eta0': 0.020777995969699686, 'max_iter': 827}. Best is trial 304 with value: -2848057453.3819666.  
[I 2024-12-23 10:28:02,759] Trial 442 finished with value: -3890066783.8933325 and parameters: {'alpha': 169.1148753147274, 'eta0': 0.020604975842316096, 'max_iter': 527}. Best is trial 304 with value: -2848057453.3819666.  
[I 2024-12-23 10:28:02,769] Trial 445 finished with value: -3692266787.580775 and parameters: {'alpha': 12.780009323876966, 'eta0': 0.025251850085161467, 'max_iter': 600}. Best is trial 304 with value: -2848057453.3819666.  
[I 2024-12-23 10:28:02,774] Trial 447 finished with value: -3751117659.9110665 and parameters: {'alpha': 13.435957903537686, 'eta0': 0.09447840364243569, 'max_iter': 604}. Best is trial 304 with value: -2848057453.3819666.  
[I 2024-12-23 10:28:02,791] Trial 443 finished with value: -3687833373.5490656 and parameters: {'alpha': 12.425060806488363, 'eta0': 0.024666807891360547, 'max_iter': 793}. Best is trial 304 with value: -2848057453.3819666.  
[I 2024-12-23 10:28:02,855] Trial 446 finished with value: -3680092497.6298575 and parameters: {'alpha': 11.875730927186117, 'eta0': 0.025268293602005897, 'max_iter': 811}. Best is trial 304 with value: -2848057453.3819666.  
[I 2024-12-23 10:28:02,878] Trial 448 finished with value: -3686869443.703023 and parameters: {'alpha': 12.358750069849826, 'eta0': 0.02493503798791077, 'max_iter': 789}. Best is trial 304 with value: -2848057453.3819666.  
[I 2024-12-23 10:28:03,000] Trial 450 finished with value: -3685706912.58049 and parameters: {'alpha': 12.27364924657499, 'eta0': 0.024991431223432448, 'max_iter': 596}. Best is trial 304 with value: -2848057453.3819666.  
[I 2024-12-23 10:28:03,024] Trial 452 finished with value: -3737820491.500224 and parameters: {'alpha': 16.891895117877013, 'eta0': 0.02544193210725167, 'max_iter': 797}. Best is trial 304 with value: -2848057453.3819666.  
[I 2024-12-23 10:28:03,040] Trial 451 finished with value: -3740784758.6615133 and parameters: {'alpha': 17.26729791269888, 'eta0': 0.025092280955735034, 'max_iter': 795}. Best is trial 304 with value: -2848057453.3819666.  
[I 2024-12-23 10:28:03,061] Trial 449 finished with value: -3698603698.2179327 and parameters: {'alpha': 13.295242448688612, 'eta0': 0.025224106687953107, 'max_iter': 601}. Best is trial 304 with value: -2848057453.3819666.  
[I 2024-12-23 10:28:03,108] Trial 453 finished with value: -3746011998.7409925 and parameters: {'alpha': 17.993831576816053, 'eta0': 0.025345904219667138, 'max_iter': 591}. Best is trial 304 with value: -2848057453.3819666.  
[I 2024-12-23 10:28:03,110] Trial 454 finished with value: -3741840167.6338487 and parameters: {'alpha': 17.386475729064912, 'eta0': 0.02442498533655205, 'max_iter': 835}. Best is trial 304 with value: -2848057453.3819666.  
[I 2024-12-23 10:28:03,137] Trial 455 finished with value: -3750248803.4105315 and parameters: {'alpha': 18.617876602890217, 'eta0': 0.025460299016958465, 'max_iter': 596}. Best is trial 304 with value: -2848057453.3819666.  
[I 2024-12-23 10:28:03,243] Trial 456 finished with value: -3746575584.0073013 and parameters: {'alpha': 18.05841951264608, 'eta0': 0.024868386102160796, 'max_iter': 598}. Best is trial 304 with value: -2848057453.3819666.  
[I 2024-12-23 10:28:03,258] Trial 458 finished with value: -3877185379.8807297 and parameters: {'alpha': 91.27036825282256, 'eta0': 0.02519410068053498, 'max_iter': 682}. Best is trial 304 with value: -2848057453.3819666.  
[I 2024-12-23 10:28:03,259] Trial 457 finished with value: -3747999369.5251646 and parameters: {'alpha': 18.261547963977886, 'eta0': 0.024788817000979513, 'max_iter': 678}. Best is trial 304 with value: -2848057453.3819666.  
[I 2024-12-23 10:28:03,263] Trial 461 finished with value: -2861724026.321899 and
```

parameters: {'alpha': 0.1427047800150924, 'eta0': 0.024818158897718174, 'max_iter': 599}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:03,276] Trial 460 finished with value: -3746092369.0330033 and parameters: {'alpha': 18.005058287801234, 'eta0': 0.025339372350950348, 'max_iter': 678}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:03,281] Trial 459 finished with value: -3891810493.2832937 and parameters: {'alpha': 173.13821103099104, 'eta0': 0.024925535129900134, 'max_iter': 596}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:03,331] Trial 462 finished with value: -3005024971.4544067 and parameters: {'alpha': 0.7074214869556774, 'eta0': 0.02483790662667644, 'max_iter': 598}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:03,365] Trial 463 finished with value: -2856904361.1089563 and parameters: {'alpha': 0.08046693201022166, 'eta0': 0.02509881514753476, 'max_iter': 677}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:03,393] Trial 464 finished with value: -2863360589.1357393 and parameters: {'alpha': 0.16066111837664918, 'eta0': 0.02453053618524085, 'max_iter': 601}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:03,408] Trial 468 finished with value: -2854753120.941078 and parameters: {'alpha': 0.011778567338805612, 'eta0': 0.02428023530605321, 'max_iter': 676}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:03,417] Trial 465 finished with value: -3073861869.403192 and parameters: {'alpha': 1.0199706073458685, 'eta0': 0.024923805884334377, 'max_iter': 597}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:03,421] Trial 466 finished with value: -3029513909.7587013 and parameters: {'alpha': 0.8157561384003548, 'eta0': 0.0247371169195617, 'max_iter': 670}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:03,470] Trial 467 finished with value: -2969433520.3743296 and parameters: {'alpha': 0.6317747671112258, 'eta0': 0.024427885441582718, 'max_iter': 676}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:03,628] Trial 469 finished with value: -3879111766.935277 and parameters: {'alpha': 94.00344119388322, 'eta0': 0.02450357263631328, 'max_iter': 686}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:03,632] Trial 471 finished with value: -2921799459.6163797 and parameters: {'alpha': 0.42073503322924677, 'eta0': 0.023891070215734927, 'max_iter': 680}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:03,667] Trial 470 finished with value: -2854246463.5138884 and parameters: {'alpha': 0.04305056566297692, 'eta0': 0.024302666487649165, 'max_iter': 683}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:03,688] Trial 474 finished with value: -2861593106.295682 and parameters: {'alpha': 0.1584807513085043, 'eta0': 0.023751473850562588, 'max_iter': 665}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:03,692] Trial 472 finished with value: -2883965275.239086 and parameters: {'alpha': 0.2230361866460024, 'eta0': 0.02430632962811363, 'max_iter': 664}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:03,799] Trial 473 finished with value: -2861949181.9640436 and parameters: {'alpha': 0.16179613410550175, 'eta0': 0.023712507855352283, 'max_iter': 689}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:03,814] Trial 475 finished with value: -2906467354.5318775 and parameters: {'alpha': 0.3434777910570881, 'eta0': 0.024413157723246072, 'max_iter': 672}. Best is trial 304 with value: -2848057453.3819666.
[I 2024-12-23 10:28:03,874] Trial 479 finished with value: -2845480821.2074065 and parameters: {'alpha': 0.23003707843306817, 'eta0': 0.004974781069508882, 'max_iter': 651}. Best is trial 479 with value: -2845480821.2074065.
[I 2024-12-23 10:28:03,896] Trial 476 finished with value: -2903232994.4504128 and parameters: {'alpha': 0.3376183034150023, 'eta0': 0.023233072555487944, 'max_iter': 652}. Best is trial 479 with value: -2845480821.2074065.
[I 2024-12-23 10:28:03,922] Trial 477 finished with value: -3016902538.9631104 and parameters: {'alpha': 0.7707087836494536, 'eta0': 0.023035777816545627, 'max_iter': 569}. Best is trial 479 with value: -2845480821.2074065.
[I 2024-12-23 10:28:03,979] Trial 481 finished with value: -2934846675.9091444 an

d parameters: {'alpha': 0.4507932855100718, 'eta0': 0.028369511663552067, 'max_iter': 714}. Best is trial 479 with value: -2845480821.2074065.
[I 2024-12-23 10:28:03,986] Trial 480 finished with value: -2977223609.2987533 and parameters: {'alpha': 0.6745095229912321, 'eta0': 0.022871821956779625, 'max_iter': 574}. Best is trial 479 with value: -2845480821.2074065.
[I 2024-12-23 10:28:03,998] Trial 482 finished with value: -3513476933.1571093 and parameters: {'alpha': 5.054169622827566, 'eta0': 0.02328655675645714, 'max_iter': 710}. Best is trial 479 with value: -2845480821.2074065.
[I 2024-12-23 10:28:04,017] Trial 484 finished with value: -3481732937.87994 and parameters: {'alpha': 4.444233326282177, 'eta0': 0.02305245832034485, 'max_iter': 656}. Best is trial 479 with value: -2845480821.2074065.
[I 2024-12-23 10:28:04,022] Trial 478 finished with value: -2944931904.8550367 and parameters: {'alpha': 0.14384143833426283, 'eta0': 0.07190373785749073, 'max_iter': 569}. Best is trial 479 with value: -2845480821.2074065.
[I 2024-12-23 10:28:04,058] Trial 486 finished with value: -3533628340.103746 and parameters: {'alpha': 5.547118322551554, 'eta0': 0.02840866217338235, 'max_iter': 694}. Best is trial 479 with value: -2845480821.2074065.
[I 2024-12-23 10:28:04,106] Trial 483 finished with value: -2857952048.433127 and parameters: {'alpha': 0.0074662126973776, 'eta0': 0.029653132190140083, 'max_iter': 695}. Best is trial 479 with value: -2845480821.2074065.
[I 2024-12-23 10:28:04,107] Trial 485 finished with value: -3463968891.5280447 and parameters: {'alpha': 4.637675852698446, 'eta0': 0.02840721291272772, 'max_iter': 705}. Best is trial 479 with value: -2845480821.2074065.
[I 2024-12-23 10:28:04,108] Trial 487 finished with value: -3520742904.8333826 and parameters: {'alpha': 5.255150183277462, 'eta0': 0.029098027241170683, 'max_iter': 711}. Best is trial 479 with value: -2845480821.2074065.
[I 2024-12-23 10:28:04,150] Trial 488 finished with value: -2859116337.3270984 and parameters: {'alpha': 0.042961486486232395, 'eta0': 0.028751939553394005, 'max_iter': 650}. Best is trial 479 with value: -2845480821.2074065.
[I 2024-12-23 10:28:04,162] Trial 490 finished with value: -3533996511.1669755 and parameters: {'alpha': 5.559873734679205, 'eta0': 0.028861855757637746, 'max_iter': 650}. Best is trial 479 with value: -2845480821.2074065.
[I 2024-12-23 10:28:04,206] Trial 492 finished with value: -3507688000.485944 and parameters: {'alpha': 5.584451575158703, 'eta0': 0.030179711856862704, 'max_iter': 692}. Best is trial 479 with value: -2845480821.2074065.
[I 2024-12-23 10:28:04,219] Trial 491 finished with value: -3463894491.9835663 and parameters: {'alpha': 4.637645951658467, 'eta0': 0.028525830376182185, 'max_iter': 694}. Best is trial 479 with value: -2845480821.2074065.
[I 2024-12-23 10:28:04,224] Trial 495 finished with value: -3535373155.5764923 and parameters: {'alpha': 5.596271796157091, 'eta0': 0.0292293121887703, 'max_iter': 716}. Best is trial 479 with value: -2845480821.2074065.
[I 2024-12-23 10:28:04,226] Trial 493 finished with value: -3462616024.098525 and parameters: {'alpha': 4.6200599255466726, 'eta0': 0.02907238942448339, 'max_iter': 706}. Best is trial 479 with value: -2845480821.2074065.
[I 2024-12-23 10:28:04,227] Trial 496 finished with value: -3535090212.663746 and parameters: {'alpha': 5.609384904332577, 'eta0': 0.07006246721750341, 'max_iter': 700}. Best is trial 479 with value: -2845480821.2074065.
[I 2024-12-23 10:28:04,232] Trial 489 finished with value: -2857497502.689193 and parameters: {'alpha': 0.0212315117373106, 'eta0': 0.029941603634136085, 'max_iter': 700}. Best is trial 479 with value: -2845480821.2074065.
[I 2024-12-23 10:28:04,241] Trial 494 finished with value: -3534783922.1117415 and parameters: {'alpha': 5.585574554041942, 'eta0': 0.07281301854492069, 'max_iter': 714}. Best is trial 479 with value: -2845480821.2074065.
[I 2024-12-23 10:28:04,249] Trial 497 finished with value: -3513067985.381955 and parameters: {'alpha': 5.110291491891147, 'eta0': 0.0686280320401185, 'max_iter': 726}. Best is trial 479 with value: -2845480821.2074065.
[I 2024-12-23 10:28:04,254] Trial 498 finished with value: -3542433951.7745667 and parameters: {'alpha': 5.7625280957513, 'eta0': 0.028303285540571103, 'max_iter': 690}. Best is trial 479 with value: -2845480821.2074065.
[I 2024-12-23 10:28:04,260] Trial 499 finished with value: -3504596601.802667 and

```
parameters: {'alpha': 5.257932081436895, 'eta0': 0.0060891400662108405, 'max_iter': 719}. Best is trial 479 with value: -2845480821.2074065.  
Best Hyperparameters: {'alpha': 0.23003707843306817, 'eta0': 0.004974781069508882, 'max_iter': 651}
```

```
In [26]: best_params = study.best_params  
best_model = SGDRegressor(**best_params, random_state=42)  
best_model.fit(X_train_scaled, y_train)  
  
y_pred = best_model.predict(X_test_scaled)  
  
mse = mean_squared_error(y_test, y_pred)  
mape = mean_absolute_percentage_error(y_test, y_pred)  
rmse = np.sqrt(mse)  
r2 = r2_score(y_test, y_pred)  
  
print(f"Mean Squared Error (MSE): {mse}")  
print(f"Mean Absolute Percentage Error (MAPE): {mape}")  
print(f"Root Mean Squared Error (RMSE): {rmse}")  
print(f"R-squared (R^2): {r2}")
```

```
Mean Squared Error (MSE): 2827177487.7341948  
Mean Absolute Percentage Error (MAPE): 8.524880935585587e+19  
Root Mean Squared Error (RMSE): 53171.209199473684  
R-squared (R^2): 0.26732965566042755
```

Model Evaluation Summary:

For {'alpha': 0.23003707843306817, 'eta0': 0.004974781069508882, 'max_iter': 651} hyperparameters The MSE and RMSE indicate moderate prediction errors, with an RMSE of around 53,171. The MAPE suggests significant deviation from actual values, but the positive R^2 (0.27) indicates that the model explains some of the variance in the data, though there is room for improvement.

Gaussian Process Regression

⚠ WE HAVEN'T BEEN ABLE TO RUN THIS REGRESSOR ⚠ :

We have tried to train it in different devices, but when we try to initialize it our PCs explodes, Google Collab is also resilient of helping out.

```
In [ ]: '''from sklearn.model_selection import train_test_split, cross_val_score  
from sklearn.preprocessing import StandardScaler  
from sklearn.gaussian_process import GaussianProcessRegressor  
from sklearn.gaussian_process.kernels import RBF, ConstantKernel as C  
from sklearn.metrics import mean_squared_error, mean_absolute_percentage_error,  
import numpy as np  
import optuna  
  
scaler = StandardScaler()  
X_train_scaled = scaler.fit_transform(X_train)  
X_test_scaled = scaler.transform(X_test)  
  
def objective(trial):  
    length_scale = trial.suggest_float('length_scale', 1e-2, 10.0)  
    constant_value = trial.suggest_float('constant_value', 1e-2, 10.0)
```

```

alpha = trial.suggest_float('alpha', 1e-5, 1.0)
n_restarts_optimizer = trial.suggest_int('n_restarts_optimizer', 0, 10)

kernel = C(constant_value) * RBF(length_scale=length_scale)

model = GaussianProcessRegressor(kernel=kernel, alpha=alpha, n_restarts_optimizer=n_restarts_optimizer)

score = cross_val_score(model, X_train_scaled, y_train, cv=5, scoring='neg_mean_squared_error')
return score.mean()

study = optuna.create_study(direction='maximize')
study.optimize(objective, n_trials=10, n_jobs=-1)

print(f"Best Hyperparameters: {study.best_params}")

```

[I 2024-12-23 10:28:27,115] A new study created in memory with name: no-name-6c3642c6-583c-4904-81b3-09472b6ef4cd

```

In [ ]: '''best_params = study.best_params
length_scale = best_params['length_scale']
constant_value = best_params['constant_value']
alpha = best_params['alpha']
n_restarts_optimizer = best_params['n_restarts_optimizer']
best_kernel = C(constant_value) * RBF(length_scale=length_scale)

best_model = GaussianProcessRegressor(kernel=best_kernel, alpha=alpha, n_restarts_optimizer=n_restarts_optimizer)
best_model.fit(X_train_scaled, y_train)

y_pred, _ = best_model.predict(X_test_scaled, return_std=True)

mse = mean_squared_error(y_test, y_pred)
mape = mean_absolute_percentage_error(y_test, y_pred)
rmse = np.sqrt(mse)
r2 = r2_score(y_test, y_pred)

print(f"Mean Squared Error (MSE): {mse}")
print(f"Mean Absolute Percentage Error (MAPE): {mape}")
print(f"Root Mean Squared Error (RMSE): {rmse}")
print(f"R-squared (R²): {r2}")'''

```

CART (Decision Tree Regressor)

For our Decision Tree Classifier, we are using Optuna for hyperparameter tuning, evaluating the following hyperparameters:

- max_depth: Tree depth (3 to 50) to control model complexity and prevent overfitting by limiting how deep each tree can grow.
- min_samples_split: Minimum samples required to split a node (2 to 32), preventing the model from creating overly complex trees.
- min_samples_leaf: Minimum samples at a leaf node (1 to 32), controlling the smallest size of terminal nodes to ensure the model generalizes well.
- max_features: Number of features to consider at each split (sqrt, log2, or all), providing flexibility in feature selection and improving model robustness.

With the Decision Tree Regressor, we expect to capture more complex patterns in the data compared to a Linear Regressor, which may have struggled with non-linear relationships and this could help us to obtain better results.

```
In [49]: X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_
scaler = StandardScaler()
X_train_scaled = scaler.fit_transform(X_train)
X_test_scaled = scaler.transform(X_test)

def objective(trial):
    max_depth = trial.suggest_int('max_depth', 3, 30)
    min_samples_split = trial.suggest_int('min_samples_split', 2, 20)
    min_samples_leaf = trial.suggest_int('min_samples_leaf', 1, 10)
    max_features = trial.suggest_categorical('max_features', ['sqrt', 'log2', 'No
    model = DecisionTreeRegressor(
        max_depth=max_depth,
        min_samples_split=min_samples_split,
        min_samples_leaf=min_samples_leaf,
        max_features=max_features,
        random_state=42
    )

    score = cross_val_score(model, X_train_scaled, y_train, cv=5, scoring='neg_rmse')
    return score.mean()

study = optuna.create_study(direction='maximize')
study.optimize(objective, n_trials=100, n_jobs=-1)

best_params = study.best_params

print(f"Best Hyperparameters: {study.best_params}")
```

```
[I 2024-12-22 21:04:35,038] A new study created in memory with name: no-name-a9c7
7e2d-e1fd-4ebb-a6fe-a50b6b0bfad8
```

```
[I 2024-12-22 21:04:35,235] Trial 3 finished with value: -2864624631.3827405 and parameters: {'max_depth': 8, 'min_samples_split': 13, 'min_samples_leaf': 2, 'max_features': 'sqrt'}. Best is trial 3 with value: -2864624631.3827405.
[I 2024-12-22 21:04:35,239] Trial 5 finished with value: -2837743013.8976803 and parameters: {'max_depth': 4, 'min_samples_split': 4, 'min_samples_leaf': 1, 'max_features': 'log2'}. Best is trial 5 with value: -2837743013.8976803.
[I 2024-12-22 21:04:35,250] Trial 0 finished with value: -3057633001.186614 and parameters: {'max_depth': 22, 'min_samples_split': 8, 'min_samples_leaf': 9, 'max_features': 'sqrt'}. Best is trial 5 with value: -2837743013.8976803.
[I 2024-12-22 21:04:35,274] Trial 19 finished with value: -2795297948.7129655 and parameters: {'max_depth': 8, 'min_samples_split': 15, 'min_samples_leaf': 4, 'max_features': 'sqrt'}. Best is trial 19 with value: -2795297948.7129655.
[I 2024-12-22 21:04:35,275] Trial 13 finished with value: -3230794268.5292416 and parameters: {'max_depth': 12, 'min_samples_split': 5, 'min_samples_leaf': 3, 'max_features': 'log2'}. Best is trial 19 with value: -2795297948.7129655.
[I 2024-12-22 21:04:35,279] Trial 8 finished with value: -3031627818.58026 and parameters: {'max_depth': 30, 'min_samples_split': 4, 'min_samples_leaf': 10, 'max_features': 'sqrt'}. Best is trial 19 with value: -2795297948.7129655.
[I 2024-12-22 21:04:35,284] Trial 4 finished with value: -3266718690.334713 and parameters: {'max_depth': 18, 'min_samples_split': 9, 'min_samples_leaf': 6, 'max_features': 'sqrt'}. Best is trial 19 with value: -2795297948.7129655.
[I 2024-12-22 21:04:35,288] Trial 14 finished with value: -2711350749.2949715 and parameters: {'max_depth': 4, 'min_samples_split': 12, 'min_samples_leaf': 5, 'max_features': 'log2'}. Best is trial 14 with value: -2711350749.2949715.
[I 2024-12-22 21:04:35,290] Trial 12 finished with value: -2912716268.326997 and parameters: {'max_depth': 15, 'min_samples_split': 5, 'min_samples_leaf': 10, 'max_features': 'log2'}. Best is trial 14 with value: -2711350749.2949715.
[I 2024-12-22 21:04:35,293] Trial 9 finished with value: -3199529095.3499117 and parameters: {'max_depth': 3, 'min_samples_split': 3, 'min_samples_leaf': 9, 'max_features': 'sqrt'}. Best is trial 14 with value: -2711350749.2949715.
[I 2024-12-22 21:04:35,297] Trial 7 finished with value: -3186301549.2675524 and parameters: {'max_depth': 23, 'min_samples_split': 8, 'min_samples_leaf': 7, 'max_features': 'sqrt'}. Best is trial 14 with value: -2711350749.2949715.
[I 2024-12-22 21:04:35,328] Trial 15 finished with value: -4252524232.78139 and parameters: {'max_depth': 30, 'min_samples_split': 7, 'min_samples_leaf': 1, 'max_features': 'sqrt'}. Best is trial 14 with value: -2711350749.2949715.
[I 2024-12-22 21:04:35,341] Trial 11 finished with value: -2727944610.7976155 and parameters: {'max_depth': 7, 'min_samples_split': 19, 'min_samples_leaf': 8, 'max_features': None}. Best is trial 14 with value: -2711350749.2949715.
[I 2024-12-22 21:04:35,347] Trial 1 finished with value: -3095265083.4150577 and parameters: {'max_depth': 11, 'min_samples_split': 14, 'min_samples_leaf': 7, 'max_features': None}. Best is trial 14 with value: -2711350749.2949715.
[I 2024-12-22 21:04:35,348] Trial 6 finished with value: -2731842826.36836 and parameters: {'max_depth': 7, 'min_samples_split': 11, 'min_samples_leaf': 4, 'max_features': None}. Best is trial 14 with value: -2711350749.2949715.
[I 2024-12-22 21:04:35,377] Trial 10 finished with value: -2804743493.4677877 and parameters: {'max_depth': 8, 'min_samples_split': 10, 'min_samples_leaf': 8, 'max_features': None}. Best is trial 14 with value: -2711350749.2949715.
[I 2024-12-22 21:04:35,437] Trial 2 finished with value: -3435137800.329786 and parameters: {'max_depth': 16, 'min_samples_split': 7, 'min_samples_leaf': 8, 'max_features': None}. Best is trial 14 with value: -2711350749.2949715.
[I 2024-12-22 21:04:35,448] Trial 17 finished with value: -3559852167.931225 and parameters: {'max_depth': 29, 'min_samples_split': 13, 'min_samples_leaf': 8, 'max_features': None}. Best is trial 14 with value: -2711350749.2949715.
[I 2024-12-22 21:04:35,555] Trial 18 finished with value: -4210812618.28192 and parameters: {'max_depth': 20, 'min_samples_split': 10, 'min_samples_leaf': 1, 'max_features': None}. Best is trial 14 with value: -2711350749.2949715.
[I 2024-12-22 21:04:35,570] Trial 16 finished with value: -4351983205.791146 and parameters: {'max_depth': 22, 'min_samples_split': 8, 'min_samples_leaf': 2, 'max_features': None}. Best is trial 14 with value: -2711350749.2949715.
```

```
[I 2024-12-22 21:04:35,614] Trial 20 finished with value: -3330165720.6438713 and parameters: {'max_depth': 30, 'min_samples_split': 12, 'min_samples_leaf': 4, 'max_features': 'sqrt'}. Best is trial 14 with value: -2711350749.2949715.  
[I 2024-12-22 21:04:35,645] Trial 22 finished with value: -3057633001.186614 and parameters: {'max_depth': 21, 'min_samples_split': 18, 'min_samples_leaf': 9, 'max_features': 'sqrt'}. Best is trial 14 with value: -2711350749.2949715.  
[I 2024-12-22 21:04:35,658] Trial 21 finished with value: -3719764273.2732515 and parameters: {'max_depth': 28, 'min_samples_split': 11, 'min_samples_leaf': 1, 'max_features': 'sqrt'}. Best is trial 14 with value: -2711350749.2949715.  
[I 2024-12-22 21:04:35,745] Trial 23 finished with value: -2894518070.427404 and parameters: {'max_depth': 9, 'min_samples_split': 19, 'min_samples_leaf': 4, 'max_features': None}. Best is trial 14 with value: -2711350749.2949715.  
[I 2024-12-22 21:04:35,749] Trial 28 finished with value: -2991595472.310168 and parameters: {'max_depth': 5, 'min_samples_split': 20, 'min_samples_leaf': 5, 'max_features': 'log2'}. Best is trial 14 with value: -2711350749.2949715.  
[I 2024-12-22 21:04:35,751] Trial 25 finished with value: -2615160295.023144 and parameters: {'max_depth': 5, 'min_samples_split': 20, 'min_samples_leaf': 6, 'max_features': None}. Best is trial 25 with value: -2615160295.023144.  
[I 2024-12-22 21:04:35,756] Trial 26 finished with value: -3200088385.342457 and parameters: {'max_depth': 3, 'min_samples_split': 20, 'min_samples_leaf': 5, 'max_features': 'log2'}. Best is trial 25 with value: -2615160295.023144.  
[I 2024-12-22 21:04:35,791] Trial 24 finished with value: -2894518070.427404 and parameters: {'max_depth': 9, 'min_samples_split': 19, 'min_samples_leaf': 4, 'max_features': None}. Best is trial 25 with value: -2615160295.023144.  
[I 2024-12-22 21:04:35,812] Trial 29 finished with value: -2991595472.310168 and parameters: {'max_depth': 5, 'min_samples_split': 20, 'min_samples_leaf': 5, 'max_features': 'log2'}. Best is trial 25 with value: -2615160295.023144.  
[I 2024-12-22 21:04:35,824] Trial 27 finished with value: -2553149536.0343313 and parameters: {'max_depth': 3, 'min_samples_split': 20, 'min_samples_leaf': 5, 'max_features': None}. Best is trial 27 with value: -2553149536.0343313.  
[I 2024-12-22 21:04:35,828] Trial 30 finished with value: -2991595472.310168 and parameters: {'max_depth': 5, 'min_samples_split': 20, 'min_samples_leaf': 5, 'max_features': 'log2'}. Best is trial 27 with value: -2553149536.0343313.  
[I 2024-12-22 21:04:35,831] Trial 31 finished with value: -3200088385.342457 and parameters: {'max_depth': 3, 'min_samples_split': 20, 'min_samples_leaf': 5, 'max_features': 'log2'}. Best is trial 27 with value: -2553149536.0343313.  
[I 2024-12-22 21:04:35,881] Trial 33 finished with value: -2991595472.310168 and parameters: {'max_depth': 5, 'min_samples_split': 20, 'min_samples_leaf': 5, 'max_features': 'log2'}. Best is trial 27 with value: -2553149536.0343313.  
[I 2024-12-22 21:04:35,891] Trial 32 finished with value: -2991595472.310168 and parameters: {'max_depth': 5, 'min_samples_split': 20, 'min_samples_leaf': 5, 'max_features': 'log2'}. Best is trial 27 with value: -2553149536.0343313.  
[I 2024-12-22 21:04:35,910] Trial 36 finished with value: -2991595472.310168 and parameters: {'max_depth': 5, 'min_samples_split': 20, 'min_samples_leaf': 5, 'max_features': 'log2'}. Best is trial 27 with value: -2553149536.0343313.  
[I 2024-12-22 21:04:35,927] Trial 35 finished with value: -2773946590.8176174 and parameters: {'max_depth': 6, 'min_samples_split': 19, 'min_samples_leaf': 5, 'max_features': 'log2'}. Best is trial 27 with value: -2553149536.0343313.  
[I 2024-12-22 21:04:35,928] Trial 37 finished with value: -2991595472.310168 and parameters: {'max_depth': 5, 'min_samples_split': 20, 'min_samples_leaf': 5, 'max_features': 'log2'}. Best is trial 27 with value: -2553149536.0343313.  
[I 2024-12-22 21:04:35,941] Trial 34 finished with value: -2991595472.310168 and parameters: {'max_depth': 5, 'min_samples_split': 20, 'min_samples_leaf': 5, 'max_features': 'log2'}. Best is trial 27 with value: -2553149536.0343313.  
[I 2024-12-22 21:04:36,065] Trial 39 finished with value: -2991473048.933996 and parameters: {'max_depth': 5, 'min_samples_split': 17, 'min_samples_leaf': 5, 'max_features': 'log2'}. Best is trial 27 with value: -2553149536.0343313.  
[I 2024-12-22 21:04:36,125] Trial 38 finished with value: -2773946590.8176174 and parameters: {'max_depth': 6, 'min_samples_split': 19, 'min_samples_leaf': 5, 'max_features': 'log2'}. Best is trial 27 with value: -2553149536.0343313.
```

```
[I 2024-12-22 21:04:36,136] Trial 42 finished with value: -2776809361.9976835 and parameters: {'max_depth': 6, 'min_samples_split': 18, 'min_samples_leaf': 5, 'max_features': 'log2'}. Best is trial 27 with value: -2553149536.0343313.  
[I 2024-12-22 21:04:36,169] Trial 45 finished with value: -2698515417.7218957 and parameters: {'max_depth': 6, 'min_samples_split': 16, 'min_samples_leaf': 6, 'max_features': 'log2'}. Best is trial 27 with value: -2553149536.0343313.  
[I 2024-12-22 21:04:36,171] Trial 40 finished with value: -2991473048.933996 and parameters: {'max_depth': 5, 'min_samples_split': 19, 'min_samples_leaf': 5, 'max_features': 'log2'}. Best is trial 27 with value: -2553149536.0343313.  
[I 2024-12-22 21:04:36,175] Trial 41 finished with value: -2991473048.933996 and parameters: {'max_depth': 5, 'min_samples_split': 19, 'min_samples_leaf': 5, 'max_features': 'log2'}. Best is trial 27 with value: -2553149536.0343313.  
[I 2024-12-22 21:04:36,192] Trial 43 finished with value: -2986072309.9469476 and parameters: {'max_depth': 12, 'min_samples_split': 17, 'min_samples_leaf': 6, 'max_features': 'log2'}. Best is trial 27 with value: -2553149536.0343313.  
[I 2024-12-22 21:04:36,197] Trial 44 finished with value: -2698515417.7218957 and parameters: {'max_depth': 6, 'min_samples_split': 16, 'min_samples_leaf': 6, 'max_features': 'log2'}. Best is trial 27 with value: -2553149536.0343313.  
[I 2024-12-22 21:04:36,306] Trial 46 finished with value: -3161110599.6712165 and parameters: {'max_depth': 12, 'min_samples_split': 16, 'min_samples_leaf': 6, 'max_features': None}. Best is trial 27 with value: -2553149536.0343313.  
[I 2024-12-22 21:04:36,370] Trial 47 finished with value: -3161110599.6712165 and parameters: {'max_depth': 12, 'min_samples_split': 16, 'min_samples_leaf': 6, 'max_features': None}. Best is trial 27 with value: -2553149536.0343313.  
[I 2024-12-22 21:04:36,399] Trial 49 finished with value: -3072901600.5638676 and parameters: {'max_depth': 11, 'min_samples_split': 16, 'min_samples_leaf': 6, 'max_features': None}. Best is trial 27 with value: -2553149536.0343313.  
[I 2024-12-22 21:04:36,433] Trial 48 finished with value: -3154512532.42688 and parameters: {'max_depth': 12, 'min_samples_split': 17, 'min_samples_leaf': 6, 'max_features': None}. Best is trial 27 with value: -2553149536.0343313.  
[I 2024-12-22 21:04:36,440] Trial 51 finished with value: -3234979652.007627 and parameters: {'max_depth': 13, 'min_samples_split': 16, 'min_samples_leaf': 7, 'max_features': None}. Best is trial 27 with value: -2553149536.0343313.  
[I 2024-12-22 21:04:36,470] Trial 52 finished with value: -3161110599.6712165 and parameters: {'max_depth': 12, 'min_samples_split': 16, 'min_samples_leaf': 6, 'max_features': None}. Best is trial 27 with value: -2553149536.0343313.  
[I 2024-12-22 21:04:36,510] Trial 50 finished with value: -3155399058.9159684 and parameters: {'max_depth': 12, 'min_samples_split': 16, 'min_samples_leaf': 7, 'max_features': None}. Best is trial 27 with value: -2553149536.0343313.  
[I 2024-12-22 21:04:36,512] Trial 54 finished with value: -3161110599.6712165 and parameters: {'max_depth': 12, 'min_samples_split': 16, 'min_samples_leaf': 6, 'max_features': None}. Best is trial 27 with value: -2553149536.0343313.  
[I 2024-12-22 21:04:36,551] Trial 53 finished with value: -3161110599.6712165 and parameters: {'max_depth': 12, 'min_samples_split': 16, 'min_samples_leaf': 6, 'max_features': None}. Best is trial 27 with value: -2553149536.0343313.  
[I 2024-12-22 21:04:36,573] Trial 55 finished with value: -3161110599.6712165 and parameters: {'max_depth': 12, 'min_samples_split': 16, 'min_samples_leaf': 6, 'max_features': None}. Best is trial 27 with value: -2553149536.0343313.  
[I 2024-12-22 21:04:36,612] Trial 56 finished with value: -3161110599.6712165 and parameters: {'max_depth': 12, 'min_samples_split': 16, 'min_samples_leaf': 6, 'max_features': None}. Best is trial 27 with value: -2553149536.0343313.  
[I 2024-12-22 21:04:36,614] Trial 57 finished with value: -3161110599.6712165 and parameters: {'max_depth': 12, 'min_samples_split': 16, 'min_samples_leaf': 6, 'max_features': None}. Best is trial 27 with value: -2553149536.0343313.  
[I 2024-12-22 21:04:36,643] Trial 58 finished with value: -2970381987.6190763 and parameters: {'max_depth': 10, 'min_samples_split': 16, 'min_samples_leaf': 7, 'max_features': None}. Best is trial 27 with value: -2553149536.0343313.  
[I 2024-12-22 21:04:36,665] Trial 60 finished with value: -3161110599.6712165 and parameters: {'max_depth': 12, 'min_samples_split': 16, 'min_samples_leaf': 6, 'max_features': None}. Best is trial 27 with value: -2553149536.0343313.
```

```
[I 2024-12-22 21:04:36,701] Trial 59 finished with value: -3148061032.073007 and
parameters: {'max_depth': 12, 'min_samples_split': 17, 'min_samples_leaf': 7, 'ma
x_features': None}. Best is trial 27 with value: -2553149536.0343313.
[I 2024-12-22 21:04:36,767] Trial 64 finished with value: -2981877262.2322865 and
parameters: {'max_depth': 10, 'min_samples_split': 15, 'min_samples_leaf': 7, 'ma
x_features': None}. Best is trial 27 with value: -2553149536.0343313.
[I 2024-12-22 21:04:36,770] Trial 63 finished with value: -3083868391.8287797 and
parameters: {'max_depth': 11, 'min_samples_split': 15, 'min_samples_leaf': 7, 'ma
x_features': None}. Best is trial 27 with value: -2553149536.0343313.
[I 2024-12-22 21:04:36,774] Trial 61 finished with value: -2981877262.2322865 and
parameters: {'max_depth': 10, 'min_samples_split': 15, 'min_samples_leaf': 7, 'ma
x_features': None}. Best is trial 27 with value: -2553149536.0343313.
[I 2024-12-22 21:04:36,797] Trial 62 finished with value: -3083868391.8287797 and
parameters: {'max_depth': 11, 'min_samples_split': 15, 'min_samples_leaf': 7, 'ma
x_features': None}. Best is trial 27 with value: -2553149536.0343313.
[I 2024-12-22 21:04:36,826] Trial 65 finished with value: -2981877262.2322865 and
parameters: {'max_depth': 10, 'min_samples_split': 15, 'min_samples_leaf': 7, 'ma
x_features': None}. Best is trial 27 with value: -2553149536.0343313.
[I 2024-12-22 21:04:36,914] Trial 66 finished with value: -2989524375.6803813 and
parameters: {'max_depth': 10, 'min_samples_split': 13, 'min_samples_leaf': 7, 'ma
x_features': None}. Best is trial 27 with value: -2553149536.0343313.
[I 2024-12-22 21:04:36,934] Trial 67 finished with value: -2989524375.6803813 and
parameters: {'max_depth': 10, 'min_samples_split': 14, 'min_samples_leaf': 7, 'ma
x_features': None}. Best is trial 27 with value: -2553149536.0343313.
[I 2024-12-22 21:04:36,967] Trial 68 finished with value: -3432166398.041524 and
parameters: {'max_depth': 15, 'min_samples_split': 14, 'min_samples_leaf': 7, 'ma
x_features': None}. Best is trial 27 with value: -2553149536.0343313.
[I 2024-12-22 21:04:36,981] Trial 69 finished with value: -2736783307.754443 and
parameters: {'max_depth': 7, 'min_samples_split': 14, 'min_samples_leaf': 7, 'ma
x_features': None}. Best is trial 27 with value: -2553149536.0343313.
[I 2024-12-22 21:04:37,034] Trial 71 finished with value: -2736783307.754443 and
parameters: {'max_depth': 7, 'min_samples_split': 13, 'min_samples_leaf': 7, 'ma
x_features': None}. Best is trial 27 with value: -2553149536.0343313.
[I 2024-12-22 21:04:37,035] Trial 70 finished with value: -2736783307.754443 and
parameters: {'max_depth': 7, 'min_samples_split': 13, 'min_samples_leaf': 7, 'ma
x_features': None}. Best is trial 27 with value: -2553149536.0343313.
[I 2024-12-22 21:04:37,100] Trial 73 finished with value: -2736783307.754443 and
parameters: {'max_depth': 7, 'min_samples_split': 14, 'min_samples_leaf': 7, 'ma
x_features': None}. Best is trial 27 with value: -2553149536.0343313.
[I 2024-12-22 21:04:37,119] Trial 76 finished with value: -2739398048.388614 and
parameters: {'max_depth': 7, 'min_samples_split': 14, 'min_samples_leaf': 8, 'ma
x_features': 'sqrt'}. Best is trial 27 with value: -2553149536.0343313.
[I 2024-12-22 21:04:37,126] Trial 72 finished with value: -2730212813.6878877 and
parameters: {'max_depth': 7, 'min_samples_split': 14, 'min_samples_leaf': 8, 'ma
x_features': None}. Best is trial 27 with value: -2553149536.0343313.
[I 2024-12-22 21:04:37,143] Trial 77 finished with value: -2801495380.6719313 and
parameters: {'max_depth': 7, 'min_samples_split': 14, 'min_samples_leaf': 3, 'ma
x_features': 'sqrt'}. Best is trial 27 with value: -2553149536.0343313.
[I 2024-12-22 21:04:37,156] Trial 78 finished with value: -2820905052.580613 and
parameters: {'max_depth': 8, 'min_samples_split': 14, 'min_samples_leaf': 3, 'ma
x_features': 'sqrt'}. Best is trial 27 with value: -2553149536.0343313.
[I 2024-12-22 21:04:37,157] Trial 74 finished with value: -2736783307.754443 and
parameters: {'max_depth': 7, 'min_samples_split': 14, 'min_samples_leaf': 7, 'ma
x_features': None}. Best is trial 27 with value: -2553149536.0343313.
[I 2024-12-22 21:04:37,169] Trial 79 finished with value: -2801495380.6719313 and
parameters: {'max_depth': 7, 'min_samples_split': 14, 'min_samples_leaf': 3, 'ma
x_features': 'sqrt'}. Best is trial 27 with value: -2553149536.0343313.
[I 2024-12-22 21:04:37,206] Trial 75 finished with value: -2736783307.754443 and
parameters: {'max_depth': 7, 'min_samples_split': 14, 'min_samples_leaf': 7, 'ma
x_features': None}. Best is trial 27 with value: -2553149536.0343313.
```



```
Best Hyperparameters: {'max_depth': 3, 'min_samples_split': 20, 'min_samples_leaf': 5, 'max_features': None}
```

MODEL EVALUATION

```
In [50]: best_model = DecisionTreeRegressor(**best_params, random_state=42)
best_model.fit(X_train_scaled, y_train)

y_pred = best_model.predict(X_test_scaled)

mse = mean_squared_error(y_test, y_pred)
mape = mean_absolute_percentage_error(y_test, y_pred)
rmse = np.sqrt(mse)
r2 = r2_score(y_test, y_pred)

print(f"Mean Squared Error (MSE): {mse}")
print(f"Mean Absolute Percentage Error (MAPE): {mape}")
print(f"Root Mean Squared Error (RMSE): {rmse}")
print(f"R-squared (R²): {r2}")
```

```
Mean Squared Error (MSE): 2575884064.0823545
Mean Absolute Percentage Error (MAPE): 7.0397755281579516e+19
Root Mean Squared Error (RMSE): 50753.16802015766
R-squared (R²): 0.332452995116848
```

With {'max_depth': 3, 'min_samples_split': 20, 'min_samples_leaf': 5, 'max_features': None} hyperparameters. The MSE and RMSE indicate moderate prediction errors, with an RMSE of about 50,753. The MAPE suggests some significant deviation from actual values, while the R² value of 0.33 shows that the model explains a larger portion of the variance compared to previous models, but there is still room for improvement in capturing the data's underlying patterns.

RANDOM FOREST REGRESSOR

For our Random Forest model, we are using Optuna for hyperparameter tuning, evaluating the following hyperparameters:

- n_estimators: The number of trees (100 to 1000) to balance model complexity and performance, ensuring sufficient trees to reduce variance without overfitting.
- max_depth: Tree depth (3 to 50) to control model complexity and prevent overfitting by limiting how deep each tree can grow.
- min_samples_split: Minimum samples required to split a node (2 to 32), preventing the model from creating overly complex trees.
- min_samples_leaf: Minimum samples at a leaf node (1 to 32), controlling the smallest size of terminal nodes to ensure the model generalizes well.
- max_features: Number of features to consider at each split (sqrt, log2, or all), providing flexibility in feature selection and improving model robustness.

```
In [37]: from sklearn.model_selection import KFold, cross_val_score
from sklearn.ensemble import RandomForestRegressor
from sklearn.preprocessing import StandardScaler
import optuna
```

```
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_
scaler = StandardScaler()
X_train_scaled = scaler.fit_transform(X_train)
X_test_scaled = scaler.transform(X_test)

def objective(trial):
    n_estimators = trial.suggest_int("n_estimators", 100, 1000)
    max_depth = trial.suggest_int("max_depth", 3, 50)
    min_samples_split = trial.suggest_int("min_samples_split", 2, 32)
    min_samples_leaf = trial.suggest_int("min_samples_leaf", 1, 32)
    max_features = trial.suggest_categorical("max_features", ["sqrt", "log2", No
        model = RandomForestRegressor(
            n_estimators=n_estimators,
            max_depth=max_depth,
            min_samples_split=min_samples_split,
            min_samples_leaf=min_samples_leaf,
            max_features=max_features,
            random_state=42,
        )

        kf = KFold(n_splits=5, shuffle=True, random_state=42)
        score = cross_val_score(model, X_train_scaled, y_train, cv=kf, scoring="neg_
        return score
rdForestStudy = optuna.create_study(direction="maximize", sampler=optuna.sampler
rdForestStudy.optimize(objective, n_trials=50, n_jobs=-1)

print("Best hyperparameters:", rdForestStudy.best_params)
```

```
[I 2024-12-22 23:43:43,145] A new study created in memory with name: no-name-3635  
45bd-7543-479a-9730-59ab0a7da9f3  
[I 2024-12-22 23:44:06,408] Trial 2 finished with value: -0.12198683564443949 and  
parameters: {'n_estimators': 710, 'max_depth': 31, 'min_samples_split': 32, 'min_  
samples_leaf': 10, 'max_features': None}. Best is trial 2 with value: -0.12198683  
564443949.  
[I 2024-12-22 23:44:20,295] Trial 0 finished with value: -0.12407361372088395 and  
parameters: {'n_estimators': 845, 'max_depth': 23, 'min_samples_split': 21, 'min_  
samples_leaf': 1, 'max_features': None}. Best is trial 2 with value: -0.12198683  
564443949.  
[I 2024-12-22 23:44:21,005] Trial 1 finished with value: -0.12314961744194641 and  
parameters: {'n_estimators': 787, 'max_depth': 22, 'min_samples_split': 25, 'min_  
samples_leaf': 5, 'max_features': 'log2'}. Best is trial 2 with value: -0.1219868  
3564443949.  
[I 2024-12-22 23:44:22,753] Trial 7 finished with value: -0.12283717618920531 and  
parameters: {'n_estimators': 575, 'max_depth': 44, 'min_samples_split': 20, 'min_  
samples_leaf': 5, 'max_features': None}. Best is trial 2 with value: -0.12198683  
564443949.  
[I 2024-12-22 23:44:23,691] Trial 9 finished with value: -0.12537265130664146 and  
parameters: {'n_estimators': 795, 'max_depth': 21, 'min_samples_split': 31, 'min_  
samples_leaf': 21, 'max_features': 'sqrt'}. Best is trial 2 with value: -0.121986  
83564443949.  
[I 2024-12-22 23:44:24,885] Trial 3 finished with value: -0.12626581713732843 and  
parameters: {'n_estimators': 617, 'max_depth': 49, 'min_samples_split': 29, 'min_  
samples_leaf': 28, 'max_features': 'log2'}. Best is trial 2 with value: -0.121986  
83564443949.  
[I 2024-12-22 23:44:27,865] Trial 6 finished with value: -0.1300981083354525 and  
parameters: {'n_estimators': 219, 'max_depth': 5, 'min_samples_split': 14, 'min_s  
amples_leaf': 11, 'max_features': 'log2'}. Best is trial 2 with value: -0.1219868  
3564443949.  
[I 2024-12-22 23:44:28,257] Trial 4 finished with value: -0.12392683107340893 and  
parameters: {'n_estimators': 744, 'max_depth': 16, 'min_samples_split': 7, 'min_s  
amples_leaf': 12, 'max_features': 'log2'}. Best is trial 2 with value: -0.1219868  
3564443949.  
[I 2024-12-22 23:44:31,731] Trial 8 finished with value: -0.1234690045560967 and  
parameters: {'n_estimators': 559, 'max_depth': 14, 'min_samples_split': 22, 'min_  
samples_leaf': 9, 'max_features': 'log2'}. Best is trial 2 with value: -0.1219868  
3564443949.  
[I 2024-12-22 23:44:55,127] Trial 11 finished with value: -0.1242976624816804 and  
parameters: {'n_estimators': 914, 'max_depth': 46, 'min_samples_split': 3, 'min_s  
amples_leaf': 3, 'max_features': None}. Best is trial 2 with value: -0.1219868356  
4443949.  
[I 2024-12-22 23:44:55,903] Trial 13 finished with value: -0.12428544823942198 an  
d parameters: {'n_estimators': 120, 'max_depth': 47, 'min_samples_split': 20, 'mi  
n_samples_leaf': 13, 'max_features': 'sqrt'}. Best is trial 2 with value: -0.1219  
8683564443949.  
[I 2024-12-22 23:44:56,258] Trial 12 finished with value: -0.12430267933835606 an  
d parameters: {'n_estimators': 616, 'max_depth': 10, 'min_samples_split': 20, 'mi  
n_samples_leaf': 13, 'max_features': 'sqrt'}. Best is trial 2 with value: -0.1219  
8683564443949.  
[I 2024-12-22 23:44:58,155] Trial 10 finished with value: -0.12201608159725053 an  
d parameters: {'n_estimators': 922, 'max_depth': 40, 'min_samples_split': 25, 'mi  
n_samples_leaf': 12, 'max_features': None}. Best is trial 2 with value: -0.121986  
83564443949.  
[I 2024-12-22 23:44:59,590] Trial 14 finished with value: -0.12624420183064172 an  
d parameters: {'n_estimators': 593, 'max_depth': 28, 'min_samples_split': 16, 'mi  
n_samples_leaf': 28, 'max_features': 'sqrt'}. Best is trial 2 with value: -0.1219  
8683564443949.  
[I 2024-12-22 23:45:02,201] Trial 15 finished with value: -0.1251883093451101 and  
parameters: {'n_estimators': 543, 'max_depth': 16, 'min_samples_split': 8, 'min_s
```

```
amples_leaf': 19, 'max_features': 'log2'}. Best is trial 2 with value: -0.1219868  
3564443949.  
[I 2024-12-22 23:45:05,674] Trial 17 finished with value: -0.12604249679229382 an  
d parameters: {'n_estimators': 612, 'max_depth': 27, 'min_samples_split': 4, 'min  
_samples_leaf': 26, 'max_features': 'sqrt'}. Best is trial 2 with value: -0.12198  
683564443949.  
[I 2024-12-22 23:45:06,509] Trial 18 finished with value: -0.12631388489977127 an  
d parameters: {'n_estimators': 280, 'max_depth': 25, 'min_samples_split': 18, 'mi  
n_samples_leaf': 28, 'max_features': 'log2'}. Best is trial 2 with value: -0.1219  
8683564443949.  
[I 2024-12-22 23:45:12,164] Trial 5 finished with value: -0.12190492283892677 and  
parameters: {'n_estimators': 846, 'max_depth': 29, 'min_samples_split': 3, 'mi  
n_samples_leaf': 22, 'max_features': None}. Best is trial 5 with value: -0.12190492  
283892677.  
[I 2024-12-22 23:45:15,709] Trial 19 finished with value: -0.12223383956554165 an  
d parameters: {'n_estimators': 335, 'max_depth': 30, 'min_samples_split': 17, 'mi  
n_samples_leaf': 9, 'max_features': None}. Best is trial 5 with value: -0.1219049  
2283892677.  
[I 2024-12-22 23:45:20,068] Trial 16 finished with value: -0.12206013751978617 an  
d parameters: {'n_estimators': 814, 'max_depth': 40, 'min_samples_split': 15, 'mi  
n_samples_leaf': 27, 'max_features': None}. Best is trial 5 with value: -0.121904  
92283892677.  
[I 2024-12-22 23:45:20,330] Trial 20 finished with value: -0.12420778563731438 an  
d parameters: {'n_estimators': 846, 'max_depth': 50, 'min_samples_split': 24, 'mi  
n_samples_leaf': 14, 'max_features': 'sqrt'}. Best is trial 5 with value: -0.1219  
0492283892677.  
[I 2024-12-22 23:45:36,285] Trial 21 finished with value: -0.12184627180862262 an  
d parameters: {'n_estimators': 654, 'max_depth': 32, 'min_samples_split': 30, 'mi  
n_samples_leaf': 18, 'max_features': None}. Best is trial 21 with value: -0.12184  
627180862262.  
[I 2024-12-22 23:45:37,277] Trial 23 finished with value: -0.12420081831396154 an  
d parameters: {'n_estimators': 962, 'max_depth': 40, 'min_samples_split': 6, 'mi  
n_samples_leaf': 14, 'max_features': 'log2'}. Best is trial 21 with value: -0.1218  
4627180862262.  
[I 2024-12-22 23:45:37,729] Trial 24 finished with value: -0.1230141714876247 and  
parameters: {'n_estimators': 366, 'max_depth': 32, 'min_samples_split': 20, 'mi  
n_samples_leaf': 5, 'max_features': 'sqrt'}. Best is trial 21 with value: -0.121846  
27180862262.  
[I 2024-12-22 23:45:43,910] Trial 26 finished with value: -0.1230376664692854 and  
parameters: {'n_estimators': 254, 'max_depth': 13, 'min_samples_split': 18, 'mi  
n_samples_leaf': 2, 'max_features': 'sqrt'}. Best is trial 21 with value: -0.121846  
27180862262.  
[I 2024-12-22 23:45:44,510] Trial 22 finished with value: -0.12187634412584089 an  
d parameters: {'n_estimators': 921, 'max_depth': 19, 'min_samples_split': 9, 'mi  
n_samples_leaf': 21, 'max_features': None}. Best is trial 21 with value: -0.121846  
27180862262.  
[I 2024-12-22 23:45:47,847] Trial 27 finished with value: -0.12887921197002516 an  
d parameters: {'n_estimators': 726, 'max_depth': 6, 'min_samples_split': 12, 'mi  
n_samples_leaf': 32, 'max_features': 'log2'}. Best is trial 21 with value: -0.1218  
4627180862262.  
[I 2024-12-22 23:45:53,710] Trial 28 finished with value: -0.12333293671433032 an  
d parameters: {'n_estimators': 817, 'max_depth': 41, 'min_samples_split': 13, 'mi  
n_samples_leaf': 8, 'max_features': 'sqrt'}. Best is trial 21 with value: -0.1218  
4627180862262.  
[I 2024-12-22 23:45:55,898] Trial 30 finished with value: -0.12423432641993574 an  
d parameters: {'n_estimators': 129, 'max_depth': 29, 'min_samples_split': 25, 'mi  
n_samples_leaf': 13, 'max_features': 'sqrt'}. Best is trial 21 with value: -0.121  
84627180862262.  
[I 2024-12-22 23:45:59,093] Trial 25 finished with value: -0.12242939482460431 an  
d parameters: {'n_estimators': 732, 'max_depth': 20, 'min_samples_split': 22, 'mi
```

```
n_samples_leaf': 7, 'max_features': None}. Best is trial 21 with value: -0.121846  
27180862262.  
[I 2024-12-22 23:46:02,818] Trial 32 finished with value: -0.12294990516471067 an  
d parameters: {'n_estimators': 268, 'max_depth': 24, 'min_samples_split': 2, 'min  
_samples_leaf': 7, 'max_features': 'sqrt'}. Best is trial 21 with value: -0.12184  
627180862262.  
[I 2024-12-22 23:46:03,013] Trial 29 finished with value: -0.12237127567790518 an  
d parameters: {'n_estimators': 360, 'max_depth': 45, 'min_samples_split': 19, 'mi  
n_samples_leaf': 8, 'max_features': None}. Best is trial 21 with value: -0.121846  
27180862262.  
[I 2024-12-22 23:46:03,655] Trial 31 finished with value: -0.12364273484075086 an  
d parameters: {'n_estimators': 145, 'max_depth': 33, 'min_samples_split': 24, 'mi  
n_samples_leaf': 2, 'max_features': None}. Best is trial 21 with value: -0.121846  
27180862262.  
[I 2024-12-22 23:46:08,518] Trial 35 finished with value: -0.1259023708471691 and  
parameters: {'n_estimators': 298, 'max_depth': 32, 'min_samples_split': 19, 'mi  
n_samples_leaf': 23, 'max_features': 'log2'}. Best is trial 21 with value: -0.12184  
627180862262.  
[I 2024-12-22 23:46:16,276] Trial 33 finished with value: -0.12374649644472568 an  
d parameters: {'n_estimators': 424, 'max_depth': 36, 'min_samples_split': 12, 'mi  
n_samples_leaf': 3, 'max_features': None}. Best is trial 21 with value: -0.121846  
27180862262.  
[I 2024-12-22 23:46:16,425] Trial 34 finished with value: -0.12188956261846602 an  
d parameters: {'n_estimators': 475, 'max_depth': 47, 'min_samples_split': 25, 'mi  
n_samples_leaf': 17, 'max_features': None}. Best is trial 21 with value: -0.12184  
627180862262.  
[I 2024-12-22 23:46:16,596] Trial 37 finished with value: -0.1260069927033985 and  
parameters: {'n_estimators': 171, 'max_depth': 7, 'min_samples_split': 13, 'mi  
n_samples_leaf': 13, 'max_features': 'sqrt'}. Best is trial 21 with value: -0.121846  
27180862262.  
[I 2024-12-22 23:46:21,117] Trial 36 finished with value: -0.12486863376496435 an  
d parameters: {'n_estimators': 988, 'max_depth': 20, 'min_samples_split': 23, 'mi  
n_samples_leaf': 18, 'max_features': 'sqrt'}. Best is trial 21 with value: -0.12184  
627180862262.  
[I 2024-12-22 23:46:22,762] Trial 38 finished with value: -0.1255153423006839 and  
parameters: {'n_estimators': 995, 'max_depth': 25, 'min_samples_split': 15, 'mi  
n_samples_leaf': 22, 'max_features': 'sqrt'}. Best is trial 21 with value: -0.12184  
627180862262.  
[I 2024-12-22 23:46:24,128] Trial 39 finished with value: -0.12309889365233859 an  
d parameters: {'n_estimators': 562, 'max_depth': 42, 'min_samples_split': 3, 'mi  
n_samples_leaf': 6, 'max_features': 'sqrt'}. Best is trial 21 with value: -0.12184  
627180862262.  
[I 2024-12-22 23:46:24,439] Trial 40 finished with value: -0.12547786587061438 an  
d parameters: {'n_estimators': 491, 'max_depth': 22, 'min_samples_split': 8, 'mi  
n_samples_leaf': 22, 'max_features': 'log2'}. Best is trial 21 with value: -0.12184  
627180862262.  
[I 2024-12-22 23:46:26,799] Trial 42 finished with value: -0.12337994081759027 an  
d parameters: {'n_estimators': 363, 'max_depth': 17, 'min_samples_split': 15, 'mi  
n_samples_leaf': 8, 'max_features': 'log2'}. Best is trial 21 with value: -0.12184  
627180862262.  
[I 2024-12-22 23:46:28,950] Trial 41 finished with value: -0.1239252336120645 and  
parameters: {'n_estimators': 944, 'max_depth': 32, 'min_samples_split': 19, 'mi  
n_samples_leaf': 12, 'max_features': 'sqrt'}. Best is trial 21 with value: -0.12184  
627180862262.  
[I 2024-12-22 23:46:39,304] Trial 43 finished with value: -0.12264931561454886 an  
d parameters: {'n_estimators': 427, 'max_depth': 48, 'min_samples_split': 3, 'mi  
n_samples_leaf': 7, 'max_features': None}. Best is trial 21 with value: -0.1218462  
7180862262.  
[I 2024-12-22 23:46:44,016] Trial 45 finished with value: -0.12295839834858746 an  
d parameters: {'n_estimators': 924, 'max_depth': 16, 'min_samples_split': 9, 'mi
```

```

    _samples_leaf': 3, 'max_features': 'sqrt'}. Best is trial 21 with value: -0.12184
627180862262.
[I 2024-12-22 23:46:45,640] Trial 47 finished with value: -0.12373849227377035 an
d parameters: {'n_estimators': 113, 'max_depth': 43, 'min_samples_split': 17, 'mi
n_samples_leaf': 9, 'max_features': 'log2'}. Best is trial 21 with value: -0.1218
4627180862262.
[I 2024-12-22 23:46:51,016] Trial 48 finished with value: -0.12527259174354202 an
d parameters: {'n_estimators': 512, 'max_depth': 41, 'min_samples_split': 22, 'mi
n_samples_leaf': 20, 'max_features': 'sqrt'}. Best is trial 21 with value: -0.121
84627180862262.
[I 2024-12-22 23:46:51,641] Trial 46 finished with value: -0.12199033922067773 an
d parameters: {'n_estimators': 379, 'max_depth': 13, 'min_samples_split': 20, 'mi
n_samples_leaf': 12, 'max_features': None}. Best is trial 21 with value: -0.12184
627180862262.
[I 2024-12-22 23:46:52,112] Trial 44 finished with value: -0.12188233096999539 an
d parameters: {'n_estimators': 944, 'max_depth': 44, 'min_samples_split': 18, 'mi
n_samples_leaf': 17, 'max_features': None}. Best is trial 21 with value: -0.12184
627180862262.
[I 2024-12-22 23:46:53,367] Trial 49 finished with value: -0.12710843916867787 an
d parameters: {'n_estimators': 857, 'max_depth': 8, 'min_samples_split': 13, 'mi
n_samples_leaf': 31, 'max_features': 'sqrt'}. Best is trial 21 with value: -0.1218
4627180862262.

Best hyperparameters: {'n_estimators': 654, 'max_depth': 32, 'min_samples_split': 30,
'min_samples_leaf': 18, 'max_features': None}

```

```
In [39]: randomForestReg = RandomForestRegressor(**rdForestStudy.best_params, random_state=42)
randomForestReg.fit(X_train_scaled, y_train)

y_pred = randomForestReg.predict(X_test_scaled)
```

MODEL EVALUATION

```
In [41]: mse = mean_squared_error(y_test, y_pred)
rmse = np.sqrt(mse)
mape = mean_absolute_percentage_error(y_test, y_pred)
r2 = r2_score(y_test, y_pred)

print(f'MSE: {mse:.4f}')
print(f'RMSE: {rmse:.4f}')
print(f'MAPE: {mape:.4f}')
print(f'R²: {r2:.4f}')
```

```
MSE: 0.1150
RMSE: 0.3391
MAPE: 561346791693300.5000
R²: 0.2716
```

We are expecting the Random Forest Regressor to have better results than the previous two algorithms, particularly outperforming the Decision Tree. The Random Forest Regressor combines multiple decision trees to make more robust and accurate predictions. By averaging the predictions of several individual trees, it can reduce overfitting we think will handle a higher degree of feature interactions so we are expecting to perform better in our dataset.

KNNeighborsRegressor

Now we are testing the K-Nearest Neighbors Regressor (KNN Regressor), using Optuna for hyperparameter tuning. Unlike parametric models, KNN Regressor makes predictions based on the average of the nearest data points, allowing it to capture non-linear patterns. The following hyperparameters are being evaluated:

- n_neighbors: Number of neighbors to consider. A lower value increases model complexity, while a higher value smooths predictions and reduces overfitting.
- weights: Weighting function (uniform or distance). Distance-based weighting gives closer points more influence, improving performance on uneven data distributions.
- p: The power parameter for the Minkowski distance. Tuning this controls whether the model uses Manhattan ($p=1$) or Euclidean ($p=2$) distance.

While we aim to capture local relationships with KNN Regressor, we do not expect significantly better results as the previous models have also struggled, possibly due to limitations in the dataset itself.

```
In [17]: X = dfFeature.drop(['Balance'], axis=1)
y = dfFeature['Balance']
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_
scaler = StandardScaler()
X_train_scaled = scaler.fit_transform(X_train)
X_test_scaled = scaler.transform(X_test)

def objective(trial):
    n_neighbors = trial.suggest_int('n_neighbors', 2, 50)
    weights = trial.suggest_categorical('weights', ['uniform', 'distance'])
    p = trial.suggest_int('p', 1, 2)

    model = KNeighborsRegressor(
        n_neighbors=n_neighbors,
        weights=weights,
        p=p
    )
    score = cross_val_score(model, X_train_scaled, y_train, cv=5, scoring='neg_mse')
    return score.mean()

study = optuna.create_study(direction='maximize')
study.optimize(objective, n_trials=50, n_jobs=-1)

best_params = study.best_params

best_model = KNeighborsRegressor(**best_params)

best_model.fit(X_train_scaled, y_train)

y_pred = best_model.predict(X_test_scaled)

mse = mean_squared_error(y_test, y_pred)
mape = mean_absolute_percentage_error(y_test, y_pred)
rmse = np.sqrt(mse)
r2 = r2_score(y_test, y_pred)

print(f"Mean Squared Error (MSE): {mse}")
```

```
print(f"Mean Absolute Percentage Error (MAPE): {mape}")
print(f"Root Mean Squared Error (RMSE): {rmse}")
print(f"R-squared (R2): {r2}")
```

```
[I 2024-12-23 15:23:36,761] A new study created in memory with name: no-name-adb9  
26ae-8598-4006-9150-3b65f73511cf  
[I 2024-12-23 15:23:38,188] Trial 7 finished with value: -2862178119.8161874 and  
parameters: {'n_neighbors': 30, 'weights': 'distance', 'p': 2}. Best is trial 7 w  
ith value: -2862178119.8161874.  
[I 2024-12-23 15:23:38,230] Trial 17 finished with value: -2923526795.640704 and  
parameters: {'n_neighbors': 17, 'weights': 'uniform', 'p': 2}. Best is trial 7 wi  
th value: -2862178119.8161874.  
[I 2024-12-23 15:23:38,841] Trial 4 finished with value: -2863834141.6170034 and  
parameters: {'n_neighbors': 39, 'weights': 'distance', 'p': 2}. Best is trial 7 wi  
th value: -2862178119.8161874.  
[I 2024-12-23 15:23:38,968] Trial 2 finished with value: -2963643934.4662733 and  
parameters: {'n_neighbors': 12, 'weights': 'uniform', 'p': 2}. Best is trial 7 wi  
th value: -2862178119.8161874.  
[I 2024-12-23 15:23:38,981] Trial 0 finished with value: -2882718741.9378586 and  
parameters: {'n_neighbors': 30, 'weights': 'uniform', 'p': 2}. Best is trial 7 wi  
th value: -2862178119.8161874.  
[I 2024-12-23 15:23:39,010] Trial 10 finished with value: -2878688180.1491203 and  
parameters: {'n_neighbors': 31, 'weights': 'uniform', 'p': 2}. Best is trial 7 wi  
th value: -2862178119.8161874.  
[I 2024-12-23 15:23:39,015] Trial 16 finished with value: -3212375784.0699744 and  
parameters: {'n_neighbors': 5, 'weights': 'uniform', 'p': 1}. Best is trial 7 wit  
h value: -2862178119.8161874.  
[I 2024-12-23 15:23:39,078] Trial 15 finished with value: -2831798721.63618 and p  
arameters: {'n_neighbors': 47, 'weights': 'uniform', 'p': 1}. Best is trial 15 wi  
th value: -2831798721.63618.  
[I 2024-12-23 15:23:39,106] Trial 11 finished with value: -2826895407.991778 and  
parameters: {'n_neighbors': 38, 'weights': 'uniform', 'p': 1}. Best is trial 11 w  
ith value: -2826895407.991778.  
[I 2024-12-23 15:23:39,124] Trial 19 finished with value: -2871150387.5687637 and  
parameters: {'n_neighbors': 17, 'weights': 'uniform', 'p': 1}. Best is trial 11 w  
ith value: -2826895407.991778.  
[I 2024-12-23 15:23:39,197] Trial 5 finished with value: -2886659226.8925796 and  
parameters: {'n_neighbors': 27, 'weights': 'uniform', 'p': 2}. Best is trial 11 w  
ith value: -2826895407.991778.  
[I 2024-12-23 15:23:39,242] Trial 8 finished with value: -2880999000.4243846 and  
parameters: {'n_neighbors': 33, 'weights': 'uniform', 'p': 2}. Best is trial 11 w  
ith value: -2826895407.991778.  
[I 2024-12-23 15:23:39,250] Trial 9 finished with value: -2863264015.671459 and p  
arameters: {'n_neighbors': 17, 'weights': 'distance', 'p': 1}. Best is trial 11 w  
ith value: -2826895407.991778.  
[I 2024-12-23 15:23:39,304] Trial 1 finished with value: -2867586494.961644 and p  
arameters: {'n_neighbors': 25, 'weights': 'distance', 'p': 2}. Best is trial 11 w  
ith value: -2826895407.991778.  
[I 2024-12-23 15:23:39,322] Trial 13 finished with value: -2896164724.0382805 and  
parameters: {'n_neighbors': 50, 'weights': 'uniform', 'p': 2}. Best is trial 11 w  
ith value: -2826895407.991778.  
[I 2024-12-23 15:23:39,329] Trial 14 finished with value: -2814469719.3958244 and  
parameters: {'n_neighbors': 34, 'weights': 'distance', 'p': 1}. Best is trial 14  
with value: -2814469719.3958244.  
[I 2024-12-23 15:23:39,331] Trial 3 finished with value: -2918219514.0093155 and  
parameters: {'n_neighbors': 15, 'weights': 'distance', 'p': 2}. Best is trial 14  
with value: -2814469719.3958244.  
[I 2024-12-23 15:23:39,375] Trial 20 finished with value: -2889627370.1360025 and  
parameters: {'n_neighbors': 14, 'weights': 'uniform', 'p': 1}. Best is trial 14 wi  
th value: -2814469719.3958244.  
[I 2024-12-23 15:23:39,395] Trial 6 finished with value: -2983681872.264716 and p  
arameters: {'n_neighbors': 10, 'weights': 'distance', 'p': 2}. Best is trial 14 wi  
th value: -2814469719.3958244.  
[I 2024-12-23 15:23:39,500] Trial 21 finished with value: -2816981835.357902 and
```

```
parameters: {'n_neighbors': 33, 'weights': 'distance', 'p': 1}. Best is trial 14
with value: -2814469719.3958244.
[I 2024-12-23 15:23:39,549] Trial 12 finished with value: -2866755219.556266 and
parameters: {'n_neighbors': 24, 'weights': 'distance', 'p': 2}. Best is trial 14
with value: -2814469719.3958244.
[I 2024-12-23 15:23:39,823] Trial 18 finished with value: -2868800157.354754 and
parameters: {'n_neighbors': 46, 'weights': 'distance', 'p': 2}. Best is trial 14
with value: -2814469719.3958244.
[I 2024-12-23 15:23:40,728] Trial 37 finished with value: -2807228235.155959 and
parameters: {'n_neighbors': 40, 'weights': 'distance', 'p': 1}. Best is trial 37
with value: -2807228235.155959.
[I 2024-12-23 15:23:40,732] Trial 39 finished with value: -2808054875.075886 and
parameters: {'n_neighbors': 42, 'weights': 'distance', 'p': 1}. Best is trial 37
with value: -2807228235.155959.
[I 2024-12-23 15:23:41,285] Trial 25 finished with value: -2807957872.345935 and
parameters: {'n_neighbors': 41, 'weights': 'distance', 'p': 1}. Best is trial 37
with value: -2807228235.155959.
[I 2024-12-23 15:23:41,295] Trial 22 finished with value: -2866340871.8089957 and
parameters: {'n_neighbors': 45, 'weights': 'distance', 'p': 2}. Best is trial 37
with value: -2807228235.155959.
[I 2024-12-23 15:23:41,707] Trial 23 finished with value: -3170853583.780899 and
parameters: {'n_neighbors': 6, 'weights': 'uniform', 'p': 2}. Best is trial 37 wi
th value: -2807228235.155959.
[I 2024-12-23 15:23:41,931] Trial 26 finished with value: -2808054875.075886 and
parameters: {'n_neighbors': 42, 'weights': 'distance', 'p': 1}. Best is trial 37
with value: -2807228235.155959.
[I 2024-12-23 15:23:41,949] Trial 24 finished with value: -2862724766.289893 and
parameters: {'n_neighbors': 35, 'weights': 'distance', 'p': 2}. Best is trial 37
with value: -2807228235.155959.
[I 2024-12-23 15:23:41,953] Trial 43 finished with value: -2807957872.345935 and
parameters: {'n_neighbors': 41, 'weights': 'distance', 'p': 1}. Best is trial 37
with value: -2807228235.155959.
[I 2024-12-23 15:23:41,980] Trial 42 finished with value: -2807957872.345935 and
parameters: {'n_neighbors': 41, 'weights': 'distance', 'p': 1}. Best is trial 37
with value: -2807228235.155959.
[I 2024-12-23 15:23:42,022] Trial 27 finished with value: -3167154976.8668327 and
parameters: {'n_neighbors': 6, 'weights': 'distance', 'p': 2}. Best is trial 37 w
ith value: -2807228235.155959.
[I 2024-12-23 15:23:42,037] Trial 28 finished with value: -2886200071.884205 and
parameters: {'n_neighbors': 25, 'weights': 'uniform', 'p': 2}. Best is trial 37 w
ith value: -2807228235.155959.
[I 2024-12-23 15:23:42,179] Trial 29 finished with value: -2810766604.8718576 and
parameters: {'n_neighbors': 48, 'weights': 'distance', 'p': 1}. Best is trial 37
with value: -2807228235.155959.
[I 2024-12-23 15:23:42,204] Trial 32 finished with value: -2833233091.9531393 and
parameters: {'n_neighbors': 50, 'weights': 'uniform', 'p': 1}. Best is trial 37 w
ith value: -2807228235.155959.
[I 2024-12-23 15:23:42,233] Trial 31 finished with value: -2833233091.9531393 and
parameters: {'n_neighbors': 50, 'weights': 'uniform', 'p': 1}. Best is trial 37 w
ith value: -2807228235.155959.
[I 2024-12-23 15:23:42,321] Trial 30 finished with value: -2810007698.341278 and
parameters: {'n_neighbors': 47, 'weights': 'distance', 'p': 1}. Best is trial 37
with value: -2807228235.155959.
[I 2024-12-23 15:23:42,364] Trial 35 finished with value: -2808703325.521978 and
parameters: {'n_neighbors': 39, 'weights': 'distance', 'p': 1}. Best is trial 37
with value: -2807228235.155959.
[I 2024-12-23 15:23:42,466] Trial 33 finished with value: -2807228235.155959 and
parameters: {'n_neighbors': 40, 'weights': 'distance', 'p': 1}. Best is trial 37
with value: -2807228235.155959.
[I 2024-12-23 15:23:42,479] Trial 34 finished with value: -2807957872.345935 and
```

```

parameters: {'n_neighbors': 41, 'weights': 'distance', 'p': 1}. Best is trial 37
with value: -2807228235.155959.
[I 2024-12-23 15:23:42,509] Trial 36 finished with value: -2807957872.345935 and
parameters: {'n_neighbors': 41, 'weights': 'distance', 'p': 1}. Best is trial 37
with value: -2807228235.155959.
[I 2024-12-23 15:23:42,519] Trial 38 finished with value: -2808703325.521978 and
parameters: {'n_neighbors': 39, 'weights': 'distance', 'p': 1}. Best is trial 37
with value: -2807228235.155959.
[I 2024-12-23 15:23:42,570] Trial 40 finished with value: -2808138765.159474 and
parameters: {'n_neighbors': 38, 'weights': 'distance', 'p': 1}. Best is trial 37
with value: -2807228235.155959.
[I 2024-12-23 15:23:42,627] Trial 41 finished with value: -2808138765.159474 and
parameters: {'n_neighbors': 38, 'weights': 'distance', 'p': 1}. Best is trial 37
with value: -2807228235.155959.
[I 2024-12-23 15:23:42,963] Trial 45 finished with value: -2807957872.345935 and
parameters: {'n_neighbors': 41, 'weights': 'distance', 'p': 1}. Best is trial 37
with value: -2807228235.155959.
[I 2024-12-23 15:23:42,974] Trial 44 finished with value: -2808054875.075886 and
parameters: {'n_neighbors': 42, 'weights': 'distance', 'p': 1}. Best is trial 37
with value: -2807228235.155959.
[I 2024-12-23 15:23:43,110] Trial 49 finished with value: -2808138765.159474 and
parameters: {'n_neighbors': 38, 'weights': 'distance', 'p': 1}. Best is trial 37
with value: -2807228235.155959.
[I 2024-12-23 15:23:43,115] Trial 46 finished with value: -2807957872.345935 and
parameters: {'n_neighbors': 41, 'weights': 'distance', 'p': 1}. Best is trial 37
with value: -2807228235.155959.
[I 2024-12-23 15:23:43,132] Trial 47 finished with value: -2808138765.159474 and
parameters: {'n_neighbors': 38, 'weights': 'distance', 'p': 1}. Best is trial 37
with value: -2807228235.155959.
[I 2024-12-23 15:23:43,141] Trial 48 finished with value: -2808138765.159474 and
parameters: {'n_neighbors': 38, 'weights': 'distance', 'p': 1}. Best is trial 37
with value: -2807228235.155959.

```

Mean Squared Error (MSE): 2791797360.482463

Mean Absolute Percentage Error (MAPE): 8.16649329092971e+19

Root Mean Squared Error (RMSE): 52837.461714984594

R-squared (R^2): 0.276498506971945

HuberRegressor

Now we are testing the HuberRegressor model, using Optuna for hyperparameter tuning.

The following hyperparameters are being evaluated:

- epsilon: The threshold for considering a prediction error as an outlier (ranging from 1e-1 to 1e1). It defines the point where the loss function changes from quadratic to linear, helping the model handle outliers.
- alpha: Regularization strength (ranging from 1e-5 to 1e1). It controls the penalty applied to large coefficients to prevent overfitting.
- max_iter: Maximum number of iterations for the solver (ranging from 100 to 10000). This determines how many passes the algorithm will make through the data during training.

With HuberRegressor, as the next algorithms are more robust we expect to have predictions while minimizing the influence of outliers, but taking into account that none of

the models are working maybe these one can perform better.

```
In [11]: X = dfFeature.drop(['Balance'], axis=1)
y = dfFeature['Balance']

X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_
scaler = StandardScaler()
X_train_scaled = scaler.fit_transform(X_train)
X_test_scaled = scaler.transform(X_test)

def objective(trial):
    epsilon = trial.suggest_float('epsilon', 1.1, 4.0)
    alpha = trial.suggest_float('alpha', 1e-4, 1.0)
    max_iter = trial.suggest_int('max_iter', 100, 1000)

    model = HuberRegressor(
        epsilon=epsilon,
        alpha=alpha,
        max_iter=max_iter
    )

    score = cross_val_score(model, X_train_scaled, y_train, cv=5, scoring='neg_r
return score.mean()

study = optuna.create_study(direction='maximize')
study.optimize(objective, n_trials=100, n_jobs=-1)

best_params = study.best_params
print(f"Best Hyperparameters: {study.best_params}")
```

```
[I 2024-12-23 12:40:23,421] A new study created in memory with name: no-name-8e95
5591-1e36-4134-a8a9-78ec5356eb24
```

```
[I 2024-12-23 12:40:24,680] Trial 6 finished with value: -3158390477.5757155 and parameters: {'epsilon': 3.5651579210805906, 'alpha': 0.1898423191428365, 'max_iter': 169}. Best is trial 6 with value: -3158390477.5757155.  
[I 2024-12-23 12:40:24,697] Trial 8 finished with value: -2858661682.074204 and parameters: {'epsilon': 3.8054038741228675, 'alpha': 0.03713110322647028, 'max_iter': 189}. Best is trial 8 with value: -2858661682.074204.  
[I 2024-12-23 12:40:24,708] Trial 0 finished with value: -2901357557.740528 and parameters: {'epsilon': 3.8587681801925755, 'alpha': 0.05835623455972851, 'max_iter': 557}. Best is trial 8 with value: -2858661682.074204.  
[I 2024-12-23 12:40:24,737] Trial 17 finished with value: -3410291683.0193543 and parameters: {'epsilon': 3.7570795427052697, 'alpha': 0.4180356420015677, 'max_iter': 870}. Best is trial 8 with value: -2858661682.074204.  
[I 2024-12-23 12:40:24,768] Trial 10 finished with value: -3175259174.1873503 and parameters: {'epsilon': 3.253840755740499, 'alpha': 0.2006042351119946, 'max_iter': 481}. Best is trial 8 with value: -2858661682.074204.  
[I 2024-12-23 12:40:24,785] Trial 9 finished with value: -2895847441.962567 and parameters: {'epsilon': 3.4511032200193252, 'alpha': 0.05576339869823581, 'max_iter': 779}. Best is trial 8 with value: -2858661682.074204.  
[I 2024-12-23 12:40:24,826] Trial 12 finished with value: -3440217633.2433915 and parameters: {'epsilon': 3.4843231673380513, 'alpha': 0.46062809933350296, 'max_iter': 172}. Best is trial 8 with value: -2858661682.074204.  
[I 2024-12-23 12:40:24,903] Trial 15 finished with value: -3310811936.9235125 and parameters: {'epsilon': 2.90780286670138, 'alpha': 0.3064229935374154, 'max_iter': 323}. Best is trial 8 with value: -2858661682.074204.  
[I 2024-12-23 12:40:24,917] Trial 4 finished with value: -3618028891.958808 and parameters: {'epsilon': 2.6728874690068642, 'alpha': 0.8940102456795398, 'max_iter': 542}. Best is trial 8 with value: -2858661682.074204.  
[I 2024-12-23 12:40:24,924] Trial 19 finished with value: -3173729121.2602887 and parameters: {'epsilon': 1.6638887730859238, 'alpha': 0.20588348910002746, 'max_iter': 512}. Best is trial 8 with value: -2858661682.074204.  
[I 2024-12-23 12:40:24,964] Trial 7 finished with value: -3539774719.587232 and parameters: {'epsilon': 2.277345569602688, 'alpha': 0.6518607813258227, 'max_iter': 535}. Best is trial 8 with value: -2858661682.074204.  
[I 2024-12-23 12:40:24,989] Trial 2 finished with value: -3595160128.439781 and parameters: {'epsilon': 3.1250600048076795, 'alpha': 0.8104011407581136, 'max_iter': 471}. Best is trial 8 with value: -2858661682.074204.  
[I 2024-12-23 12:40:24,994] Trial 1 finished with value: -3210308127.574252 and parameters: {'epsilon': 1.6245537689131764, 'alpha': 0.23158708538494405, 'max_iter': 201}. Best is trial 8 with value: -2858661682.074204.  
[I 2024-12-23 12:40:25,011] Trial 16 finished with value: -3564643958.1269403 and parameters: {'epsilon': 1.662350075565441, 'alpha': 0.7237645195503923, 'max_iter': 114}. Best is trial 8 with value: -2858661682.074204.  
[I 2024-12-23 12:40:25,053] Trial 11 finished with value: -3625970155.8585067 and parameters: {'epsilon': 2.0032938112202245, 'alpha': 0.9275426832514323, 'max_iter': 418}. Best is trial 8 with value: -2858661682.074204.  
[I 2024-12-23 12:40:25,075] Trial 13 finished with value: -3557769588.2457466 and parameters: {'epsilon': 2.127070494015454, 'alpha': 0.6983328459499542, 'max_iter': 814}. Best is trial 8 with value: -2858661682.074204.  
[I 2024-12-23 12:40:25,108] Trial 18 finished with value: -3604525274.074088 and parameters: {'epsilon': 2.4997339548505124, 'alpha': 0.843256323987211, 'max_iter': 137}. Best is trial 8 with value: -2858661682.074204.  
[I 2024-12-23 12:40:25,116] Trial 5 finished with value: -3549580305.968913 and parameters: {'epsilon': 1.8332361041017284, 'alpha': 0.6793611895571645, 'max_iter': 458}. Best is trial 8 with value: -2858661682.074204.  
[I 2024-12-23 12:40:25,147] Trial 14 finished with value: -3453446369.818531 and parameters: {'epsilon': 2.465716096432139, 'alpha': 0.48138317758112126, 'max_iter': 773}. Best is trial 8 with value: -2858661682.074204.  
[I 2024-12-23 12:40:25,299] Trial 3 finished with value: -3119806762.055553 and parameters: {'epsilon': 1.261278300193964, 'alpha': 0.19962684087083707, 'max_iter': 310}. Best is trial 8 with value: -2858661682.074204.
```

```
[I 2024-12-23 12:40:25,997] Trial 20 finished with value: -3340218326.6817093 and parameters: {'epsilon': 3.5126126166880294, 'alpha': 0.33546253151051225, 'max_iter': 193}. Best is trial 8 with value: -2858661682.074204.  
[I 2024-12-23 12:40:26,218] Trial 23 finished with value: -3586707301.1246386 and parameters: {'epsilon': 3.883316349505515, 'alpha': 0.7825910238505003, 'max_iter': 989}. Best is trial 8 with value: -2858661682.074204.  
[I 2024-12-23 12:40:26,265] Trial 22 finished with value: -3078644823.7857466 and parameters: {'epsilon': 1.5427137792675134, 'alpha': 0.15311363388089638, 'max_iter': 523}. Best is trial 8 with value: -2858661682.074204.  
[I 2024-12-23 12:40:26,325] Trial 33 finished with value: -2854175675.4981475 and parameters: {'epsilon': 3.9531388847347317, 'alpha': 0.03467127931063137, 'max_iter': 857}. Best is trial 33 with value: -2854175675.4981475.  
[I 2024-12-23 12:40:26,351] Trial 24 finished with value: -3638503580.0239496 and parameters: {'epsilon': 3.76619146954467, 'alpha': 0.9808632895156041, 'max_iter': 573}. Best is trial 33 with value: -2854175675.4981475.  
[I 2024-12-23 12:40:26,422] Trial 25 finished with value: -2933378816.976153 and parameters: {'epsilon': 1.8855789827239418, 'alpha': 0.07660470022736654, 'max_iter': 839}. Best is trial 33 with value: -2854175675.4981475.  
[I 2024-12-23 12:40:26,437] Trial 29 finished with value: -3591170302.901094 and parameters: {'epsilon': 1.9557787773057047, 'alpha': 0.7988683065346658, 'max_iter': 329}. Best is trial 33 with value: -2854175675.4981475.  
[I 2024-12-23 12:40:26,448] Trial 34 finished with value: -2833238069.382927 and parameters: {'epsilon': 3.9088885225660297, 'alpha': 0.021611208083257005, 'max_iter': 759}. Best is trial 34 with value: -2833238069.382927.  
[I 2024-12-23 12:40:26,493] Trial 36 finished with value: -2837472464.871716 and parameters: {'epsilon': 3.970514497800526, 'alpha': 0.02457257848941975, 'max_iter': 704}. Best is trial 34 with value: -2833238069.382927.  
[I 2024-12-23 12:40:26,514] Trial 26 finished with value: -3529453913.2123847 and parameters: {'epsilon': 1.6241888705941037, 'alpha': 0.6353102292111117, 'max_iter': 580}. Best is trial 34 with value: -2833238069.382927.  
[I 2024-12-23 12:40:26,667] Trial 27 finished with value: -3421498069.6572266 and parameters: {'epsilon': 2.6859183032547422, 'alpha': 0.43346968533201224, 'max_iter': 985}. Best is trial 34 with value: -2833238069.382927.  
[I 2024-12-23 12:40:26,670] Trial 31 finished with value: -2988707677.2624054 and parameters: {'epsilon': 2.383131500562257, 'alpha': 0.09936347126840436, 'max_iter': 841}. Best is trial 34 with value: -2833238069.382927.  
[I 2024-12-23 12:40:26,763] Trial 39 finished with value: -2824516862.6369696 and parameters: {'epsilon': 3.94231518426527, 'alpha': 0.014316755766137057, 'max_iter': 694}. Best is trial 39 with value: -2824516862.6369696.  
[I 2024-12-23 12:40:26,811] Trial 38 finished with value: -2817984858.7062044 and parameters: {'epsilon': 3.9988241707362127, 'alpha': 0.0041035824291046075, 'max_iter': 697}. Best is trial 38 with value: -2817984858.7062044.  
[I 2024-12-23 12:40:26,951] Trial 32 finished with value: -2823293660.8388777 and parameters: {'epsilon': 2.2655682696307, 'alpha': 0.014283126843135784, 'max_iter': 808}. Best is trial 38 with value: -2817984858.7062044.  
[I 2024-12-23 12:40:27,043] Trial 21 finished with value: -3481894550.3474617 and parameters: {'epsilon': 1.2313765917669859, 'alpha': 0.5757594984620772, 'max_iter': 260}. Best is trial 38 with value: -2817984858.7062044.  
[I 2024-12-23 12:40:27,119] Trial 28 finished with value: -3247096150.815899 and parameters: {'epsilon': 1.1326962570252967, 'alpha': 0.22549719579425423, 'max_iter': 419}. Best is trial 38 with value: -2817984858.7062044.  
[I 2024-12-23 12:40:27,267] Trial 30 finished with value: -2818264962.7738028 and parameters: {'epsilon': 3.0284292443444722, 'alpha': 0.0004913084384412653, 'max_iter': 844}. Best is trial 38 with value: -2817984858.7062044.  
[I 2024-12-23 12:40:27,448] Trial 40 finished with value: -2839974955.320247 and parameters: {'epsilon': 3.9927077089863863, 'alpha': 0.0262193410887744, 'max_iter': 674}. Best is trial 38 with value: -2817984858.7062044.  
[I 2024-12-23 12:40:27,468] Trial 35 finished with value: -2938792870.941285 and parameters: {'epsilon': 1.2260715627868073, 'alpha': 0.004318477879380042, 'max_iter': 708}. Best is trial 38 with value: -2817984858.7062044.
```

```
[I 2024-12-23 12:40:27,563] Trial 37 finished with value: -2992799556.584058 and parameters: {'epsilon': 1.1974092407316028, 'alpha': 0.001874711247015104, 'max_iter': 703}. Best is trial 38 with value: -2817984858.7062044.  
[I 2024-12-23 12:40:27,768] Trial 42 finished with value: -2837563414.9365172 and parameters: {'epsilon': 3.9718302750782812, 'alpha': 0.024633664865436437, 'max_iter': 721}. Best is trial 38 with value: -2817984858.7062044.  
[I 2024-12-23 12:40:27,843] Trial 41 finished with value: -2819790091.2598124 and parameters: {'epsilon': 3.988982483248515, 'alpha': 0.008468223187433184, 'max_iter': 700}. Best is trial 38 with value: -2817984858.7062044.  
[I 2024-12-23 12:40:27,851] Trial 47 finished with value: -2980839527.9790926 and parameters: {'epsilon': 3.975652737746233, 'alpha': 0.09525478450537815, 'max_iter': 656}. Best is trial 38 with value: -2817984858.7062044.  
[I 2024-12-23 12:40:27,877] Trial 43 finished with value: -2858833576.0425634 and parameters: {'epsilon': 3.341595660148255, 'alpha': 0.03725149153579571, 'max_iter': 666}. Best is trial 38 with value: -2817984858.7062044.  
[I 2024-12-23 12:40:27,894] Trial 49 finished with value: -3056535918.0703025 and parameters: {'epsilon': 3.980698664216051, 'alpha': 0.13228840858703816, 'max_iter': 663}. Best is trial 38 with value: -2817984858.7062044.  
[I 2024-12-23 12:40:27,969] Trial 48 finished with value: -2978994804.47085 and parameters: {'epsilon': 3.902243374135658, 'alpha': 0.09438738174556466, 'max_iter': 653}. Best is trial 38 with value: -2817984858.7062044.  
[I 2024-12-23 12:40:27,980] Trial 45 finished with value: -2870230493.7118106 and parameters: {'epsilon': 3.2884981701035794, 'alpha': 0.04322360425114641, 'max_iter': 676}. Best is trial 38 with value: -2817984858.7062044.  
[I 2024-12-23 12:40:28,119] Trial 46 finished with value: -2819034467.6838923 and parameters: {'epsilon': 3.9704034476728443, 'alpha': 0.007080332447260737, 'max_iter': 703}. Best is trial 38 with value: -2817984858.7062044.  
[I 2024-12-23 12:40:28,136] Trial 44 finished with value: -2821065346.7249236 and parameters: {'epsilon': 3.232615146018857, 'alpha': 0.010399562558164592, 'max_iter': 640}. Best is trial 38 with value: -2817984858.7062044.  
[I 2024-12-23 12:40:28,220] Trial 53 finished with value: -3033697964.8447237 and parameters: {'epsilon': 3.9806481995052736, 'alpha': 0.12073673371577559, 'max_iter': 663}. Best is trial 38 with value: -2817984858.7062044.  
[I 2024-12-23 12:40:28,334] Trial 52 finished with value: -2820494970.74615 and parameters: {'epsilon': 3.982705144122108, 'alpha': 0.00956520137265763, 'max_iter': 662}. Best is trial 38 with value: -2817984858.7062044.  
[I 2024-12-23 12:40:28,519] Trial 55 finished with value: -3021433033.5271597 and parameters: {'epsilon': 3.6683234089160943, 'alpha': 0.11468265236754349, 'max_iter': 653}. Best is trial 38 with value: -2817984858.7062044.  
[I 2024-12-23 12:40:28,521] Trial 50 finished with value: -2817958904.398982 and parameters: {'epsilon': 3.985127649084069, 'alpha': 0.001103122103241358, 'max_iter': 665}. Best is trial 50 with value: -2817958904.398982.  
[I 2024-12-23 12:40:28,619] Trial 51 finished with value: -2818222129.05079 and parameters: {'epsilon': 3.9607071469184847, 'alpha': 0.0005416592418786489, 'max_iter': 659}. Best is trial 50 with value: -2817958904.398982.  
[I 2024-12-23 12:40:28,658] Trial 54 finished with value: -3029763331.171003 and parameters: {'epsilon': 3.1712426355397403, 'alpha': 0.11881402142102021, 'max_iter': 665}. Best is trial 50 with value: -2817958904.398982.  
[I 2024-12-23 12:40:28,921] Trial 56 finished with value: -3042066146.856906 and parameters: {'epsilon': 3.1971540262532083, 'alpha': 0.12494861115427683, 'max_iter': 656}. Best is trial 50 with value: -2817958904.398982.  
[I 2024-12-23 12:40:29,011] Trial 57 finished with value: -3043298464.2120667 and parameters: {'epsilon': 3.028381965163349, 'alpha': 0.1255885598121277, 'max_iter': 663}. Best is trial 50 with value: -2817958904.398982.  
[I 2024-12-23 12:40:29,127] Trial 60 finished with value: -3063408627.341535 and parameters: {'epsilon': 3.64408297048085, 'alpha': 0.13583894032998303, 'max_iter': 925}. Best is trial 50 with value: -2817958904.398982.  
[I 2024-12-23 12:40:29,257] Trial 58 finished with value: -3094803719.836628 and parameters: {'epsilon': 3.0352417636385405, 'alpha': 0.15265733029615408, 'max_iter': 647}. Best is trial 50 with value: -2817958904.398982.
```

```
[I 2024-12-23 12:40:29,304] Trial 62 finished with value: -3023591110.731785 and parameters: {'epsilon': 3.660073238462055, 'alpha': 0.1157400920989425, 'max_iter': 927}. Best is trial 50 with value: -2817958904.398982.  
[I 2024-12-23 12:40:29,319] Trial 61 finished with value: -3030584245.1920385 and parameters: {'epsilon': 3.6501831516674836, 'alpha': 0.11918904823028555, 'max_iter': 630}. Best is trial 50 with value: -2817958904.398982.  
[I 2024-12-23 12:40:29,380] Trial 63 finished with value: -3052417605.7533507 and parameters: {'epsilon': 3.653468432011612, 'alpha': 0.13017232815341523, 'max_iter': 906}. Best is trial 50 with value: -2817958904.398982.  
[I 2024-12-23 12:40:29,392] Trial 59 finished with value: -3068367012.094633 and parameters: {'epsilon': 2.970077486801076, 'alpha': 0.13848215170942538, 'max_iter': 622}. Best is trial 50 with value: -2817958904.398982.  
[I 2024-12-23 12:40:29,487] Trial 66 finished with value: -3274508933.868948 and parameters: {'epsilon': 3.6789237737189318, 'alpha': 0.2739863760619219, 'max_iter': 921}. Best is trial 50 with value: -2817958904.398982.  
[I 2024-12-23 12:40:29,557] Trial 67 finished with value: -3070461506.0019183 and parameters: {'epsilon': 3.627828256934314, 'alpha': 0.13952824131010338, 'max_iter': 607}. Best is trial 50 with value: -2817958904.398982.  
[I 2024-12-23 12:40:29,641] Trial 68 finished with value: -3288836109.1735063 and parameters: {'epsilon': 3.6821414261458774, 'alpha': 0.28634176996618055, 'max_iter': 610}. Best is trial 50 with value: -2817958904.398982.  
[I 2024-12-23 12:40:29,698] Trial 69 finished with value: -3293755995.0830884 and parameters: {'epsilon': 3.6535816675846697, 'alpha': 0.2907076673435285, 'max_iter': 610}. Best is trial 50 with value: -2817958904.398982.  
[I 2024-12-23 12:40:29,764] Trial 70 finished with value: -3138891877.8001513 and parameters: {'epsilon': 3.650853985988123, 'alpha': 0.17790026107223134, 'max_iter': 614}. Best is trial 50 with value: -2817958904.398982.  
[I 2024-12-23 12:40:29,811] Trial 64 finished with value: -3067610010.744196 and parameters: {'epsilon': 2.985343662829051, 'alpha': 0.13808362763547377, 'max_iter': 604}. Best is trial 50 with value: -2817958904.398982.  
[I 2024-12-23 12:40:29,831] Trial 65 finished with value: -3047692177.4152865 and parameters: {'epsilon': 3.0221965023612496, 'alpha': 0.12781164285293142, 'max_iter': 913}. Best is trial 50 with value: -2817958904.398982.  
[I 2024-12-23 12:40:29,879] Trial 71 finished with value: -2928667493.04869 and parameters: {'epsilon': 3.6395881891559405, 'alpha': 0.0710696087955191, 'max_iter': 615}. Best is trial 50 with value: -2817958904.398982.  
[I 2024-12-23 12:40:30,143] Trial 72 finished with value: -3278489538.785148 and parameters: {'epsilon': 3.694531622581346, 'alpha': 0.2773667869548237, 'max_iter': 598}. Best is trial 50 with value: -2817958904.398982.  
[I 2024-12-23 12:40:30,247] Trial 74 finished with value: -3108398590.4546404 and parameters: {'epsilon': 3.629307682372732, 'alpha': 0.1601805549283694, 'max_iter': 605}. Best is trial 50 with value: -2817958904.398982.  
[I 2024-12-23 12:40:30,249] Trial 73 finished with value: -3117377310.860329 and parameters: {'epsilon': 3.638954993863299, 'alpha': 0.16528582228949557, 'max_iter': 616}. Best is trial 50 with value: -2817958904.398982.  
[I 2024-12-23 12:40:30,336] Trial 75 finished with value: -3125448080.347164 and parameters: {'epsilon': 3.6392343535310703, 'alpha': 0.16995252043406872, 'max_iter': 600}. Best is trial 50 with value: -2817958904.398982.  
[I 2024-12-23 12:40:30,528] Trial 76 finished with value: -3269494109.0649366 and parameters: {'epsilon': 3.6389885480614566, 'alpha': 0.26977953896741713, 'max_iter': 913}. Best is trial 50 with value: -2817958904.398982.  
[I 2024-12-23 12:40:30,680] Trial 77 finished with value: -3127381994.633176 and parameters: {'epsilon': 3.632266247573772, 'alpha': 0.17108226735229656, 'max_iter': 605}. Best is trial 50 with value: -2817958904.398982.  
[I 2024-12-23 12:40:30,872] Trial 78 finished with value: -3127781062.285 and parameters: {'epsilon': 3.6388876839801543, 'alpha': 0.17131589252529278, 'max_iter': 598}. Best is trial 50 with value: -2817958904.398982.  
[I 2024-12-23 12:40:30,913] Trial 80 finished with value: -2935010576.8498254 and parameters: {'epsilon': 3.7906605105243054, 'alpha': 0.0739986733192809, 'max_iter': 615}. Best is trial 50 with value: -2817958904.398982.
```

```
[I 2024-12-23 12:40:30,922] Trial 79 finished with value: -3286244511.697109 and parameters: {'epsilon': 3.646987294893501, 'alpha': 0.2840646527261127, 'max_iter': 743}. Best is trial 50 with value: -2817958904.398982.  
[I 2024-12-23 12:40:30,974] Trial 81 finished with value: -2901632497.906365 and parameters: {'epsilon': 3.803195684779636, 'alpha': 0.058487460664656814, 'max_iter': 602}. Best is trial 50 with value: -2817958904.398982.  
[I 2024-12-23 12:40:30,976] Trial 83 finished with value: -2921462428.4648776 and parameters: {'epsilon': 3.7964875051840026, 'alpha': 0.06774025077145404, 'max_iter': 769}. Best is trial 50 with value: -2817958904.398982.  
[I 2024-12-23 12:40:31,060] Trial 84 finished with value: -2927616308.9003015 and parameters: {'epsilon': 3.8432711904978123, 'alpha': 0.07058497171770427, 'max_iter': 750}. Best is trial 50 with value: -2817958904.398982.  
[I 2024-12-23 12:40:31,087] Trial 82 finished with value: -3130125931.4341335 and parameters: {'epsilon': 3.7522366674843557, 'alpha': 0.17269072719400366, 'max_iter': 607}. Best is trial 50 with value: -2817958904.398982.  
[I 2024-12-23 12:40:31,120] Trial 85 finished with value: -2931441103.9121923 and parameters: {'epsilon': 3.7865041492954457, 'alpha': 0.07235218377125263, 'max_iter': 749}. Best is trial 50 with value: -2817958904.398982.  
[I 2024-12-23 12:40:31,186] Trial 87 finished with value: -2920390986.3139315 and parameters: {'epsilon': 3.8218535206025757, 'alpha': 0.06724309876509856, 'max_iter': 757}. Best is trial 50 with value: -2817958904.398982.  
[I 2024-12-23 12:40:31,190] Trial 88 finished with value: -2926388430.972764 and parameters: {'epsilon': 3.808002336978201, 'alpha': 0.07001839067685707, 'max_iter': 739}. Best is trial 50 with value: -2817958904.398982.  
[I 2024-12-23 12:40:31,201] Trial 86 finished with value: -2919064961.047082 and parameters: {'epsilon': 3.8093828469053066, 'alpha': 0.06662904382556031, 'max_iter': 750}. Best is trial 50 with value: -2817958904.398982.  
[I 2024-12-23 12:40:31,248] Trial 89 finished with value: -2917581753.656761 and parameters: {'epsilon': 3.8154675859167937, 'alpha': 0.06594075377512382, 'max_iter': 744}. Best is trial 50 with value: -2817958904.398982.  
[I 2024-12-23 12:40:31,256] Trial 90 finished with value: -2906988013.8384175 and parameters: {'epsilon': 3.8098908662042033, 'alpha': 0.06100334694529851, 'max_iter': 751}. Best is trial 50 with value: -2817958904.398982.  
[I 2024-12-23 12:40:31,264] Trial 91 finished with value: -2899852436.9186015 and parameters: {'epsilon': 3.8070341408444652, 'alpha': 0.05764687479722322, 'max_iter': 746}. Best is trial 50 with value: -2817958904.398982.  
[I 2024-12-23 12:40:31,364] Trial 92 finished with value: -2912624824.367489 and parameters: {'epsilon': 3.824837296097667, 'alpha': 0.06363577388067562, 'max_iter': 749}. Best is trial 50 with value: -2817958904.398982.  
[I 2024-12-23 12:40:31,391] Trial 94 finished with value: -2930860251.7848506 and parameters: {'epsilon': 3.8278791631061244, 'alpha': 0.07208275917351474, 'max_iter': 743}. Best is trial 50 with value: -2817958904.398982.  
[I 2024-12-23 12:40:31,402] Trial 93 finished with value: -2912554407.4135923 and parameters: {'epsilon': 3.8217166714177635, 'alpha': 0.06360310255316699, 'max_iter': 752}. Best is trial 50 with value: -2817958904.398982.  
[I 2024-12-23 12:40:31,414] Trial 95 finished with value: -2921875037.758853 and parameters: {'epsilon': 3.8268628641481457, 'alpha': 0.06793025099649277, 'max_iter': 740}. Best is trial 50 with value: -2817958904.398982.  
[I 2024-12-23 12:40:31,456] Trial 96 finished with value: -2911306846.2618876 and parameters: {'epsilon': 3.807321147645648, 'alpha': 0.06302183438845249, 'max_iter': 750}. Best is trial 50 with value: -2817958904.398982.  
[I 2024-12-23 12:40:31,481] Trial 97 finished with value: -2907497282.7334127 and parameters: {'epsilon': 3.8075771617232004, 'alpha': 0.061241886191969866, 'max_iter': 739}. Best is trial 50 with value: -2817958904.398982.  
[I 2024-12-23 12:40:31,489] Trial 98 finished with value: -2909072405.688218 and parameters: {'epsilon': 3.8003410752804165, 'alpha': 0.06197873396922041, 'max_iter': 752}. Best is trial 50 with value: -2817958904.398982.  
[I 2024-12-23 12:40:31,507] Trial 99 finished with value: -2909581096.4200745 and parameters: {'epsilon': 2.78143914783702, 'alpha': 0.06230331607653366, 'max_iter': 742}. Best is trial 50 with value: -2817958904.398982.
```

```
Best Hyperparameters: {'epsilon': 3.985127649084069, 'alpha': 0.00110312210324135  
8, 'max_iter': 665}
```

MODEL EVALUATION

```
In [12]: best_model = HuberRegressor(**best_params)  
best_model.fit(X_train_scaled, y_train)  
  
y_pred = best_model.predict(X_test_scaled)  
  
mse = mean_squared_error(y_test, y_pred)  
mape = mean_absolute_percentage_error(y_test, y_pred)  
rmse = np.sqrt(mse)  
r2 = r2_score(y_test, y_pred)  
  
print(f"Mean Squared Error (MSE): {mse}")  
print(f"Mean Absolute Percentage Error (MAPE): {mape}")  
print(f"Root Mean Squared Error (RMSE): {rmse}")  
print(f"R-squared (R²): {r2}")
```

```
Mean Squared Error (MSE): 2790919336.3787293  
Mean Absolute Percentage Error (MAPE): 7.92283341042909e+19  
Root Mean Squared Error (RMSE): 52829.15233447088  
R-squared (R²): 0.2767260491850575
```

With this hyperparams {'epsilon': 3.985127649084069, 'alpha': 0.001103122103241358, 'max_iter': 665}. The MSE and RMSE indicate moderate prediction errors, with an RMSE of around 52,829. The MAPE suggests significant deviation between predictions and actual values, and the R² value of 0.28 shows that the model only explains a small portion of the variance, all models are having the same issue as we are in thought that our dataset is not prepared for this task.

THEIL SEN

Now we are testing the TheilSenRegressor model, using Optuna for hyperparameter tuning. The following hyperparameters are being evaluated:

- max_iter: Maximum number of iterations for the solver (ranging from 100 to 10,000). Controls how long the model will train.
- tol: Tolerance for optimization (ranging from 1e-6 to 1e-1). A smaller value leads to a more precise solution, but might require more iterations.
- fit_intercept: Whether or not to include an intercept in the model. This is tuned between True and False to see if the intercept improves the fit.

With TheilSenRegressor, we aim to achieve robust predictions, especially in the presence of outliers, which is gonna be hard because our data is builded for classification task and maybe the results are not optimal.

```
In [10]: X = dfFeature.drop(['Balance'], axis=1)  
y = dfFeature['Balance']
```

```

X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_
scaler = StandardScaler()
X_train_scaled = scaler.fit_transform(X_train)
X_test_scaled = scaler.transform(X_test)

def objective(trial):
    max_iter = trial.suggest_int("max_iter", 100, 10000, step=100)
    tol = trial.suggest_float("tol", 1e-6, 1e-1, log=True)
    fit_intercept = trial.suggest_categorical("fit_intercept", [True, False])
    model = TheilSenRegressor(max_iter=max_iter, tol=tol, fit_intercept=fit_intercept)
    score = cross_val_score(model, X_train_scaled, y_train, cv=5, scoring='neg_mse')
    return score.mean()

study = optuna.create_study(direction='maximize')
study.optimize(objective, n_trials=5, n_jobs=-1)

best_params = study.best_params

best_model = TheilSenRegressor(**best_params)
best_model.fit(X_train_scaled, y_train)

y_pred = best_model.predict(X_test_scaled)

mse = mean_squared_error(y_test, y_pred)
mape = mean_absolute_percentage_error(y_test, y_pred)
rmse = np.sqrt(mse)
r2 = r2_score(y_test, y_pred)

print(f"Best Hyperparameters: {study.best_params}")
print(f"Mean Squared Error (MSE): {mse}")
print(f"Mean Absolute Percentage Error (MAPE): {mape}")
print(f"Root Mean Squared Error (RMSE): {rmse}")
print(f"R-squared (R²): {r2}")

```

```

[I 2024-12-23 13:13:12,990] A new study created in memory with name: no-name-791de492-804e-4ad0-b326-6f3c37ce20ce
[I 2024-12-23 13:14:17,954] Trial 1 finished with value: -2863891299.678733 and parameters: {'max_iter': 3100, 'tol': 1.4697095676291161e-05, 'fit_intercept': True}. Best is trial 1 with value: -2863891299.678733.
[I 2024-12-23 13:14:19,553] Trial 0 finished with value: -2863891299.300743 and parameters: {'max_iter': 3200, 'tol': 0.0016675717318288248, 'fit_intercept': True}. Best is trial 0 with value: -2863891299.300743.
[I 2024-12-23 13:14:21,309] Trial 2 finished with value: -2863891299.656935 and parameters: {'max_iter': 8100, 'tol': 8.880754271594837e-05, 'fit_intercept': True}. Best is trial 0 with value: -2863891299.300743.
[I 2024-12-23 13:14:23,217] Trial 3 finished with value: -6964267384905.508 and parameters: {'max_iter': 4300, 'tol': 0.0215672786648107, 'fit_intercept': False}. Best is trial 0 with value: -2863891299.300743.
[I 2024-12-23 13:14:23,728] Trial 4 finished with value: -6964267427962.799 and parameters: {'max_iter': 800, 'tol': 2.4635677850142743e-05, 'fit_intercept': False}. Best is trial 0 with value: -2863891299.300743.

Best Hyperparameters: {'max_iter': 3200, 'tol': 0.0016675717318288248, 'fit_intercept': True}
Mean Squared Error (MSE): 2840334325.9876394
Mean Absolute Percentage Error (MAPE): 7.242721910383224e+19
Root Mean Squared Error (RMSE): 53294.78704327131
R-squared (R²): 0.2639200270625085

```

With this hyperparameters {'max_iter': 3200, 'tol': 0.0016675717318288248, 'fit_intercept': True}. The MSE and RMSE indicate moderate prediction errors, with an RMSE of about 53,295. The MAPE suggests significant deviation between predictions and actual values. The R² value of 0.26 indicates that the model explains a small portion of the variance, suggesting there is room for improvement in the model's performance.

5. CLUSTERING

Pre-Clustering Analysis

Before performing a clustering process, it is essential to be clear about what is expected to be obtained and how the result can be interpreted. Clustering is an unsupervised learning technique that seeks to group similar data without the need for predefined labels. Next we will mention our expectations before starting to perform the process:

Objectives

The main objective of clustering is to identify underlying patterns in the data that are not immediately obvious. This can allow us to:

Segment customers or users into groups with similar characteristics. Detect atypical behavior or outliers, which could be customers with extreme characteristics or errors in our data, even if we already performed the outlier management during the EDA process. Group customers according to their financial behavior. This information could guide the bank management employees while developing strategies targeted to each group.

- Partitioning Clustering
- Hierarchical Clustering
- Density Based Clustering
- Probabilistic-Model based Clustering
- Clustering Evaluation

```
In [7]: # Import Libraries
import pandas as pd
import numpy as np
import seaborn as sns
import matplotlib.pyplot as plt
from sklearn.cluster import KMeans, Birch, DBSCAN
from sklearn.mixture import GaussianMixture
from sklearn.preprocessing import StandardScaler
from sklearn.neighbors import NearestNeighbors
from sklearn.metrics import pairwise_distances
from numpy.random import uniform
from random import sample
from scipy import stats
from sklearn.metrics import silhouette_score, calinski_harabasz_score, davies_bouldin_score
from sklearn.metrics import homogeneity_score, completeness_score, v_measure_score
```

```
In [8]: # Data preparation
clustering_df = pd.read_csv(r'entregaDos/featureIng_dataframe.csv')
clustering_df = clustering_df.drop(columns=['Exited', 'Complain'])
scaler = StandardScaler()
clustering_df[['CreditScore', 'Balance', 'EstimatedSalary']] = scaler.fit_transform(
clustering_df)
```

Out[8]:

	CreditScore	Tenure	Balance	NumOfProducts	HasCrCard	IsActiveMember	Estima
0	-0.326221	2	-1.225848	0	1	1	1
1	-0.440036	1	0.117350	0	0	0	1
2	-1.536794	8	1.333053	1	1	0	0
3	0.501521	1	-1.225848	1	0	0	0
4	2.063884	2	0.785728	0	1	1	1

5 rows × 23 columns



Partitioning Clustering

- *K-means*

We will first try to find the optimal number of clusters for K-means. This will mean testing increasing numbers of clusters and stopping when the change in inertia between next cluster counts becomes insignificant, as defined by a specified threshold.

```
In [9]: means = []
inertias = []
threshold = 0.25
k = 1
prev_inertia = None

while True:
    kmeans = KMeans(n_clusters=k, random_state=42)
    kmeans.fit(clustering_df)

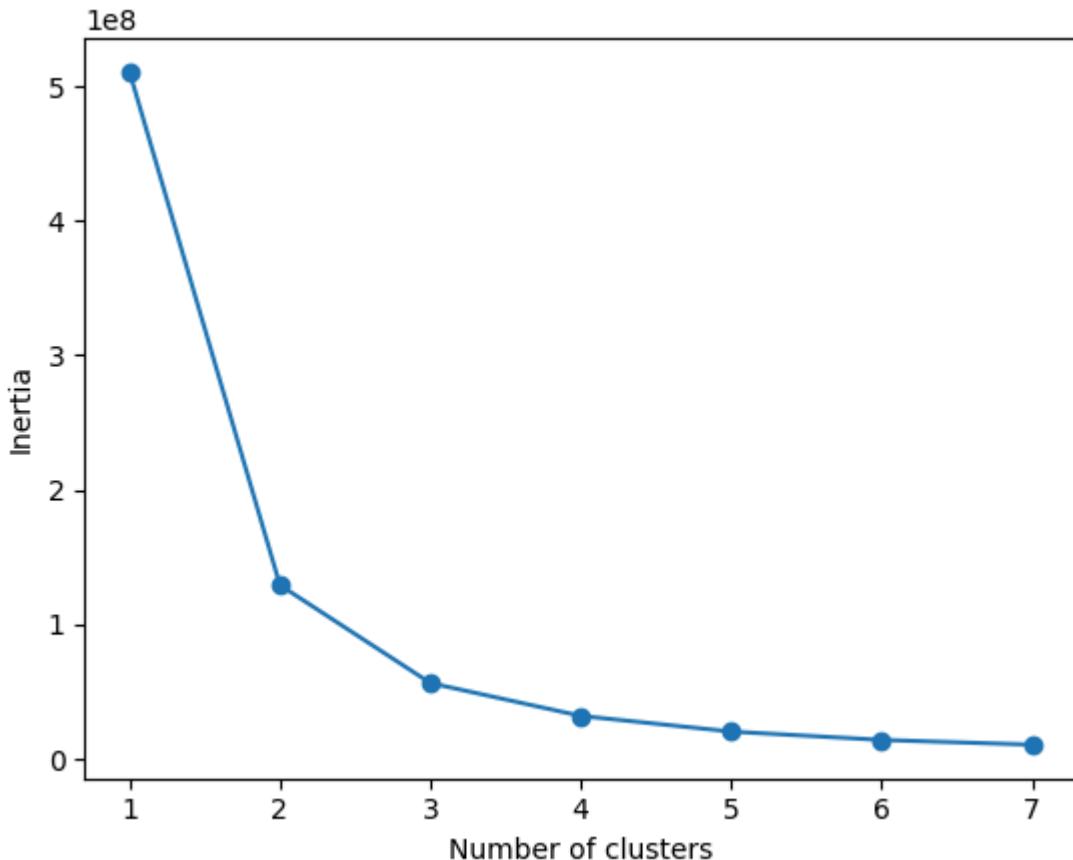
    means.append(k)
    inertias.append(kmeans.inertia_)

    if prev_inertia is not None:
        inertia_diff = abs(prev_inertia - kmeans.inertia_)
        if inertia_diff / prev_inertia < threshold:
            break

    prev_inertia = kmeans.inertia_
    k += 1

plt.plot(means, inertias, 'o-')
plt.xlabel('Number of clusters')
plt.ylabel('Inertia')
```

```
Out[9]: Text(0, 0.5, 'Inertia')
```



The inertia plot shows the "elbow" at 3 clusters, where more increases provide minimal improvement, so we will use 3 clusters as the optimal choice for K-means.

```
In [10]: kmeans = KMeans(n_clusters=3)  
kmeans.fit(clustering_df)
```

```
Out[10]: ▾ KMeans ⓘ ?  
KMeans(n_clusters=3)
```

```
In [11]: clustering_df['Cluster'] = kmeans.labels_  
  
cluster_sizes = clustering_df['Cluster'].value_counts()  
print("\nCluster Sizes:")  
print(cluster_sizes)
```

```
Cluster Sizes:  
Cluster  
0      3374  
2      3351  
1      3275  
Name: count, dtype: int64
```

```
In [12]: print("\nInertia:", kmeans.inertia_)
```

```
Inertia: 56406042.495005086
```

K-means algorithm has grouped the data into three clusters, with Cluster 2 having the largest number of points, followed by Cluster 1, and then Cluster 0. The distribution of

data points across clusters is relatively balanced and they are fairly similar in terms of the number of data points they contain.

Hierarchical Clustering

- *BIRCH Clustering*

BIRCH can automatically form clusters based on a user-defined threshold parameter. This controls the maximum radius of a subcluster (or "leaf") in the clustering feature tree.

```
In [13]: clustering_df.drop(columns='Cluster', inplace=True)
birch = Birch(threshold=0.25)
birch.fit(clustering_df)
```

```
Out[13]: Birch
Birch(threshold=0.25)
```

```
In [14]: clustering_df['Cluster'] = birch.labels_
cluster_sizes = clustering_df['Cluster'].value_counts()
print("\nCluster Sizes:")
print(cluster_sizes)
```

```
Cluster Sizes:
Cluster
0    4310
1    3385
2    2305
Name: count, dtype: int64
```

The cluster sizes show that Cluster 0 is the largest with 4.295 members, followed by Cluster 1 with 3.400, and Cluster 2 with 2.305, Clustter 0 having significantly more members than the 2 others and Cluster 1 being also bigger than Cluster 2. This could suggest that some clusters represent more common patterns or dominant groups in the dataset.

Density Based Clustering

- DBSCAN clustering

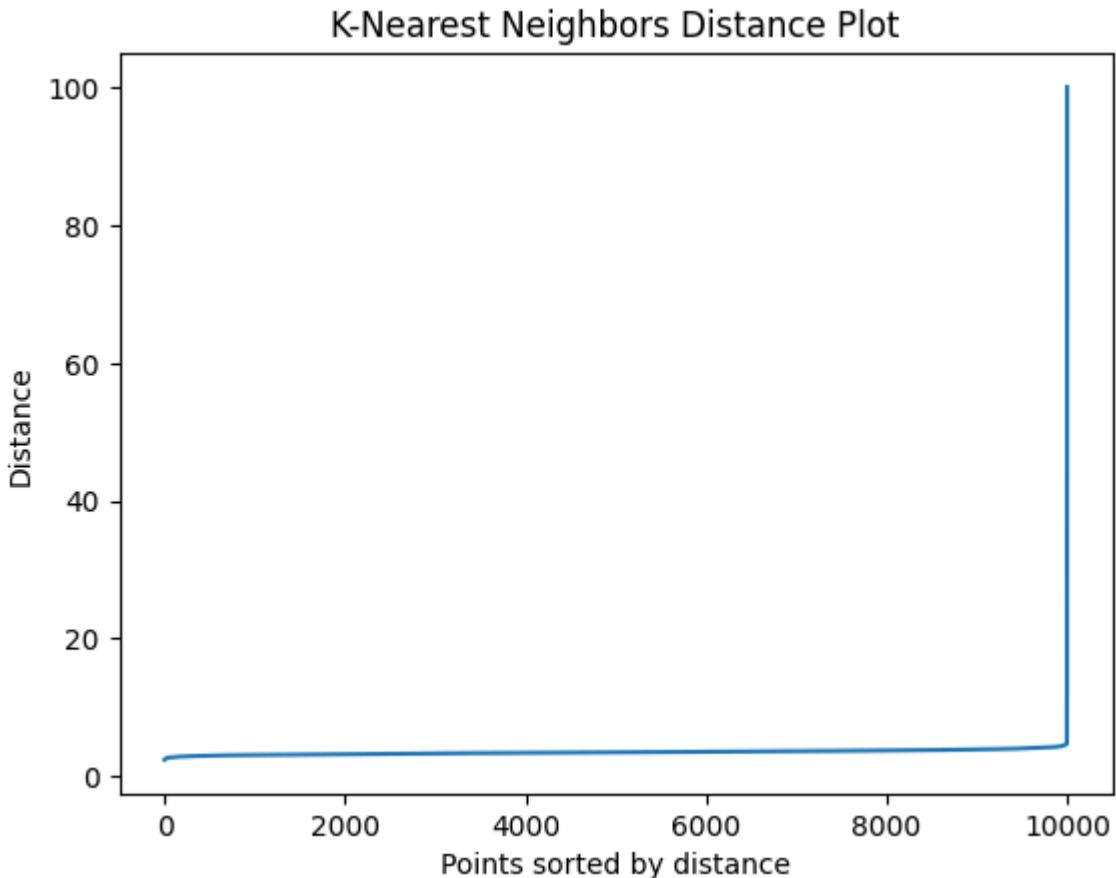
Lets first try choosing the right values for eps (the maximum distance between two points for them to be considered neighbors) and min_samples (the number of samples in a neighborhood for a point to be considered a core point) for DBSCAN.

If eps is too large, DBSCAN will consider most points as neighbors and in the other side if eps is too small, DBSCAN will only consider points that are very close to each other as neighbors. This could lead few large clusters or many small clusters.

```
In [15]: clustering_df.drop(columns='Cluster', inplace=True)
neighbors = NearestNeighbors(n_neighbors=4)
neighbors_fit = neighbors.fit(clustering_df)

distances, indices = neighbors_fit.kneighbors(clustering_df)
distances = np.sort(distances[:, -1], axis=0)

plt.plot(distances)
plt.title('K-Nearest Neighbors Distance Plot')
plt.xlabel('Points sorted by distance')
plt.ylabel('Distance')
plt.show()
```



The curve doesn't start to grow significantly until the 10,000th point, this could indicate that the data has a very large spread, and we're looking at a global density scale. It might be that our data is sparsely distributed, and DBSCAN may not be the best choice for this data. Due to this we will try with considerably higher values of eps.

```
In [16]: dbSCAN = DBSCAN(eps=10, min_samples=200, metric='euclidean')
dbSCAN.fit(clustering_df)
```

```
Out[16]: ▾ DBSCAN ⓘ ?
```

DBSCAN(eps=10, min_samples=200)

"min_samples" specifies the minimum number of points required to form a dense region. Putting "min_samples" at 200, DBSCAN will only create clusters with at least 200 points, which helps in ignoring small, potentially noisy clusters that are too sparse.

```
In [17]: clustering_df['Cluster'] = dbscan.labels_
cluster_sizes = clustering_df['Cluster'].value_counts()
print("\nCluster Sizes:")
print(cluster_sizes)
```

```
Cluster Sizes:
Cluster
0      7239
1      2757
-1       4
Name: count, dtype: int64
```

This algorithm made Cluster 0 with 7239 points and Cluster 1 with 2757 points, while 4 points were classified as noise (outliers, labeled as -1). This suggests the data primarily forms two dense groups with minimal noise.

Probabilistic-Model Based Clustering

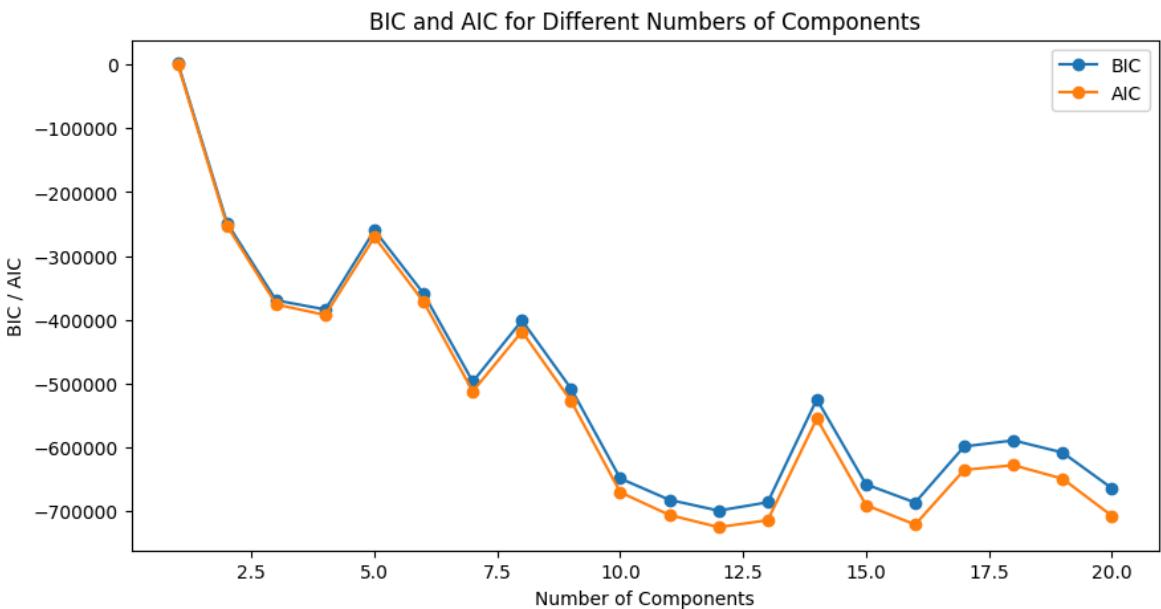
- *Gaussian Mixture* clustering

We'll use metrics like the Bayesian Information Criterion (BIC) or Akaike Information Criterion (AIC) to evaluate different numbers of components. Lower values of BIC/AIC indicate a better fit while penalizing model complexity.

```
In [18]: clustering_df.drop(columns='Cluster', inplace=True)
n_components = range(1, 21)
bics = []
aics = []

for n in n_components:
    gmm = GaussianMixture(n_components=n, random_state=42)
    gmm.fit(clustering_df)
    bics.append(gmm.bic(clustering_df))
    aics.append(gmm.aic(clustering_df))

plt.figure(figsize=(10, 5))
plt.plot(n_components, bics, label='BIC', marker='o')
plt.plot(n_components, aics, label='AIC', marker='o')
plt.xlabel('Number of Components')
plt.ylabel('BIC / AIC')
plt.title('BIC and AIC for Different Numbers of Components')
plt.legend()
plt.show()
```



The plot shows that both BIC and AIC decrease significantly up to 10 components, indicating better model fit, but the improvement slows afterward. Therefore, 10 components is likely the optimal balance between model complexity and fit. This large number of components allows the model to capture these subtleties more accurately.

```
In [19]: gmm = GaussianMixture(n_components=10)
gmm.fit(clustering_df)
```

```
Out[19]: ▾ GaussianMixture ⓘ ?
```

```
GaussianMixture(n_components=10)
```

```
In [20]: labels = gmm.predict(clustering_df)
cluster_sizes = np.unique(labels, return_counts=True)

print("Cluster Sizes:")
for cluster, size in zip(*cluster_sizes):
    print(f"Cluster {cluster}: {size} points")
```

```
Cluster Sizes:
Cluster 0: 231 points
Cluster 1: 6964 points
Cluster 2: 638 points
Cluster 3: 245 points
Cluster 4: 186 points
Cluster 5: 419 points
Cluster 6: 198 points
Cluster 7: 838 points
Cluster 8: 180 points
Cluster 9: 101 points
```

The GMM with 10 clusters shows diverse customer segments, with Cluster 6 representing the largest group (3,567 points), likely the most common customer behavior. Clusters 1 and 2 are small, possibly indicating rare or outlier groups. Larger clusters like 3, 5, and 8 suggest significant customer segments with shared characteristics.

Clustering Evaluation

1. Cluster tendency: Hopkins Statistic

Our Hopkin test implementation converts the input data into a NumPy array and uses 5% of the data size as the sample. Nearest neighbor distances are computed for the uniform random sample (`u_distances`) and the second-nearest neighbor distances for the data sample (`w_distances`). The Hopkins statistic is then calculated as the ratio of the uniform distances sum to the total of uniform and real data distances.

```
In [22]: def hopkins_statistic(X):

    X=X.values
    sample_size = int(X.shape[0]*0.05)

    X_uniform_random_sample = uniform(X.min(axis=0), X.max(axis=0) ,(sample_size

    random_indices=sample(range(0, X.shape[0], 1), sample_size)
    X_sample = X[random_indices]

    neigh = NearestNeighbors(n_neighbors=2)
    nbrs=neigh.fit(X)

    #uniform random sample
    u_distances , u_indices = nbrs.kneighbors(X_uniform_random_sample , n_neigh
    u_distances = u_distances[:, 0]

    #actual sample
    w_distances , w_indices = nbrs.kneighbors(X_sample , n_neighbors=2)
    w_distances = w_distances[:, 1]

    u_sum = np.sum(u_distances)
    w_sum = np.sum(w_distances)

    H = u_sum/ (u_sum + w_sum)
    return H
```

```
In [25]: print("\nHopkins Statistic:", hopkins_statistic(clustering_df))
```

```
Hopkins Statistic: 0.572590949922156
```

Since multiple calls of the function will result in different values of `H`, we call the function and compute Hopkins' Statistic multiple times, and take its average.

```
In [24]: l = []
for i in range(20):
    H=hopkins_statistic(clustering_df)
    l.append(H)

print("\nHopkins Statistic:", np.mean(l))
```

```
Hopkins Statistic: 0.5824437136419893
```

A Hopkins statistic of 0.583 indicates that the data is likely uniformly distributed, showing no distinct clustering structure, this means a moderate clustering tendency, with some structure but not strongly pronounced.

2. Internal Evaluation Methods: Shilhouette Coefficient, Calinski-Harabasz Index and Davies-Bouldin Index

```
In [26]: def evaluate_clustering(models, X):
    results = {}
    for name, model in models.items():
        labels = (
            model.labels_ if hasattr(model, "labels_") else model.predict(X)
        )

        if len(set(labels)) <= 1 or (set(labels) == {-1}):
            results[name] = {"Silhouette": "N/A", "Calinski-Harabasz": "N/A", "Davies-Bouldin": "N/A"}
            continue

        results[name] = {
            "Silhouette": silhouette_score(X, labels),
            "Calinski-Harabasz": calinski_harabasz_score(X, labels),
            "Davies-Bouldin": davies_bouldin_score(X, labels),
        }
    return results
```

```
In [27]: models = {"KMeans": kmeans, "Birch": birch, "DBSCAN": dbscan, "GMM": gmm}
metrics = evaluate_clustering(models, clustering_df)

for model, scores in metrics.items():
    print(f"\n{model} Metrics:")
    for metric, value in scores.items():
        print(f"  {metric}: {value}")
```

KMeans Metrics:

Silhouette: 0.5919335990759582
Calinski-Harabasz: 40243.31596170991
Davies-Bouldin: 0.49813616963438356

Birch Metrics:

Silhouette: 0.5603096662513172
Calinski-Harabasz: 33613.68570021595
Davies-Bouldin: 0.49610383070871494

DBSCAN Metrics:

Silhouette: 0.4327036561795056
Calinski-Harabasz: 7507.734000111658
Davies-Bouldin: 1.2753910551975063

GMM Metrics:

Silhouette: -0.09919178623709302
Calinski-Harabasz: 2.124035356830845
Davies-Bouldin: 165.5224268644997

- Shillouette

- kmeans: (0.59) Moderate clustering quality; data points are fairly well-separated between clusters.
- birch: (0.56) Similar to KMeans.
- dbscan: (0.43) Indicates weaker clustering quality.
- gmm: (-0.46) Negative value indicates poor clustering, with many points assigned to incorrect clusters.
- Calinski-Harabasz
 - kmeans: (40243.31) High value indicates well-defined clusters with good separation and compactness.
 - birch: (33613.69) Lower than KMeans, indicating slightly less compact.
 - dbscan: (7507.73) Much lower, suggesting less compact or poorly separated clusters.
 - gmm: (42.62): Extremely low.
- Davies-Bouldin
 - kmeans: (0.50) Low value suggests good clustering quality.
 - birch: (0.50) Comparable clustering quality to KMeans.
 - dbscan: (1.27) Higher value reflects worse clustering quality.
 - gmm: (104.56) Very high value, indicating clusters are poorly defined.

KMeans performs the best, providing well-defined, compact, and well-separated clusters. Birch is slightly less effective but still produces reasonable results. DBSCAN and GMM struggle, with DBSCAN hindered by noise and GMM failing to form meaningful clusters.

3. External Evaluation Methods

As we don't know the expected labels for each datapoint, we will simulate them by using the cluster assignments from KMeans as the true labels, as it is the most reliable algorithm based on internal evaluation metrics.

```
In [28]: def evaluate_clustering_external(models, X, true_labels):
    results = {}
    for name, model in models.items():

        labels = (
            model.labels_ if hasattr(model, "labels_") else model.predict(X)
        )

        if len(set(labels)) <= 1 or (set(labels) == {-1}):
            results[name] = {"Homogeneity": "N/A", "Completeness": "N/A", "V-measure": "N/A"}
            continue

        homogeneity = homogeneity_score(true_labels, labels)
        completeness = completeness_score(true_labels, labels)
        v_measure = v_measure_score(true_labels, labels)

        results[name] = {
            "Homogeneity": homogeneity,
            "Completeness": completeness,
            "V-measure": v_measure,
```

```
    }
    return results
```

```
In [29]: models_to_evaluate = {key: models[key] for key in ["Birch", "DBSCAN", "GMM"]}
metrics = evaluate_clustering_external(models_to_evaluate, clustering_df, kmeans)
for model, scores in metrics.items():
    print(f"\n{model} Metrics:")
    for metric, value in scores.items():
        print(f"  {metric}: {value}")
```

Birch Metrics:

```
Homogeneity: 0.7734703758733057
Completeness: 0.7958179116375509
V-measure: 0.7844850231022287
```

DBSCAN Metrics:

```
Homogeneity: 0.4068247655845901
Completeness: 0.7546009277962076
V-measure: 0.528643971474382
```

GMM Metrics:

```
Homogeneity: 0.000997629326149786
Completeness: 0.0009007691691446348
V-measure: 0.0009467282464221469
```

The Birch model shows the best clustering performance with high Homogeneity, Completeness, and V-measure, indicating it more accurately captures the true data structure. DBSCAN performs decently, particularly in Completeness, but struggles with Homogeneity. The GMM model performs poorly across all metrics, suggesting it fails to effectively cluster the data.

Most Reliable Method Visualization

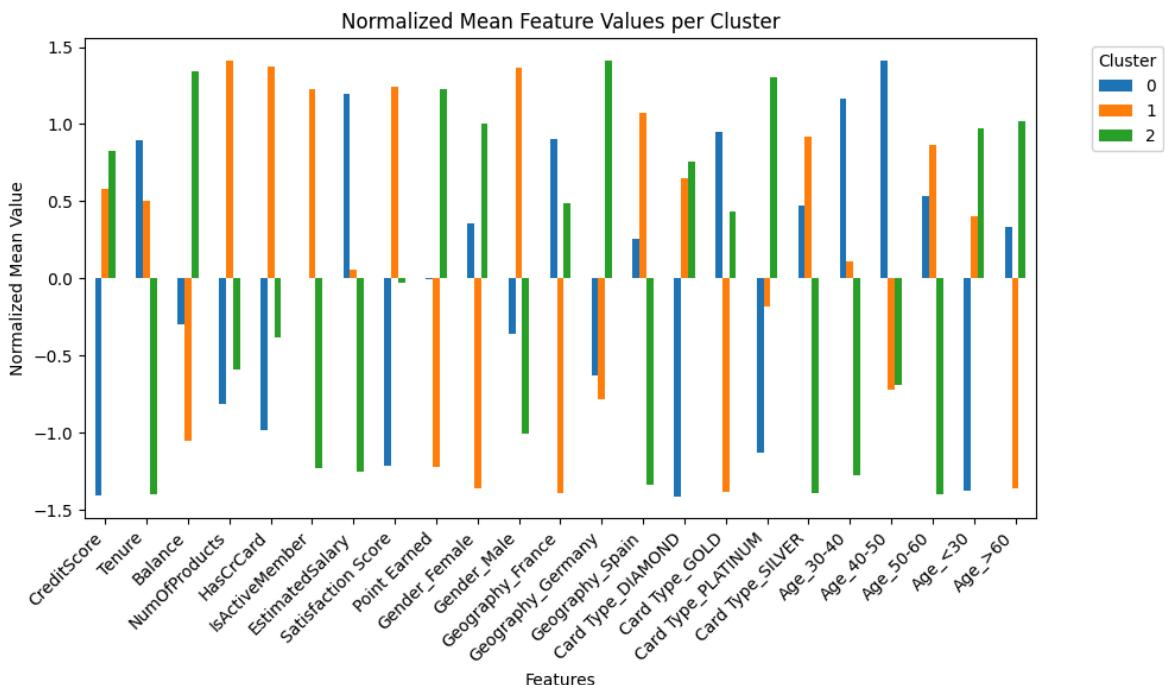
```
In [30]: clustering_df['Cluster'] = kmeans.labels_
cluster_profile = clustering_df.groupby('Cluster').mean()

scaler = StandardScaler()
normalized_cluster_profile = pd.DataFrame(scaler.fit_transform(cluster_profile))

normalized_cluster_profile.T.plot(kind='bar', figsize=(10, 6))

plt.xlabel('Features')
plt.ylabel('Normalized Mean Value')
plt.title('Normalized Mean Feature Values per Cluster')
plt.xticks(rotation=45, ha='right')
plt.legend(title='Cluster', bbox_to_anchor=(1.05, 1), loc='upper left')

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



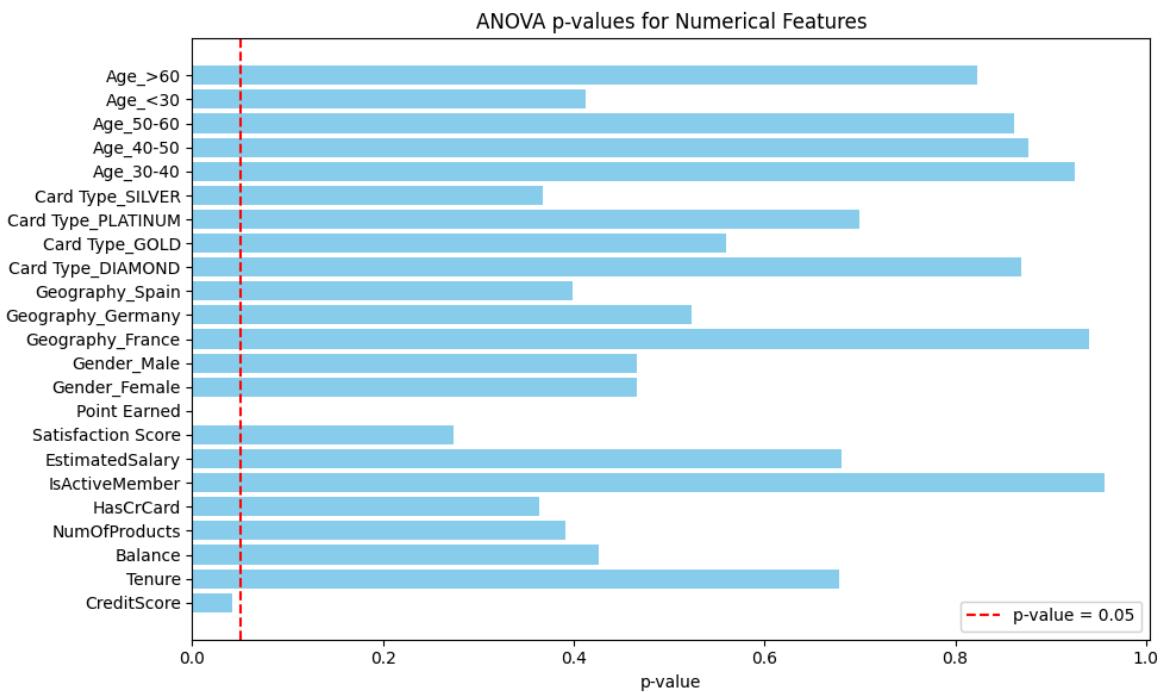
This plot shows the mean values of each feature for each cluster. We normalized the feature values to ensure that all features have a similar scale, making it easier to compare them visually. This prevents features with larger ranges, like "Point Earned," from dominating the plot.

```
In [31]: p_values = []

# Perform ANOVA for each numerical feature against cluster labels
for column in clustering_df.select_dtypes(include=['float64', 'int64']):
    f_stat, p_value = stats.f_oneway(*[clustering_df[column][clustering_df['Cluster'] == i] for i in range(3)])
    p_values.append((column, p_value))

p_values_df = pd.DataFrame(p_values, columns=['Feature', 'p-value'])

plt.figure(figsize=(10, 6))
plt.barh(p_values_df['Feature'], p_values_df['p-value'], color='skyblue')
plt.xlabel('p-value')
plt.title('ANOVA p-values for Numerical Features')
plt.axvline(x=0.05, color='red', linestyle='--', label='p-value = 0.05')
plt.legend()
plt.tight_layout()
plt.show()
```



The ANOVA p-value plot shows how statistically significant each feature is in differentiating the clusters. A low p-value (below 0.05) indicates that the feature is highly significant. For instance, PointEarned and CreditScore have low p-values, suggesting they significantly differentiate the clusters. On the other hand, Age_30-40, Geography_France, and IsActiveMember have higher p-values, indicating they do not play a significant role in clustering. This means these features have less impact on the variance between clusters, and their values are similar across clusters.

```
In [32]: import matplotlib.pyplot as plt
from mpl_toolkits.mplot3d import Axes3D
import numpy as np

centroids = kmeans.cluster_centers_
u_labels = np.unique(kmeans.labels_)

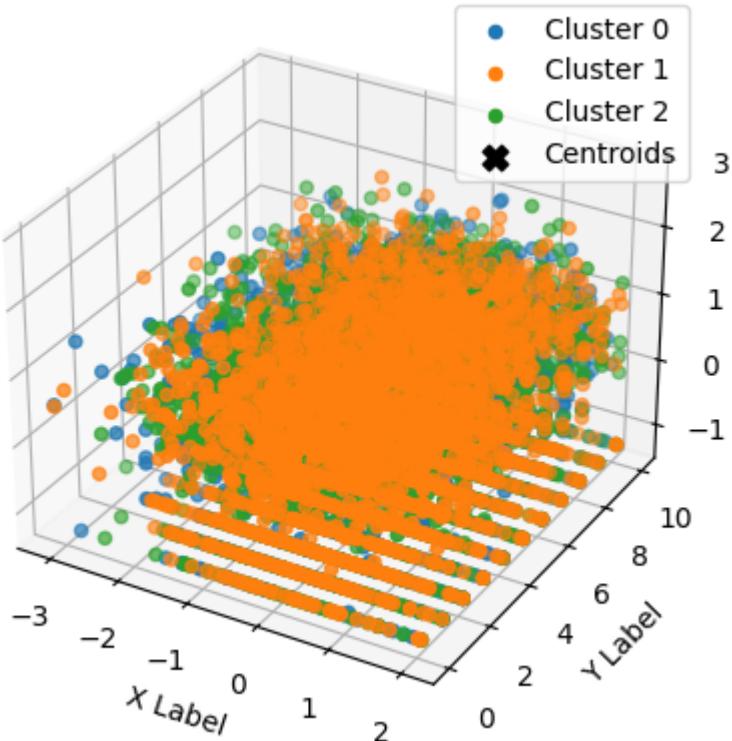
fig = plt.figure()
ax = fig.add_subplot(111, projection='3d')

for i in u_labels:
    ax.scatter(clustering_df.iloc[kmeans.labels_ == i, 0],
               clustering_df.iloc[kmeans.labels_ == i, 1],
               clustering_df.iloc[kmeans.labels_ == i, 2],
               label=f"Cluster {i}")

ax.scatter(centroids[:, 0], centroids[:, 1], centroids[:, 2], s=80, color='k', m

ax.set_xlabel('X Label')
ax.set_ylabel('Y Label')
ax.set_zlabel('Z Label')
ax.legend()

plt.show()
```



CLUSTERING CONCLUSION

As concluded and mentioned in the hopkins test, data is uniformly distributed, meaning there is no clear clustering structure. This is reflected in the visualization, where clusters are not clearly defined and hard to distinguish. As a result, applying clustering algorithms may not produce meaningful insights. Clustering methods are best suited for data with inherent groupings, which this dataset lacks. Therefore, other analysis techniques should be considered instead of clustering.

6. INTERPRETABILITY:

- Data load and preparation

```
In [1]: import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
from sklearn.model_selection import train_test_split
from sklearn.linear_model import LogisticRegression
from sklearn.preprocessing import StandardScaler
from sklearn.tree import DecisionTreeClassifier, plot_tree
import optuna
from sklearn.model_selection import StratifiedKFold, cross_val_score
from sklearn.metrics import roc_auc_score
from sklearn.ensemble import RandomForestRegressor
from sklearn.inspection import PartialDependenceDisplay
from sklearn.metrics import mean_squared_error
from sklearn.metrics import mean_absolute_error
```

```
In [2]: X = dfFeature.drop(['Exited', 'Complain'], axis=1)
y = dfFeature['Exited']

X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_
```

```
NameError Traceback (most recent call last)
Cell In[2], line 1
----> 1 X = dfFeature.drop(['Exited', 'Complain'], axis=1)
      2 y = dfFeature['Exited']
      3 X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2,
random_state=42, stratify=y)

NameError: name 'dfFeature' is not defined
```

INTRINSICALLY INTERPRETABLE MODELS:

First, we are going to analyze the interpretability of some classification models we have used, which are Logistic Regression and Decision Trees. The objective is to determine which of the variables have more impact in the outcome

Logistic Regression

```
In [21]: best_params = logisticStudy.best_params
logistic_model = LogisticRegression(
    solver=best_params["solver"],
    C=best_params["C"],
    random_state=42,
    class_weight='balanced',
    max_iter=best_params["max_iter"]
)

logistic_model.fit(X_train_scaled, y_train)
#Score
skf = StratifiedKFold(n_splits=5, shuffle=True, random_state=42)
logistic_score = cross_val_score(logistic_model, X_train_scaled, y_train, cv=skf
print(logistic_score)
```

0.796143252015294

```
In [22]: coefs_log = logistic_model.coef_
intercept_log = logistic_model.intercept_
print('coefficients: %s' % coefs_log)
print('intercept: %s' % intercept_log)

coefficients: [[-0.07078676 -0.01185544  0.07119003 -0.42785958 -0.01853562 -0.41
116684
 0.03856907 -0.01583394 -0.05133057  0.14376867 -0.14376867 -0.14630825
 0.26159324 -0.09328861  0.03098735 -0.02272501 -0.006128   -0.00189051
 -0.29958235  0.26892291  0.47812588 -0.37379236  0.15468402]]
intercept: [-0.37900038]
```

```
In [23]: # Feature Importance
coef_df = pd.DataFrame({'feature': X_train.columns.values, 'coef': coefs_log[0]})
```

Out[23]:

	feature	coef
0	CreditScore	-0.070787
1	Tenure	-0.011855
2	Balance	0.071190
3	NumOfProducts	-0.427860
4	HasCrCard	-0.018536
5	IsActiveMember	-0.411167
6	EstimatedSalary	0.038569
7	Satisfaction Score	-0.015834
8	Point Earned	-0.051331
9	Gender_Female	0.143769
10	Gender_Male	-0.143769
11	Geography_France	-0.146308
12	Geography_Germany	0.261593
13	Geography_Spain	-0.093289
14	Card Type_DIAMOND	0.030987
15	Card Type_GOLD	-0.022725
16	Card Type_PLATINUM	-0.006128
17	Card Type_SILVER	-0.001891
18	Age_30-40	-0.299582
19	Age_40-50	0.268923
20	Age_50-60	0.478126
21	Age_<30	-0.373792
22	Age_>60	0.154684

In [24]:

```
#Standardized
stdv = np.std(X_train, 0)
abs(coefs_log.reshape(23,) * stdv).sort_values(ascending=False)
```

```
Out[24]: Balance          4435.444086
          EstimatedSalary   2214.832170
          Point_Earned      11.603854
          CreditScore        6.844376
          NumOfProducts      0.213901
          IsActiveMember     0.205470
          Age_30-40           0.148593
          Age_<30             0.138702
          Age_50-60           0.134840
          Age_40-50           0.117570
          Geography_Germany  0.113461
          Geography_France   0.073154
          Gender_Female       0.071544
          Gender_Male          0.071544
          Geography_Spain    0.040307
          Age_>60              0.034885
          Tenure                0.034265
          Satisfaction_Score  0.022330
          Card_Type_DIAMOND   0.013371
          Card_Type_GOLD       0.009902
          HasCrCard            0.008432
          Card_Type_PLATINUM  0.002652
          Card_Type_SILVER     0.000817
          dtype: float64
```

-Most positively influential variables: 'Age_50-60' (0.47), 'Age_40-50' (0.26) and 'Geography_Germany' (0.26)

-Most negatively influential variables: NumOfProducts (-0.42), 'IsActiveMember'(-0.41) and 'Age_<30' (-0.37)

-Most influential standardized variables: 'Balance' (4435.93) and 'EstimatedSalary' (2214.62)

The logistic regression model (79.61%) indicates that age and geography, as well as the balance and the estimated salary are really important for the model's predictions.

We can see that age categories follow a clear pattern, the old customers with higher balance, have the highest chance to exit on the outcome, while the young and inactive customer is the least likely to exit.

Also, If we compare 'Gender_Female' (0.14) and 'Gender_Male' (-0.14), we can see that male customers have a negative influence and females are positively influential in this case, showing that females are more likely to exit and males to stay. Also, German people seem to be specially predisposed to exiting banks.

The negative intercept (-0.37) means that if there is no influence, customers are less likely to exit. But this is not relevant in our case because variables like age are practically never 0.

Decision Tree

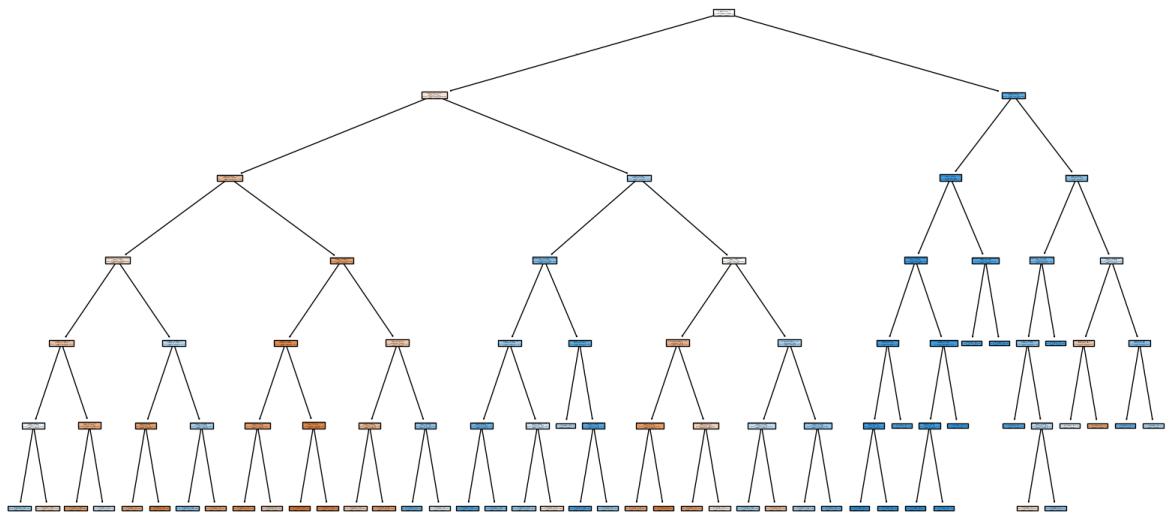
```
In [32]: best_params = treeStudy.best_params_
          decision_tree = DecisionTreeClassifier()
```

```
max_depth=best_params["max_depth"],
min_samples_split=best_params["min_samples_split"],
min_samples_leaf=best_params["min_samples_leaf"],
random_state=42,
class_weight="balanced",
)
decision_tree.fit(X_train, y_train)
#Score
skf = StratifiedKFold(n_splits=5, shuffle=True, random_state=42)
decision_score = cross_val_score(decision_tree, X_train, y_train, cv=skf, scoring='accuracy')
print(decision_score)
```

0.7807972484620794

In [33]:

```
plt.figure(figsize=(20,10))
plot_tree(decision_tree, filled=True, feature_names=X.columns, class_names=['Class 0', 'Class 1'])
plt.show()
```



In [34]:

```
dt_imp_df = pd.DataFrame({'feature':X_train.columns.values.tolist(),
                           'importance': decision_tree.feature_importances_}).sort_values(by='importance', ascending=False)
```

Out[34]:

	feature	importance
20	Age_50-60	0.240021
19	Age_40-50	0.226292
2	Balance	0.203205
3	NumOfProducts	0.129622
12	Geography_Germany	0.067535
5	IsActiveMember	0.060896
22	Age_>60	0.034305
6	EstimatedSalary	0.015292
9	Gender_Female	0.011420
1	Tenure	0.007149
0	CreditScore	0.003370
15	Card Type_GOLD	0.000628
8	Point Earned	0.000134
7	Satisfaction Score	0.000132
4	HasCrCard	0.000000
14	Card Type_DIAMOND	0.000000
13	Geography_Spain	0.000000
11	Geography_France	0.000000
10	Gender_Male	0.000000
18	Age_30-40	0.000000
17	Card Type_SILVER	0.000000
16	Card Type_PLATINUM	0.000000
21	Age_<30	0.000000

The decision tree model (78.91%) suggests that it's most important features are 'Age_50-60' (0.22), 'Balance' (0.19), 'Age_40-50' (0.19) and 'NumOfProducts' (0.10). The rest have low or 0 relevance.

In conclusion, the decision tree model supports our logistic regression model's conclusions which are the most important factors.

GLOBAL MODEL AGNOSTIC METHODS

The second step is to understand which is the way our models work, for that we are going to use PDP and ALE:

Partial Dependence Plot (PDP)

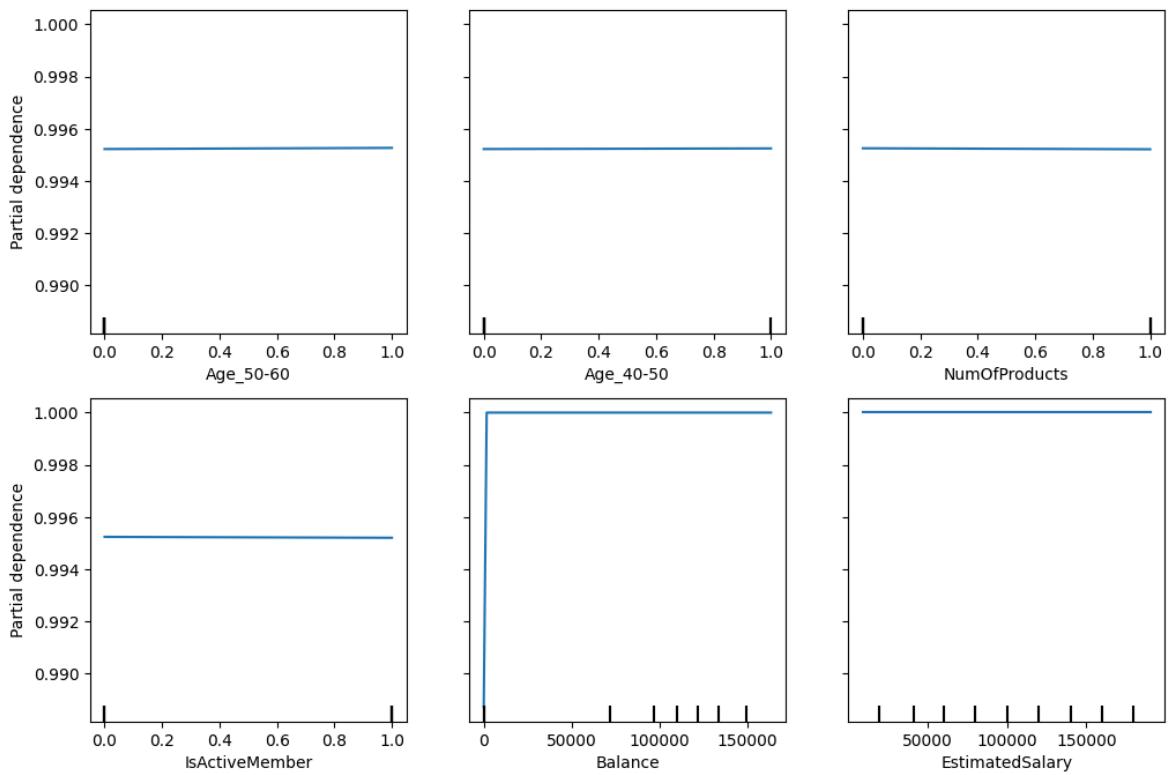
For this section, we are going to apply PDP to the most influential variables of the decision tree model

```
In [36]: features = ["Age_50-60", "Age_40-50", "NumOfProducts", "IsActiveMember", "Balance  
  
fig, ax = plt.subplots(figsize=(12, 8))  
display = PartialDependenceDisplay.from_estimator(logistic_model, X_train, features)  
display.figure_.suptitle("Partial Dependence Plots - Logistic Regression")  
  
fig, ax = plt.subplots(figsize=(12, 8))  
display = PartialDependenceDisplay.from_estimator(decision_tree, X_train, features)  
display.figure_.suptitle("Partial Dependence Plots - Decision Tree")
```

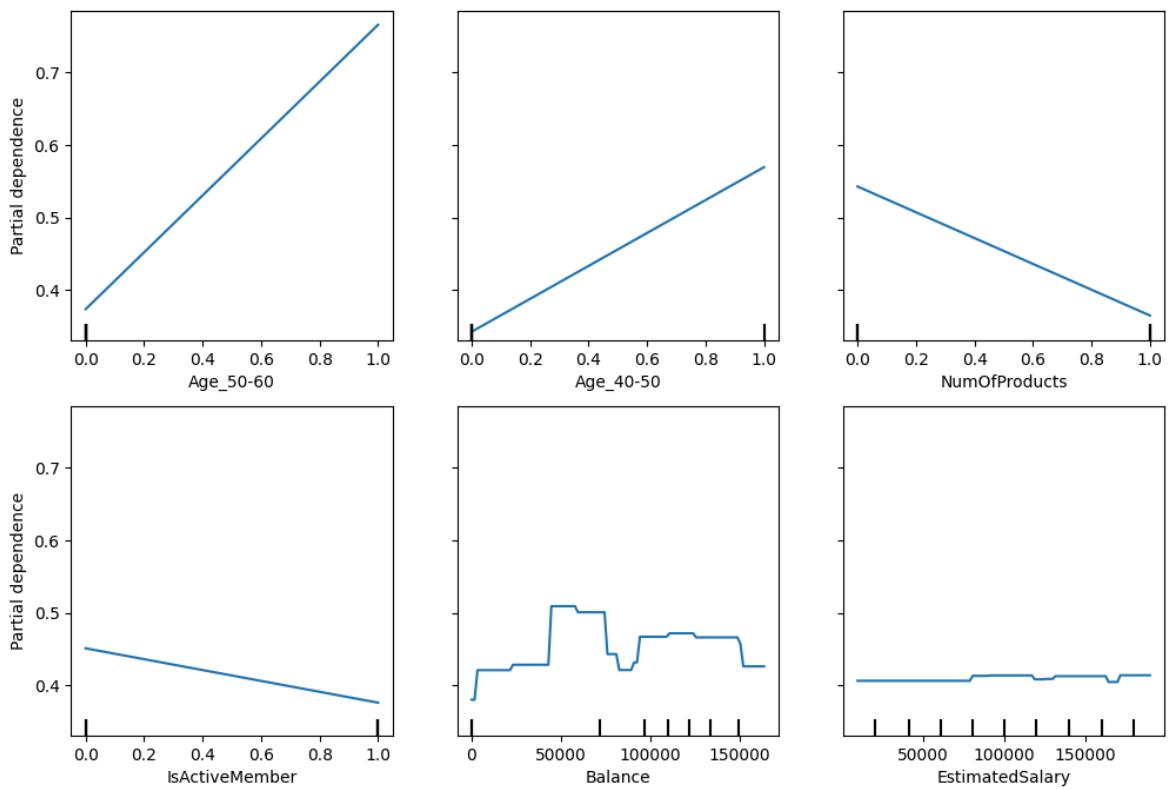


```
Out[36]: Text(0.5, 0.98, 'Partial Dependence Plots - Decision Tree')
```

Partial Dependence Plots - Logistic Regression



Partial Dependence Plots - Decision Tree



The result suggests that firstly, for both 'Age_50-60' and 'Age_40-50', as the value increases (it can only be 0 or 1), the chances of exit prediction also increases, although its less pronounced for the 40-50 age variable, the effects are really similar. Also, it seems like the 'NumOfProducts' variable has almost the contrary effect on the model if we compare it with 'Age_40-50', and much the same happens with 'IsActiveMember', but less strongly.

Secondly, the relation between the 'Balance' variable's value, and the changes of exit prediction change, not as in the previous case. So, as well as we know that this variable is really important for the model's predictions, now we know that the way this variable is considered for the model's prediction is not linear, as we could have guessed → (Higher balance → + chances of exit).

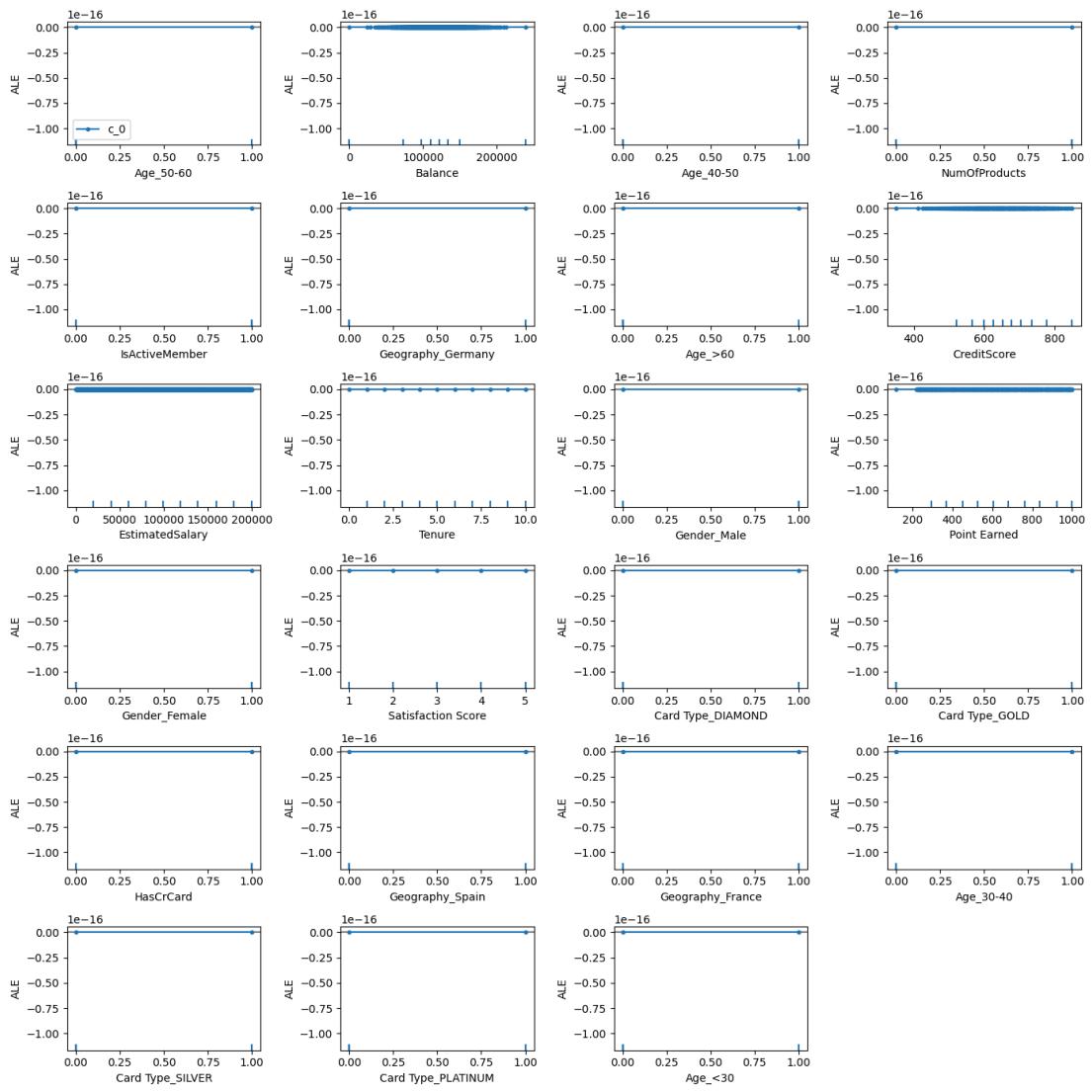
Accumulated Local Effects (ALE)

```
In [ ]: from alibi.explainers import ALE, plot_ale
import numpy as np

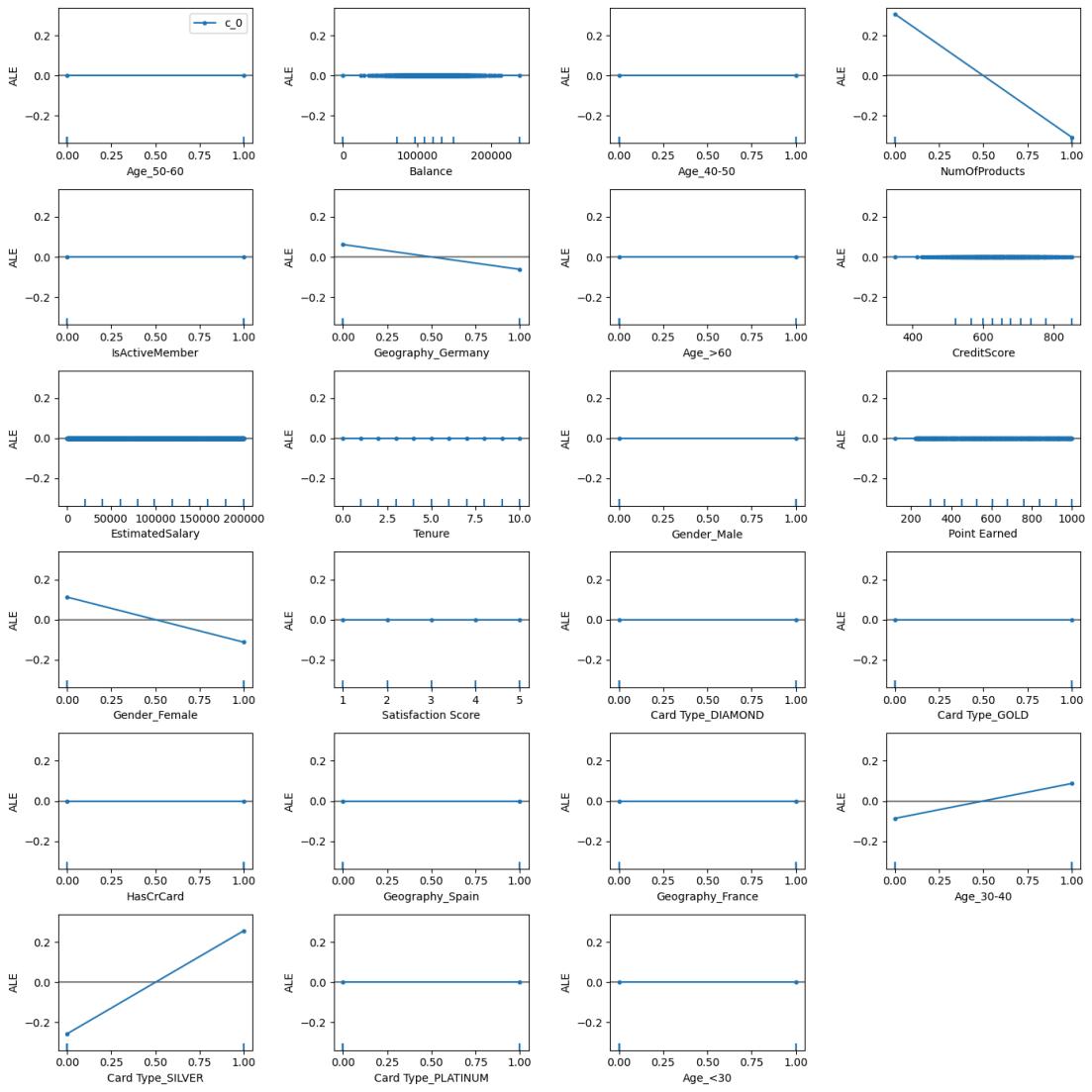
features = ['Age_50-60', 'Balance', 'Age_40-50', 'NumOfProducts', 'IsActiveMember',
            'Geography_Germany', 'Age_>60', 'CreditScore', 'EstimatedSalary', 'T
            'Gender_Male', 'Point_Earned', 'Gender_Female', 'Satisfaction_Score'
            'Card_Type_DIAMOND', 'Card_Type_GOLD', 'HasCrCard', 'Geography_Spain'
            'Geography_France', 'Age_30-40', 'Card_Type_SILVER', 'Card_Type_PLAT
#Logistic regression
X_train_np = X_train[features].to_numpy().astype(float)
logisticALE = ALE(logistic_model.predict, feature_names=features)
logisticExp = logisticALE.explain(X_train_np)
# Plot ALES
plot_ale(logisticExp, n_cols=4, fig_kw={'figwidth': 14, 'figheight': 14})
logisticMSE = mean_squared_error(y_test, logistic_model.predict(X_test))
print(f"Logistic Regression MSE: {logisticMSE}")
#Decision Tree
X_train_np = X_train[features].to_numpy().astype(float)
dTreeALE = ALE(decision_tree.predict, feature_names=features)
dTreeExp = dTreeALE.explain(X_train_np)
# Plot ALES
plot_ale(dTreeExp, n_cols=4, fig_kw={'figwidth': 14, 'figheight': 14})
dTreeMSE = mean_squared_error(y_test, decision_tree.predict(X_test))
print(f"Decision Tree MSE: {dTreeMSE}")
```

IMPORTANT: We tried to use alibi for this, but as it uses obsolete versions of different python libraries, we ended up not being able to run other methods because of that. To fix it, we have decided to run the same code in google collab, so the image below is the result. We are sorry for the inconvenience but this is the best solution we have found. So we just want to explain that the code works fine, the issue is the alibi library.

Logistic Regression MSE: 0.7885



Decision Tree MSE: 0.2565



Across both logistic regression and decision tree models, the ALE method shows that almost no variables have low or no impact on the prediction, but what we can say is that 'age_30-40' and 'CardType_SILVER' have a positive impact for the decision tree prediction, which hasn't been as clear or relevant as other age groups have been up to this moment, but in this case they can be considerent as the two only variables with any effect in the model. Also, the decision tree shows a clear negative influence of 'NumOfProducts', which supports our previous conclusions.

Overall, we can see that PDP supports the conclusions we have made for the 'intrinsically interpretable model' step's results, but also, giving some really interesting insights, on how each of the most important variables in the model affect the prediction. In the ALE case, the results dont meet with what we have seen overall, so ALE may not be the best way to interpret our case.

LOCAL MODEL AGNOSTIC METHODS

This sections requires the use of SHAP, and we will use it with our random forest regression model

- Random Forest Regression

```
In [42]: best_params = rdForestStudy.best_params
randomForestReg = RandomForestRegressor(
    max_depth=best_params["max_depth"],
    min_samples_split=best_params["min_samples_split"],
    min_samples_leaf=best_params["min_samples_leaf"],
    random_state=42,
)
randomForestReg.fit(X_train, y_train)
#Score
skf = StratifiedKFold(n_splits=5, shuffle=True, random_state=42)
forest_score = cross_val_score(randomForestReg, X_train, y_train, cv=skf, scoring='neg_mean_squared_error')
print(f'Forest Score: {forest_score.mean():.2f}')
```

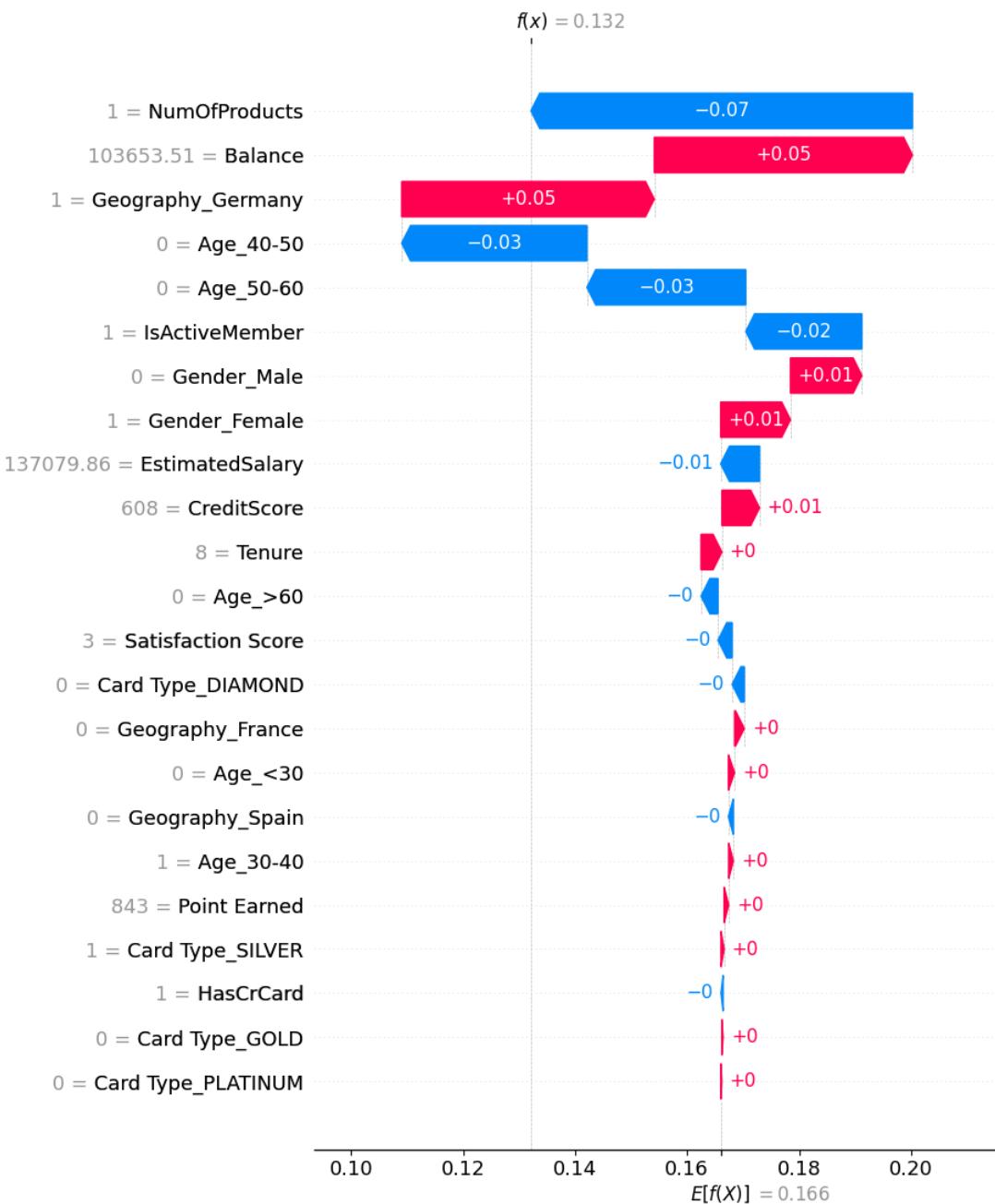
-0.1227196104451496
MAE: 0.24

IMPORTANT: Here we can't use shap because the latest accepted version of python is 3.9, but we are at 3.13.1, so we will have to run it on google colab, so the image and text below are the result of the code. Again, we are sorry for the inconvenience.

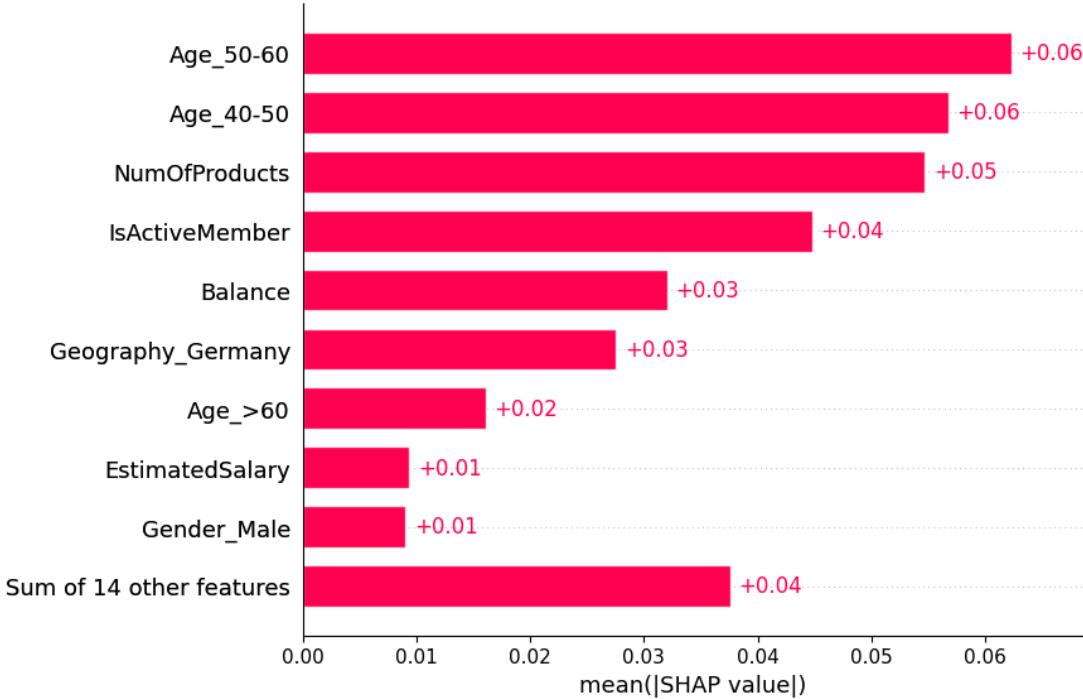
```
In [ ]: import shap
explainer = shap.Explainer(randomForestReg, X_train)
shap_values = explainer(X_test)
```

98%|=====| 1969/2000 [00:37<00:00]

```
In [ ]: shap.plots.waterfall(shap_values[0], max_display=23)
```



```
In [ ]: shap.plots.bar(shap_values)
```



```
In [ ]: shap.initjs()
shap.plots.force(shap_values[1])
```



From the SHAP results, we can guess some general ideas: First, the variables that affect more the model when they have certain values are: (The 1st value is the value at which the variable affects the model, and the 2nd is the contribution value)

Negatively: 'NumOfColumns'(1) (-0.7), 'Age_40-50' (0) (-0.03), 'Age_50-60'(0) (-0.03), 'IsActiveMember' (1) (-0.02)

Positively: 'Geography_Germany' (1) (0.05), 'Balance' (103653.51) (0.05), 'Gender_Male' (0) (0.01), 'Gender_Female' (1) (-0.01)

These SHAP results, overall, are pretty similar to the ones that have gotten before with different classification models, suggesting that SHAP supports the results we have made until this moment. Also, SHAP maker a new little contribution of suggesting that, when the estimated salary is high (138089.86), the model takes it as a possible reason for staying, although, its contribution value (-0.01) is not as strong as the rest of the variables, the ones we already knew that are really important for the model general conclusions, so even if its a new contribution for us, its not relevant enough for us to take it into consideration in the general case.

INTERPRETABILITY CONCLUSION

The interpretability analysis provided us some enriching ideas about the main reasons that guide a customer to desiding to exit, in the models evaluated. Logistic Regression

and Decision Trees demonstrated consistent results that supported each other, highlighting the importance of the customer's age, balance, geography (if its German), and number of products. Older customers with higher balances and German geography were identified as more likely to exit, while young and inactive customers showed a lower likelihood. Gender also seems to bias the exit result, with females being more inclined to it than males.

The use of the PdP and ALE global agnostic methods, confirmed those initial suspicions and provided additional insights of our models. PDP revealed a non linear relationship between balance and exit predictions, while ALE provided results that didnt were less consistent with the general conclusions.

SHAP analysis served as a suppor of the identified main conclusions and introduced minor new observations, such as the potential effect of high estimated salaries, this wasnt significant enough to alter the overall narrative.

Overall, this interpretability work really helped us to get to know which are the most influential variables for our model predictions and validated the consistency of results across methods, so we are sure that me made the right decision when we went through this optional part.

DEVELOPMENT REPORT AND CONCLUSIONS

Both steps have been written in an additional LaTeX project, which has been added as a pdf in the final delivery .zip called 'finalReport.pdf'