```python
import pandas as pd
import numpy as np
import seaborn as sns
import matplotlib.pyplot as plt
from sklearn.model_selection import train_test_split, cross_val_score
from sklearn.ensemble import RandomForestClassifier
from sklearn.neural_network import MLPClassifier
from sklearn.metrics import classification_report, confusion_matrix,
roc_auc_score
from sklearn.preprocessing import StandardScaler
from imblearn.over_sampling import SMOTE
from xgboost import XGBClassifier
import time

#Function for memory analysis and DataFrame information
def analyze_memory(df):
    print("\n=== Memory Analysis and DataFrame Information ===")
    memory = df.memory_usage(deep=True).sum() / 1024 ** 2
    print(f"Total memory used by DataFrame: {memory:.2f} MB")
    print("\nDetailed DataFrame information:")
    print(df.info())
    print("\nMissing values per column:")
    print(df.isnull().sum())

# Loading the Dataset
df = pd.read_csv(r"creditcard.csv")
# Perform memory analysis and DataFrame information
analyze_memory(df)
```

```
=== Memory Analysis and DataFrame Information ===
Total memory used by DataFrame: 67.36 MB

Detailed DataFrame information:
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 284807 entries, 0 to 284806
Data columns (total 31 columns):
 #   Column  Non-Null Count   Dtype
---  ------  --------------   -----
 0   Time    284807 non-null  float64
 1   V1      284807 non-null  float64
 2   V2      284807 non-null  float64
 3   V3      284807 non-null  float64
 4   V4      284807 non-null  float64
 5   V5      284807 non-null  float64
 6   V6      284807 non-null  float64
 7   V7      284807 non-null  float64
 8   V8      284807 non-null  float64
 9   V9      284807 non-null  float64
 10  V10     284807 non-null  float64
```

```
 11  V11     284807 non-null  float64
 12  V12     284807 non-null  float64
 13  V13     284807 non-null  float64
 14  V14     284807 non-null  float64
 15  V15     284807 non-null  float64
 16  V16     284807 non-null  float64
 17  V17     284807 non-null  float64
 18  V18     284807 non-null  float64
 19  V19     284807 non-null  float64
 20  V20     284807 non-null  float64
 21  V21     284807 non-null  float64
 22  V22     284807 non-null  float64
 23  V23     284807 non-null  float64
 24  V24     284807 non-null  float64
 25  V25     284807 non-null  float64
 26  V26     284807 non-null  float64
 27  V27     284807 non-null  float64
 28  V28     284807 non-null  float64
 29  Amount  284807 non-null  float64
 30  Class   284807 non-null  int64
dtypes: float64(30), int64(1)
memory usage: 67.4 MB
None

Missing values per column:
Time      0
V1        0
V2        0
V3        0
V4        0
V5        0
V6        0
V7        0
V8        0
V9        0
V10       0
V11       0
V12       0
V13       0
V14       0
V15       0
V16       0
V17       0
V18       0
V19       0
V20       0
V21       0
V22       0
V23       0
```

```
V24       0
V25       0
V26       0
V27       0
V28       0
Amount    0
Class     0
dtype: int64
```

```python
# Exploratory Data Analysis (EDA)
print("\nStatistical description:")
print(df.describe().T)
```

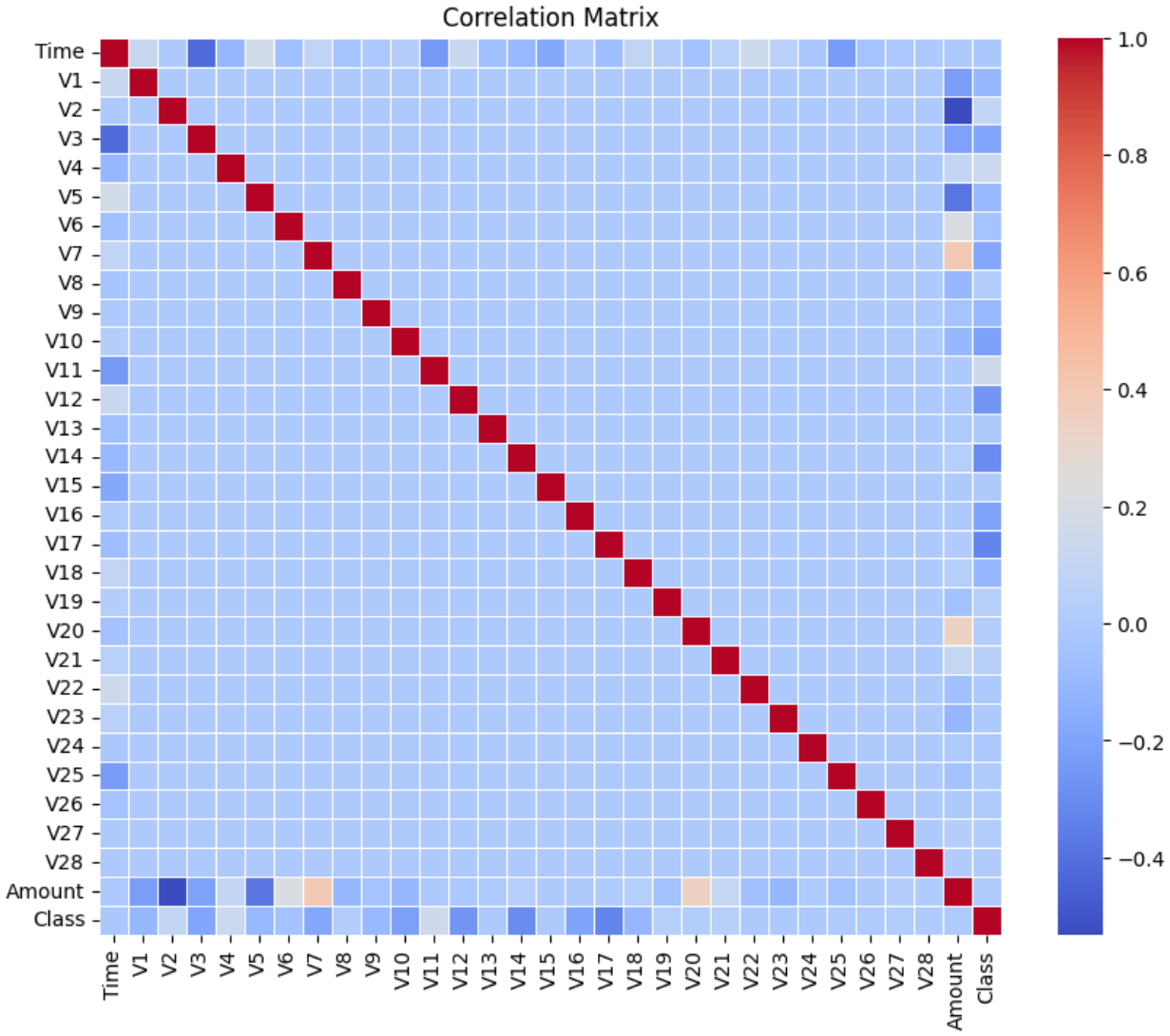
```
Statistical description:
           count          mean           std         min           25%
\
Time    284807.0  9.481386e+04  47488.145955    0.000000  54201.500000

V1      284807.0  1.168375e-15      1.958696  -56.407510     -0.920373

V2      284807.0  3.416908e-16      1.651309  -72.715728     -0.598550

V3      284807.0 -1.379537e-15      1.516255  -48.325589     -0.890365

V4      284807.0  2.074095e-15      1.415869   -5.683171     -0.848640

V5      284807.0  9.604066e-16      1.380247 -113.743307     -0.691597

V6      284807.0  1.487313e-15      1.332271  -26.160506     -0.768296

V7      284807.0 -5.556467e-16      1.237094  -43.557242     -0.554076

V8      284807.0  1.213481e-16      1.194353  -73.216718     -0.208630

V9      284807.0 -2.406331e-15      1.098632  -13.434066     -0.643098

V10     284807.0  2.239053e-15      1.088850  -24.588262     -0.535426

V11     284807.0  1.673327e-15      1.020713   -4.797473     -0.762494

V12     284807.0 -1.247012e-15      0.999201  -18.683715     -0.405571

V13     284807.0  8.190001e-16      0.995274   -5.791881     -0.648539

V14     284807.0  1.207294e-15      0.958596  -19.214325     -0.425574

V15     284807.0  4.887456e-15      0.915316   -4.498945     -0.582884

V16     284807.0  1.437716e-15      0.876253  -14.129855     -0.468037
```

V17	284807.0	-3.772171e-16	0.849337	-25.162799	-0.483748
V18	284807.0	9.564149e-16	0.838176	-9.498746	-0.498850
V19	284807.0	1.039917e-15	0.814041	-7.213527	-0.456299
V20	284807.0	6.406204e-16	0.770925	-54.497720	-0.211721
V21	284807.0	1.654067e-16	0.734524	-34.830382	-0.228395
V22	284807.0	-3.568593e-16	0.725702	-10.933144	-0.542350
V23	284807.0	2.578648e-16	0.624460	-44.807735	-0.161846
V24	284807.0	4.473266e-15	0.605647	-2.836627	-0.354586
V25	284807.0	5.340915e-16	0.521278	-10.295397	-0.317145
V26	284807.0	1.683437e-15	0.482227	-2.604551	-0.326984
V27	284807.0	-3.660091e-16	0.403632	-22.565679	-0.070840
V28	284807.0	-1.227390e-16	0.330083	-15.430084	-0.052960
Amount	284807.0	8.834962e+01	250.120109	0.000000	5.600000
Class	284807.0	1.727486e-03	0.041527	0.000000	0.000000

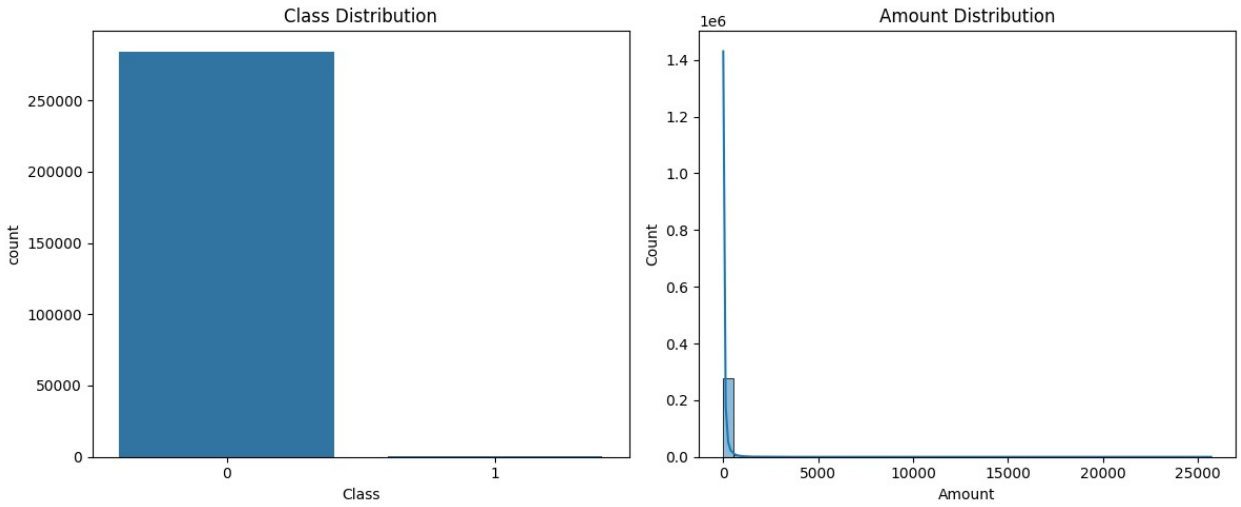
	50%	75%	max
Time	84692.000000	139320.500000	172792.000000
V1	0.018109	1.315642	2.454930
V2	0.065486	0.803724	22.057729
V3	0.179846	1.027196	9.382558
V4	-0.019847	0.743341	16.875344
V5	-0.054336	0.611926	34.801666
V6	-0.274187	0.398565	73.301626
V7	0.040103	0.570436	120.589494
V8	0.022358	0.327346	20.007208
V9	-0.051429	0.597139	15.594995
V10	-0.092917	0.453923	23.745136
V11	-0.032757	0.739593	12.018913
V12	0.140033	0.618238	7.848392
V13	-0.013568	0.662505	7.126883
V14	0.050601	0.493150	10.526766
V15	0.048072	0.648821	8.877742
V16	0.066413	0.523296	17.315112
V17	-0.065676	0.399675	9.253526
V18	-0.003636	0.500807	5.041069
V19	0.003735	0.458949	5.591971
V20	-0.062481	0.133041	39.420904

```
V21        -0.029450       0.186377      27.202839
V22         0.006782       0.528554      10.503090
V23        -0.011193       0.147642      22.528412
V24         0.040976       0.439527       4.584549
V25         0.016594       0.350716       7.519589
V26        -0.052139       0.240952       3.517346
V27         0.001342       0.091045      31.612198
V28         0.011244       0.078280      33.847808
Amount     22.000000      77.165000   25691.160000
Class       0.000000       0.000000       1.000000
```

```
 # Correlation matrix
plt.figure(figsize=(10, 8))
corr_matrix = df.corr()
sns.heatmap(corr_matrix, annot=False, cmap='coolwarm', linewidths=0.5)
plt.title('Correlation Matrix')
plt.show()
```




```
#Create a figure with 1 row and 2 columns
fig, axes = plt.subplots(1, 2, figsize=(12, 5))

#Distribution of the target variable (Class)
sns.countplot(data=df, x='Class', ax=axes[0])
axes[0].set_title('Class Distribution')

#Analysis of the distribution of the Amount variable
sns.histplot(df['Amount'], bins=50, kde=True, ax=axes[1])
axes[1].set_title('Amount Distribution')
plt.tight_layout()
plt.show()
```




```
#Separating independent and dependent variables
X = df.drop('Class', axis=1)
y = df['Class']

#Analysis of class imbalance
print("\nClass Distribution (Imbalanced):")
print(y.value_counts(normalize=True))

#Normalization of the Amount variable
scaler = StandardScaler()
df['Amount'] = scaler.fit_transform(df[['Amount']])
```

```
Class Distribution (Imbalanced):
Class
0    0.998273
1    0.001727
Name: proportion, dtype: float64
```

```
#Separation of independent and dependent variables
X = df.drop(columns=['Class'])
y = df['Class']

#Splitting the data into training and testing sets
X_train, X_test, y_train, y_test = train_test_split(X, y,
test_size=0.3, random_state=42, stratify=y)

#Applying SMOTE only to the training data
smote = SMOTE(random_state=42)
X_train_res, y_train_res = smote.fit_resample(X_train, y_train)

# Function to evaluate models
def evaluate_model(model, X_train, y_train, X_test, y_test):
    start = time.time()
```

```
# Cross-validation
    scores = cross_val_score(model, X_train, y_train, cv=5)
    mean_scores = scores.mean()

# Training
    model.fit(X_train, y_train)

# Predictions and evaluation on the test set
    y_pred = model.predict(X_test)
    report = classification_report(y_test, y_pred)
    cm = confusion_matrix(y_test, y_pred)

# Calculation of AUC-ROC
    roc_auc = roc_auc_score(y_test, model.predict_proba(X_test)[:, 1])
    execution_time = time.time() - start
    return {
        "scores": scores,
        "mean_scores": mean_scores,
        "report": report,
        "confusion_matrix": cm,
        "roc_auc": roc_auc,
        "execution_time": execution_time
    }
# Models to be evaluated
models = {
    "Random Forest": RandomForestClassifier(random_state=42,
class_weight='balanced'),
    "Neural Network": MLPClassifier(random_state=42, max_iter=300,
early_stopping=True, validation_fraction=0.1, n_iter_no_change=15,
verbose=True),
    "XGBoost": XGBClassifier(random_state=42, eval_metric='logloss')
}
# Model evaluation
results = {}
for name, model in models.items():
    print(f"\nEvaluating model: {name}")
    results[name] = evaluate_model(model, X_train_res, y_train_res,
X_test, y_test)

# Displaying the results
for name, result in results.items():
    print(f"\n=== {name} ===")
    print("Cross-Validation Scores:", result['scores'])
    print("Mean Scores:", result['mean_scores'])
    print("Classification Report:\n", result['report'])
    print("Confusion Matrix:\n", result['confusion_matrix'])
    print("AUC-ROC:\n", result['roc_auc'])
    print("Execution Time (s):\n", result['execution_time'])
```

```
Evaluating model: Random Forest

Evaluating model: Neural Network
Iteration 1, loss = 7.76122289
Validation score: 0.956161
Iteration 2, loss = 4.02164323
Validation score: 0.963447
Iteration 3, loss = 3.05947908
Validation score: 0.554359
Iteration 4, loss = 2.19839319
Validation score: 0.964263
Iteration 5, loss = 1.79721593
Validation score: 0.953052
Iteration 6, loss = 2.27394166
Validation score: 0.931730
Iteration 7, loss = 1.50038783
Validation score: 0.972397
Iteration 8, loss = 1.54070610
Validation score: 0.929783
Iteration 9, loss = 1.78563438
Validation score: 0.967812
Iteration 10, loss = 1.29271966
Validation score: 0.968471
Iteration 11, loss = 1.68292684
Validation score: 0.968126
Iteration 12, loss = 1.45293470
Validation score: 0.623320
Iteration 13, loss = 1.22926841
Validation score: 0.967090
Iteration 14, loss = 1.50446255
Validation score: 0.971580
Iteration 15, loss = 1.08011057
Validation score: 0.970261
Iteration 16, loss = 1.20355129
Validation score: 0.846627
Iteration 17, loss = 1.33555550
Validation score: 0.969759
Iteration 18, loss = 1.07063269
Validation score: 0.978143
Iteration 19, loss = 0.98503756
Validation score: 0.972868
Iteration 20, loss = 1.25530825
Validation score: 0.977641
Iteration 21, loss = 1.11367253
Validation score: 0.976919
Iteration 22, loss = 1.21988803
Validation score: 0.893355
Iteration 23, loss = 1.06478003
Validation score: 0.976259
```

```
Iteration 24, loss = 1.13450821
Validation score: 0.969099
Iteration 25, loss = 1.03197367
Validation score: 0.951357
Iteration 26, loss = 0.96044118
Validation score: 0.970230
Iteration 27, loss = 0.93102655
Validation score: 0.980028
Iteration 28, loss = 1.29548290
Validation score: 0.951325
Iteration 29, loss = 1.04386863
Validation score: 0.907581
Iteration 30, loss = 0.96435694
Validation score: 0.979776
Iteration 31, loss = 0.92882888
Validation score: 0.975851
Iteration 32, loss = 1.00925726
Validation score: 0.952550
Iteration 33, loss = 0.97013613
Validation score: 0.974940
Iteration 34, loss = 0.78945875
Validation score: 0.978803
Iteration 35, loss = 1.09291728
Validation score: 0.975474
Iteration 36, loss = 0.73763959
Validation score: 0.980624
Iteration 37, loss = 0.90227129
Validation score: 0.976134
Iteration 38, loss = 0.95537682
Validation score: 0.976039
Iteration 39, loss = 0.81686723
Validation score: 0.974595
Iteration 40, loss = 0.81949902
Validation score: 0.973245
Iteration 41, loss = 0.92627153
Validation score: 0.975631
Iteration 42, loss = 0.97285090
Validation score: 0.975192
Iteration 43, loss = 0.69822211
Validation score: 0.979431
Iteration 44, loss = 0.87372221
Validation score: 0.966870
Iteration 45, loss = 0.72111142
Validation score: 0.803856
Iteration 46, loss = 0.87385833
Validation score: 0.980876
Iteration 47, loss = 0.82430499
Validation score: 0.979682
Iteration 48, loss = 0.78347533
Validation score: 0.975223
```

```
Iteration 49, loss = 0.70594005
Validation score: 0.970764
Iteration 50, loss = 0.92109905
Validation score: 0.974438
Iteration 51, loss = 0.62330134
Validation score: 0.757254
Iteration 52, loss = 0.83946289
Validation score: 0.938513
Iteration 53, loss = 1.10614469
Validation score: 0.931855
Iteration 54, loss = 0.67881987
Validation score: 0.974658
Iteration 55, loss = 0.84377979
Validation score: 0.973025
Iteration 56, loss = 0.73180353
Validation score: 0.977578
Iteration 57, loss = 0.73247770
Validation score: 0.975349
Iteration 58, loss = 0.74733178
Validation score: 0.976353
Iteration 59, loss = 0.75237409
Validation score: 0.981441
Iteration 60, loss = 0.59310286
Validation score: 0.971109
Iteration 61, loss = 0.68558780
Validation score: 0.978363
Iteration 62, loss = 0.71130307
Validation score: 0.978991
Iteration 63, loss = 0.67611613
Validation score: 0.977421
Iteration 64, loss = 0.62654203
Validation score: 0.982226
Iteration 65, loss = 0.59665391
Validation score: 0.975317
Iteration 66, loss = 0.67953886
Validation score: 0.957103
Iteration 67, loss = 0.68127898
Validation score: 0.972177
Iteration 68, loss = 0.58548854
Validation score: 0.978269
Iteration 69, loss = 0.65722196
Validation score: 0.975851
Iteration 70, loss = 0.58304850
Validation score: 0.982603
Iteration 71, loss = 0.57708419
Validation score: 0.978269
Iteration 72, loss = 0.54516590
Validation score: 0.981190
Iteration 73, loss = 0.60952679
Validation score: 0.976605
```

```
Iteration 74, loss = 0.60423631
Validation score: 0.979023
Iteration 75, loss = 0.60938948
Validation score: 0.978803
Iteration 76, loss = 0.54174703
Validation score: 0.979086
Iteration 77, loss = 0.55769081
Validation score: 0.976353
Iteration 78, loss = 0.55809453
Validation score: 0.979557
Iteration 79, loss = 0.46860692
Validation score: 0.973433
Iteration 80, loss = 0.58489243
Validation score: 0.976668
Iteration 81, loss = 0.55158095
Validation score: 0.982697
Iteration 82, loss = 0.42011462
Validation score: 0.975223
Iteration 83, loss = 0.49782289
Validation score: 0.974218
Iteration 84, loss = 0.53693694
Validation score: 0.979431
Iteration 85, loss = 0.38834448
Validation score: 0.979808
Iteration 86, loss = 0.53668941
Validation score: 0.957292
Validation score did not improve more than tol=0.000100 for 15
consecutive epochs. Stopping.
Iteration 1, loss = 7.37187317
Validation score: 0.784355
Iteration 2, loss = 3.82834913
Validation score: 0.886698
Iteration 3, loss = 2.96607184
Validation score: 0.922780
Iteration 4, loss = 2.44043338
Validation score: 0.910030
Iteration 5, loss = 2.62342966
Validation score: 0.959333
Iteration 6, loss = 1.71222499
Validation score: 0.962442
Iteration 7, loss = 1.54723860
Validation score: 0.892350
Iteration 8, loss = 1.92771969
Validation score: 0.967278
Iteration 9, loss = 1.39435762
Validation score: 0.973590
Iteration 10, loss = 1.50368992
Validation score: 0.964232
Iteration 11, loss = 1.43008260
Validation score: 0.971266
```

```
Iteration 12, loss = 1.29246717
Validation score: 0.962913
Iteration 13, loss = 1.27573921
Validation score: 0.968942
Iteration 14, loss = 1.32883270
Validation score: 0.972711
Iteration 15, loss = 1.27521230
Validation score: 0.964169
Iteration 16, loss = 1.03699899
Validation score: 0.967969
Iteration 17, loss = 1.27151868
Validation score: 0.946992
Iteration 18, loss = 1.23731456
Validation score: 0.974626
Iteration 19, loss = 1.32201931
Validation score: 0.978081
Iteration 20, loss = 0.96919074
Validation score: 0.971800
Iteration 21, loss = 1.01994334
Validation score: 0.966524
Iteration 22, loss = 1.30672751
Validation score: 0.902462
Iteration 23, loss = 1.02511468
Validation score: 0.974030
Iteration 24, loss = 1.11855206
Validation score: 0.971580
Iteration 25, loss = 1.13940008
Validation score: 0.965425
Iteration 26, loss = 1.02128952
Validation score: 0.932044
Iteration 27, loss = 0.81710232
Validation score: 0.980028
Iteration 28, loss = 1.12593546
Validation score: 0.978709
Iteration 29, loss = 0.87304770
Validation score: 0.970827
Iteration 30, loss = 0.89511866
Validation score: 0.974563
Iteration 31, loss = 1.11322836
Validation score: 0.967529
Iteration 32, loss = 0.97069884
Validation score: 0.975254
Iteration 33, loss = 0.98401194
Validation score: 0.980530
Iteration 34, loss = 0.83722868
Validation score: 0.976134
Iteration 35, loss = 1.24619779
Validation score: 0.974626
Iteration 36, loss = 1.06403725
Validation score: 0.927836
```

```
Iteration 37, loss = 0.92069695
Validation score: 0.981409
Iteration 38, loss = 1.02671070
Validation score: 0.976793
Iteration 39, loss = 0.88723680
Validation score: 0.972554
Iteration 40, loss = 1.04932048
Validation score: 0.977484
Iteration 41, loss = 1.20373971
Validation score: 0.977924
Iteration 42, loss = 0.85905785
Validation score: 0.981190
Iteration 43, loss = 0.84213345
Validation score: 0.967027
Iteration 44, loss = 0.90415177
Validation score: 0.971894
Iteration 45, loss = 0.83733854
Validation score: 0.970544
Iteration 46, loss = 0.84199009
Validation score: 0.944354
Iteration 47, loss = 0.78689321
Validation score: 0.976008
Iteration 48, loss = 0.81856393
Validation score: 0.975506
Iteration 49, loss = 0.88931681
Validation score: 0.971360
Iteration 50, loss = 0.83787067
Validation score: 0.966776
Iteration 51, loss = 0.76242075
Validation score: 0.977672
Iteration 52, loss = 0.86022791
Validation score: 0.950352
Iteration 53, loss = 0.81074119
Validation score: 0.981347
Validation score did not improve more than tol=0.000100 for 15
consecutive epochs. Stopping.
Iteration 1, loss = 7.78994064
Validation score: 0.925292
Iteration 2, loss = 3.66263427
Validation score: 0.960715
Iteration 3, loss = 3.17298370
Validation score: 0.769910
Iteration 4, loss = 2.35861571
Validation score: 0.952738
Iteration 5, loss = 2.02714049
Validation score: 0.542771
Iteration 6, loss = 1.92644337
Validation score: 0.962568
Iteration 7, loss = 1.61511020
Validation score: 0.943380
```

```
Iteration 8, loss = 1.96378008
Validation score: 0.952142
Iteration 9, loss = 1.17534746
Validation score: 0.974281
Iteration 10, loss = 1.51009362
Validation score: 0.958831
Iteration 11, loss = 1.93097486
Validation score: 0.972742
Iteration 12, loss = 1.03999608
Validation score: 0.942909
Iteration 13, loss = 1.28621587
Validation score: 0.968566
Iteration 14, loss = 1.25239107
Validation score: 0.963918
Iteration 15, loss = 1.20270905
Validation score: 0.893449
Iteration 16, loss = 1.15527993
Validation score: 0.966995
Iteration 17, loss = 1.18702929
Validation score: 0.906011
Iteration 18, loss = 1.20287356
Validation score: 0.975631
Iteration 19, loss = 1.11148703
Validation score: 0.977264
Iteration 20, loss = 1.31133956
Validation score: 0.977233
Iteration 21, loss = 0.98270009
Validation score: 0.972774
Iteration 22, loss = 1.15725821
Validation score: 0.974406
Iteration 23, loss = 1.09701669
Validation score: 0.971298
Iteration 24, loss = 0.90905647
Validation score: 0.959521
Iteration 25, loss = 1.10722382
Validation score: 0.976542
Iteration 26, loss = 1.13856249
Validation score: 0.972334
Iteration 27, loss = 1.07174653
Validation score: 0.952330
Iteration 28, loss = 0.92767903
Validation score: 0.977484
Iteration 29, loss = 0.90972061
Validation score: 0.979839
Iteration 30, loss = 1.05860831
Validation score: 0.736434
Iteration 31, loss = 0.85858016
Validation score: 0.968032
Iteration 32, loss = 1.00264910
Validation score: 0.979902
```

```
Iteration 33, loss = 0.90984323
Validation score: 0.947557
Iteration 34, loss = 1.15945030
Validation score: 0.975914
Iteration 35, loss = 0.92130793
Validation score: 0.971643
Iteration 36, loss = 0.73645512
Validation score: 0.961154
Iteration 37, loss = 0.86296804
Validation score: 0.980719
Iteration 38, loss = 1.23032559
Validation score: 0.958925
Iteration 39, loss = 0.84983982
Validation score: 0.980342
Iteration 40, loss = 0.87843558
Validation score: 0.973213
Iteration 41, loss = 0.85589757
Validation score: 0.975537
Iteration 42, loss = 0.95235556
Validation score: 0.972114
Iteration 43, loss = 0.92392983
Validation score: 0.944668
Iteration 44, loss = 0.73376393
Validation score: 0.967466
Iteration 45, loss = 0.86045767
Validation score: 0.967278
Iteration 46, loss = 0.70541399
Validation score: 0.976573
Iteration 47, loss = 1.07329994
Validation score: 0.978709
Iteration 48, loss = 0.79253830
Validation score: 0.977044
Iteration 49, loss = 0.82289898
Validation score: 0.981001
Iteration 50, loss = 0.74124822
Validation score: 0.977610
Iteration 51, loss = 0.99840268
Validation score: 0.972208
Iteration 52, loss = 0.70997666
Validation score: 0.929217
Iteration 53, loss = 1.01078426
Validation score: 0.980059
Iteration 54, loss = 0.57273552
Validation score: 0.957606
Iteration 55, loss = 0.87316634
Validation score: 0.976950
Iteration 56, loss = 0.69917567
Validation score: 0.976322
Iteration 57, loss = 0.76532782
Validation score: 0.978300
```

```
Iteration 58, loss = 0.62712281
Validation score: 0.980499
Iteration 59, loss = 0.73864533
Validation score: 0.978520
Iteration 60, loss = 0.77903463
Validation score: 0.977986
Iteration 61, loss = 0.69832109
Validation score: 0.978175
Iteration 62, loss = 0.62864945
Validation score: 0.935121
Iteration 63, loss = 0.65768959
Validation score: 0.980844
Iteration 64, loss = 0.58958827
Validation score: 0.967341
Iteration 65, loss = 0.66901752
Validation score: 0.975474
Validation score did not improve more than tol=0.000100 for 15
consecutive epochs. Stopping.
Iteration 1, loss = 7.90568756
Validation score: 0.503957
Iteration 2, loss = 3.58320297
Validation score: 0.532973
Iteration 3, loss = 2.97704324
Validation score: 0.556902
Iteration 4, loss = 2.68233954
Validation score: 0.968189
Iteration 5, loss = 2.22961899
Validation score: 0.926391
Iteration 6, loss = 1.93557508
Validation score: 0.937100
Iteration 7, loss = 1.88014945
Validation score: 0.917818
Iteration 8, loss = 1.17028155
Validation score: 0.973182
Iteration 9, loss = 1.78894304
Validation score: 0.967090
Iteration 10, loss = 1.45673087
Validation score: 0.974124
Iteration 11, loss = 1.35613323
Validation score: 0.950415
Iteration 12, loss = 1.47707850
Validation score: 0.812367
Iteration 13, loss = 1.23917656
Validation score: 0.972459
Iteration 14, loss = 1.21326116
Validation score: 0.975286
Iteration 15, loss = 1.17019350
Validation score: 0.941402
Iteration 16, loss = 1.35793343
Validation score: 0.970073
```

```
Iteration 17, loss = 1.32010975
Validation score: 0.779268
Iteration 18, loss = 1.17521490
Validation score: 0.965959
Iteration 19, loss = 1.01430421
Validation score: 0.978018
Iteration 20, loss = 1.02893896
Validation score: 0.931792
Iteration 21, loss = 1.18985602
Validation score: 0.975820
Iteration 22, loss = 1.15694526
Validation score: 0.969570
Iteration 23, loss = 1.08442727
Validation score: 0.974281
Iteration 24, loss = 0.95680382
Validation score: 0.947871
Iteration 25, loss = 0.85967032
Validation score: 0.968408
Iteration 26, loss = 1.26545770
Validation score: 0.979117
Iteration 27, loss = 0.76042492
Validation score: 0.972774
Iteration 28, loss = 1.11801291
Validation score: 0.979494
Iteration 29, loss = 1.09636274
Validation score: 0.972020
Iteration 30, loss = 1.01545094
Validation score: 0.976196
Iteration 31, loss = 0.97059685
Validation score: 0.975757
Iteration 32, loss = 0.95008980
Validation score: 0.977044
Iteration 33, loss = 0.89442114
Validation score: 0.978614
Iteration 34, loss = 0.99863188
Validation score: 0.976039
Iteration 35, loss = 0.77062288
Validation score: 0.974940
Iteration 36, loss = 0.84234715
Validation score: 0.957260
Iteration 37, loss = 0.86333883
Validation score: 0.974752
Iteration 38, loss = 0.83741187
Validation score: 0.972459
Iteration 39, loss = 0.94039138
Validation score: 0.912197
Iteration 40, loss = 0.91229259
Validation score: 0.979305
Iteration 41, loss = 0.82459929
Validation score: 0.976573
```

```
Iteration 42, loss = 0.71167179
Validation score: 0.974752
Iteration 43, loss = 0.88230380
Validation score: 0.973276
Iteration 44, loss = 0.88464545
Validation score: 0.975914
Validation score did not improve more than tol=0.000100 for 15
consecutive epochs. Stopping.
Iteration 1, loss = 8.22796832
Validation score: 0.522139
Iteration 2, loss = 3.86729167
Validation score: 0.783099
Iteration 3, loss = 3.05091499
Validation score: 0.952393
Iteration 4, loss = 2.43510027
Validation score: 0.833469
Iteration 5, loss = 2.38439233
Validation score: 0.969570
Iteration 6, loss = 1.85047681
Validation score: 0.957229
Iteration 7, loss = 1.80536818
Validation score: 0.809760
Iteration 8, loss = 1.65405721
Validation score: 0.919985
Iteration 9, loss = 1.41935777
Validation score: 0.974061
Iteration 10, loss = 1.36450708
Validation score: 0.974658
Iteration 11, loss = 1.70888936
Validation score: 0.936786
Iteration 12, loss = 1.41615571
Validation score: 0.886509
Iteration 13, loss = 1.25038044
Validation score: 0.926611
Iteration 14, loss = 1.79784309
Validation score: 0.975851
Iteration 15, loss = 1.13948176
Validation score: 0.971423
Iteration 16, loss = 1.34012214
Validation score: 0.974375
Iteration 17, loss = 1.08655027
Validation score: 0.961249
Iteration 18, loss = 1.38287922
Validation score: 0.970293
Iteration 19, loss = 1.17342399
Validation score: 0.977610
Iteration 20, loss = 1.27125086
Validation score: 0.957574
Iteration 21, loss = 1.29671107
Validation score: 0.975945
```

```
Iteration 22, loss = 0.97219480
Validation score: 0.910690
Iteration 23, loss = 1.20334749
Validation score: 0.930128
Iteration 24, loss = 1.05587498
Validation score: 0.974783
Iteration 25, loss = 0.91422373
Validation score: 0.979086
Iteration 26, loss = 1.22273267
Validation score: 0.966995
Iteration 27, loss = 1.09366194
Validation score: 0.953837
Iteration 28, loss = 0.97747989
Validation score: 0.973590
Iteration 29, loss = 1.01268725
Validation score: 0.979211
Iteration 30, loss = 1.14862094
Validation score: 0.964860
Iteration 31, loss = 0.84845094
Validation score: 0.974972
Iteration 32, loss = 1.03900723
Validation score: 0.975600
Iteration 33, loss = 0.82343688
Validation score: 0.900107
Iteration 34, loss = 0.85624159
Validation score: 0.970136
Iteration 35, loss = 1.00542396
Validation score: 0.977233
Iteration 36, loss = 0.97023072
Validation score: 0.973527
Iteration 37, loss = 0.89384168
Validation score: 0.978206
Iteration 38, loss = 0.80460298
Validation score: 0.981252
Iteration 39, loss = 0.94544673
Validation score: 0.917284
Iteration 40, loss = 1.10056277
Validation score: 0.980687
Iteration 41, loss = 0.69267556
Validation score: 0.972145
Iteration 42, loss = 1.12606475
Validation score: 0.977610
Iteration 43, loss = 0.71108104
Validation score: 0.973088
Iteration 44, loss = 0.89852751
Validation score: 0.976982
Iteration 45, loss = 0.86178752
Validation score: 0.973119
Iteration 46, loss = 0.70394651
```

```
Validation score: 0.963415
Iteration 47, loss = 0.77879393
Validation score: 0.952958
Iteration 48, loss = 0.81320518
Validation score: 0.912134
Iteration 49, loss = 0.86970497
Validation score: 0.977924
Iteration 50, loss = 0.80060114
Validation score: 0.973213
Iteration 51, loss = 0.70477692
Validation score: 0.981912
Iteration 52, loss = 0.84599565
Validation score: 0.976636
Iteration 53, loss = 0.69842396
Validation score: 0.978269
Iteration 54, loss = 0.70174435
Validation score: 0.967121
Iteration 55, loss = 0.73121004
Validation score: 0.924821
Iteration 56, loss = 0.75844983
Validation score: 0.976134
Iteration 57, loss = 0.69694538
Validation score: 0.938670
Iteration 58, loss = 0.78195108
Validation score: 0.978614
Iteration 59, loss = 0.70507856
Validation score: 0.925198
Iteration 60, loss = 0.69204605
Validation score: 0.982320
Iteration 61, loss = 0.69850195
Validation score: 0.957951
Iteration 62, loss = 0.69206617
Validation score: 0.946049
Iteration 63, loss = 0.80664120
Validation score: 0.977924
Iteration 64, loss = 0.60927470
Validation score: 0.969790
Iteration 65, loss = 0.63204225
Validation score: 0.982069
Iteration 66, loss = 0.75388058
Validation score: 0.979305
Iteration 67, loss = 0.65708442
Validation score: 0.981786
Iteration 68, loss = 0.56908958
Validation score: 0.960840
Iteration 69, loss = 0.60994178
Validation score: 0.980373
Iteration 70, loss = 0.63066776
Validation score: 0.974940
```

```
Iteration 71, loss = 0.54079022
Validation score: 0.973433
Iteration 72, loss = 0.60624565
Validation score: 0.977578
Iteration 73, loss = 0.62173880
Validation score: 0.969382
Iteration 74, loss = 0.51358164
Validation score: 0.978897
Iteration 75, loss = 0.59903407
Validation score: 0.979619
Iteration 76, loss = 0.50584143
Validation score: 0.979243
Validation score did not improve more than tol=0.000100 for 15
consecutive epochs. Stopping.
Iteration 1, loss = 6.93643827
Validation score: 0.510401
Iteration 2, loss = 3.02965003
Validation score: 0.868380
Iteration 3, loss = 2.92066367
Validation score: 0.964526
Iteration 4, loss = 1.84103404
Validation score: 0.954000
Iteration 5, loss = 2.23126739
Validation score: 0.930258
Iteration 6, loss = 1.75626045
Validation score: 0.966235
Iteration 7, loss = 1.17327144
Validation score: 0.973194
Iteration 8, loss = 1.67333549
Validation score: 0.837629
Iteration 9, loss = 1.53645582
Validation score: 0.972113
Iteration 10, loss = 1.32621855
Validation score: 0.974575
Iteration 11, loss = 1.26097276
Validation score: 0.967365
Iteration 12, loss = 1.27039801
Validation score: 0.965858
Iteration 13, loss = 1.17704133
Validation score: 0.959150
Iteration 14, loss = 1.13566534
Validation score: 0.976912
Iteration 15, loss = 1.21819166
Validation score: 0.969601
Iteration 16, loss = 1.07948254
Validation score: 0.971159
Iteration 17, loss = 1.05218235
Validation score: 0.967315
Iteration 18, loss = 1.23339546
```

```
Validation score: 0.941639
Iteration 19, loss = 0.97414309
Validation score: 0.973972
Iteration 20, loss = 1.01408748
Validation score: 0.976560
Iteration 21, loss = 1.11017904
Validation score: 0.979123
Iteration 22, loss = 0.87553808
Validation score: 0.974475
Iteration 23, loss = 1.12146699
Validation score: 0.923148
Iteration 24, loss = 0.93513360
Validation score: 0.973771
Iteration 25, loss = 0.97755589
Validation score: 0.957366
Iteration 26, loss = 0.86272477
Validation score: 0.933851
Iteration 27, loss = 0.90161799
Validation score: 0.974249
Iteration 28, loss = 1.00572590
Validation score: 0.954301
Iteration 29, loss = 0.81838697
Validation score: 0.979876
Iteration 30, loss = 1.04464791
Validation score: 0.976133
Iteration 31, loss = 0.68886402
Validation score: 0.980303
Iteration 32, loss = 0.87313077
Validation score: 0.973420
Iteration 33, loss = 0.91096967
Validation score: 0.975580
Iteration 34, loss = 0.77414679
Validation score: 0.964501
Iteration 35, loss = 0.82994342
Validation score: 0.977213
Iteration 36, loss = 0.78370051
Validation score: 0.975882
Iteration 37, loss = 0.83932995
Validation score: 0.967491
Iteration 38, loss = 0.74096872
Validation score: 0.979324
Iteration 39, loss = 0.92592254
Validation score: 0.976435
Iteration 40, loss = 0.75538732
Validation score: 0.648025
Iteration 41, loss = 0.72407212
Validation score: 0.977615
Iteration 42, loss = 0.88007785
Validation score: 0.979474
```

```
Iteration 43, loss = 0.71700785
Validation score: 0.979449
Iteration 44, loss = 0.70620369
Validation score: 0.971460
Iteration 45, loss = 0.65797177
Validation score: 0.976711
Iteration 46, loss = 0.73994833
Validation score: 0.975078
Iteration 47, loss = 0.76528840
Validation score: 0.977113
Validation score did not improve more than tol=0.000100 for 15
consecutive epochs. Stopping.

Evaluating model: XGBoost

=== Random Forest ===
Cross-Validation Scores: [0.99992463 0.99981158 0.99991207 0.99991207
0.99987438]
Mean Scores: 0.9998869460355744
Classification Report:
              precision    recall  f1-score   support

           0       1.00      1.00      1.00     85295
           1       0.84      0.80      0.82       148

    accuracy                           1.00     85443
   macro avg       0.92      0.90      0.91     85443
weighted avg       1.00      1.00      1.00     85443

Confusion Matrix:
 [[85272    23]
 [   30   118]]
AUC-ROC:
 0.9665881368794786
Execution Time (s):
 1917.9671342372894

=== Neural Network ===
Cross-Validation Scores: [0.982552   0.98054216 0.98148427 0.97942418
0.98328057]
Mean Scores: 0.9814566375238669
Classification Report:
              precision    recall  f1-score   support

           0       1.00      0.98      0.99     85295
           1       0.06      0.86      0.12       148

    accuracy                           0.98     85443
   macro avg       0.53      0.92      0.55     85443
weighted avg       1.00      0.98      0.99     85443
```

```
Confusion Matrix:
 [[83386  1909]
 [   20   128]]
AUC-ROC:
 0.9554357056511344
Execution Time (s):
 336.0212106704712

=== XGBoost ===
Cross-Validation Scores: [0.99989951 0.99978645 0.99979902 0.99979902
0.99982414]
Mean Scores: 0.9998216259672394
Classification Report:
              precision    recall  f1-score   support

           0       1.00      1.00      1.00     85295
           1       0.85      0.82      0.83       148

    accuracy                           1.00     85443
   macro avg       0.93      0.91      0.92     85443
weighted avg       1.00      1.00      1.00     85443

Confusion Matrix:
 [[85274    21]
 [   27   121]]
AUC-ROC:
 0.9763857312380086
Execution Time (s):
 16.445937395095825

# Saving the Random Forest model as an example
import joblib
joblib.dump(models["Random Forest"], 'fraud-detection-model-rf.pkl')
print("\nRandom Forest model saved as 'fraud-detection-model-rf.pkl'")


Random Forest model saved as 'fraud-detection-model-rf.pkl'
```