

```
!pip install fcapy
!pip install frozendict
!pip install ipynb
!pip install sparselinear
!pip install bitsets
!pip install bitarray
import torch
!pip install torch-scatter -f https://data.pyg.org/whl/torch-
2.0.0+cu118.html
!pip install torch-sparse -f https://data.pyg.org/whl/torch-
2.0.0+cu118.html
!pip install torch-cluster -f https://data.pyg.org/whl/torch-
2.0.0+cu118.html
!pip install git+https://github.com/pyg-team/pytorch_geometric.git
!pip install xgboost
!pip install catboost
```

```
Requirement already satisfied: fcapy in c:\users\vasim\anaconda3\lib\
site-packages (0.1.4.5)
Requirement already satisfied: numpy>=1.20 in c:\users\vasim\
anaconda3\lib\site-packages (from fcapy) (1.26.4)
Requirement already satisfied: scikit-mine>=1 in c:\users\vasim\
anaconda3\lib\site-packages (from fcapy) (1.0.0)
Requirement already satisfied: bitarray>=3 in c:\users\vasim\
anaconda3\lib\site-packages (from fcapy) (3.0.0)
Requirement already satisfied: tqdm in c:\users\vasim\anaconda3\lib\
site-packages (from fcapy) (4.66.5)
Requirement already satisfied: pandas in c:\users\vasim\anaconda3\lib\
site-packages (from fcapy) (2.2.3)
Requirement already satisfied: frozendict in c:\users\vasim\anaconda3\
lib\site-packages (from fcapy) (2.4.2)
Requirement already satisfied: pydantic in c:\users\vasim\anaconda3\
lib\site-packages (from fcapy) (2.8.2)
Requirement already satisfied: joblib in c:\users\vasim\anaconda3\lib\
site-packages (from fcapy) (1.4.2)
Requirement already satisfied: scikit-learn in c:\users\vasim\
anaconda3\lib\site-packages (from fcapy) (1.5.2)
Requirement already satisfied: matplotlib in c:\users\vasim\anaconda3\
lib\site-packages (from fcapy) (3.9.3)
Requirement already satisfied: networkx>=2.5 in c:\users\vasim\
anaconda3\lib\site-packages (from fcapy) (3.3)
Requirement already satisfied: caspaille>=0.2.1 in c:\users\vasim\
anaconda3\lib\site-packages (from fcapy) (0.2.1)
Requirement already satisfied: deprecation in c:\users\vasim\
anaconda3\lib\site-packages (from caspaille>=0.2.1->fcapy) (2.1.0)
Requirement already satisfied: PyYAML in c:\users\vasim\anaconda3\lib\
site-packages (from caspaille>=0.2.1->fcapy) (6.0.1)
Requirement already satisfied: scipy>=1.2.1 in c:\users\vasim\
anaconda3\lib\site-packages (from scikit-mine>=1->fcapy) (1.14.1)
Requirement already satisfied: pyroaring>=0.3.4 in c:\users\vasim\
```

anaconda3\lib\site-packages (from scikit-mine>=1->fcapy) (1.0.0)
Requirement already satisfied: sortedcontainers>=2.1.0 in c:\users\vasim\anaconda3\lib\site-packages (from scikit-mine>=1->fcapy) (2.4.0)
Requirement already satisfied: dataclasses>=0.6 in c:\users\vasim\anaconda3\lib\site-packages (from scikit-mine>=1->fcapy) (0.6)
Requirement already satisfied: wget>=3.2 in c:\users\vasim\anaconda3\lib\site-packages (from scikit-mine>=1->fcapy) (3.2)
Requirement already satisfied: graphviz in c:\users\vasim\anaconda3\lib\site-packages (from scikit-mine>=1->fcapy) (0.20.3)
Requirement already satisfied: pydot in c:\users\vasim\anaconda3\lib\site-packages (from scikit-mine>=1->fcapy) (3.0.3)
Requirement already satisfied: python-dateutil>=2.8.2 in c:\users\vasim\anaconda3\lib\site-packages (from pandas->fcapy) (2.9.0.post0)
Requirement already satisfied: pytz>=2020.1 in c:\users\vasim\anaconda3\lib\site-packages (from pandas->fcapy) (2024.1)
Requirement already satisfied: tzdata>=2022.7 in c:\users\vasim\anaconda3\lib\site-packages (from pandas->fcapy) (2023.3)
Requirement already satisfied: contourpy>=1.0.1 in c:\users\vasim\anaconda3\lib\site-packages (from matplotlib->fcapy) (1.3.1)
Requirement already satisfied: cycler>=0.10 in c:\users\vasim\anaconda3\lib\site-packages (from matplotlib->fcapy) (0.12.1)
Requirement already satisfied: fonttools>=4.22.0 in c:\users\vasim\anaconda3\lib\site-packages (from matplotlib->fcapy) (4.55.2)
Requirement already satisfied: kiwisolver>=1.3.1 in c:\users\vasim\anaconda3\lib\site-packages (from matplotlib->fcapy) (1.4.7)
Requirement already satisfied: packaging>=20.0 in c:\users\vasim\anaconda3\lib\site-packages (from matplotlib->fcapy) (24.1)
Requirement already satisfied: pillow>=8 in c:\users\vasim\anaconda3\lib\site-packages (from matplotlib->fcapy) (10.4.0)
Requirement already satisfied: pyparsing>=2.3.1 in c:\users\vasim\anaconda3\lib\site-packages (from matplotlib->fcapy) (3.2.0)
Requirement already satisfied: annotated-types>=0.4.0 in c:\users\vasim\anaconda3\lib\site-packages (from pydantic->fcapy) (0.6.0)
Requirement already satisfied: pydantic-core==2.20.1 in c:\users\vasim\anaconda3\lib\site-packages (from pydantic->fcapy) (2.20.1)
Requirement already satisfied: typing-extensions>=4.6.1 in c:\users\vasim\anaconda3\lib\site-packages (from pydantic->fcapy) (4.11.0)
Requirement already satisfied: threadpoolctl>=3.1.0 in c:\users\vasim\anaconda3\lib\site-packages (from scikit-learn->fcapy) (3.5.0)
Requirement already satisfied: colorama in c:\users\vasim\anaconda3\lib\site-packages (from tqdm->fcapy) (0.4.6)
Requirement already satisfied: six>=1.5 in c:\users\vasim\anaconda3\lib\site-packages (from python-dateutil>=2.8.2->pandas->fcapy) (1.16.0)
Requirement already satisfied: frozendict in c:\users\vasim\anaconda3\lib\site-packages (2.4.2)
Requirement already satisfied: ipynb in c:\users\vasim\anaconda3\lib\site-packages (0.5.1)
Requirement already satisfied: sparselinear in c:\users\vasim\

```
anaconda3\lib\site-packages (0.0.5)
Requirement already satisfied: numpy in c:\users\vasim\anaconda3\lib\
site-packages (from sparselinear) (1.26.4)
Requirement already satisfied: torch in c:\users\vasim\anaconda3\lib\
site-packages (from sparselinear) (2.5.1)
Requirement already satisfied: filelock in c:\users\vasim\anaconda3\
lib\site-packages (from torch->sparselinear) (3.13.1)
Requirement already satisfied: typing-extensions>=4.8.0 in c:\users\
vasim\anaconda3\lib\site-packages (from torch->sparselinear) (4.11.0)
Requirement already satisfied: networkx in c:\users\vasim\anaconda3\
lib\site-packages (from torch->sparselinear) (3.3)
Requirement already satisfied: jinja2 in c:\users\vasim\anaconda3\lib\
site-packages (from torch->sparselinear) (3.1.4)
Requirement already satisfied: fsspec in c:\users\vasim\anaconda3\lib\
site-packages (from torch->sparselinear) (2024.6.1)
Requirement already satisfied: setuptools in c:\users\vasim\anaconda3\
lib\site-packages (from torch->sparselinear) (75.1.0)
Requirement already satisfied: sympy==1.13.1 in c:\users\vasim\
anaconda3\lib\site-packages (from torch->sparselinear) (1.13.1)
Requirement already satisfied: mpmath<1.4,>=1.1.0 in c:\users\vasim\
anaconda3\lib\site-packages (from sympy==1.13.1->torch->sparselinear)
(1.3.0)
Requirement already satisfied: MarkupSafe>=2.0 in c:\users\vasim\
anaconda3\lib\site-packages (from jinja2->torch->sparselinear) (2.1.3)
Requirement already satisfied: bitsets in c:\users\vasim\anaconda3\
lib\site-packages (0.8.4)
Requirement already satisfied: bitarray in c:\users\vasim\anaconda3\
lib\site-packages (3.0.0)
Looking in links: https://data.pyg.org/whl/torch-2.0.0+cuda118.html
Requirement already satisfied: torch-scatter in c:\users\vasim\
anaconda3\lib\site-packages (2.1.2)
Looking in links: https://data.pyg.org/whl/torch-2.0.0+cuda118.html
Requirement already satisfied: torch-sparse in c:\users\vasim\
anaconda3\lib\site-packages (0.6.18)
Requirement already satisfied: scipy in c:\users\vasim\anaconda3\lib\
site-packages (from torch-sparse) (1.14.1)
Requirement already satisfied: numpy<2.3,>=1.23.5 in c:\users\vasim\
anaconda3\lib\site-packages (from scipy->torch-sparse) (1.26.4)
Looking in links: https://data.pyg.org/whl/torch-2.0.0+cuda118.html
Requirement already satisfied: torch-cluster in c:\users\vasim\
anaconda3\lib\site-packages (1.6.3)
Requirement already satisfied: scipy in c:\users\vasim\anaconda3\lib\
site-packages (from torch-cluster) (1.14.1)
Requirement already satisfied: numpy<2.3,>=1.23.5 in c:\users\vasim\
anaconda3\lib\site-packages (from scipy->torch-cluster) (1.26.4)
Collecting git+https://github.com/pyg-team/pytorch_geometric.git
  Cloning https://github.com/pyg-team/pytorch_geometric.git to c:\
users\vasim\appdata\local\temp\pip-req-build-ur_4ud15
  Resolved https://github.com/pyg-team/pytorch_geometric.git to commit
```

```
bd5ae45c74a3fbb6b6ff818476f7651d84313d2a
Installing build dependencies: started
Installing build dependencies: finished with status 'done'
Getting requirements to build wheel: started
Getting requirements to build wheel: finished with status 'done'
Preparing metadata (pyproject.toml): started
Preparing metadata (pyproject.toml): finished with status 'done'
Requirement already satisfied: aiohttp in c:\users\vasim\anaconda3\lib\site-packages (from torch-geometric==2.7.0) (3.10.5)
Requirement already satisfied: fsspec in c:\users\vasim\anaconda3\lib\site-packages (from torch-geometric==2.7.0) (2024.6.1)
Requirement already satisfied: jinja2 in c:\users\vasim\anaconda3\lib\site-packages (from torch-geometric==2.7.0) (3.1.4)
Requirement already satisfied: numpy in c:\users\vasim\anaconda3\lib\site-packages (from torch-geometric==2.7.0) (1.26.4)
Requirement already satisfied: psutil>=5.8.0 in c:\users\vasim\anaconda3\lib\site-packages (from torch-geometric==2.7.0) (5.9.0)
Requirement already satisfied: pyparsing in c:\users\vasim\anaconda3\lib\site-packages (from torch-geometric==2.7.0) (3.2.0)
Requirement already satisfied: requests in c:\users\vasim\anaconda3\lib\site-packages (from torch-geometric==2.7.0) (2.32.3)
Requirement already satisfied: tqdm in c:\users\vasim\anaconda3\lib\site-packages (from torch-geometric==2.7.0) (4.66.5)
Requirement already satisfied: aiohappyeyeballs>=2.3.0 in c:\users\vasim\anaconda3\lib\site-packages (from aiohttp->torch-geometric==2.7.0) (2.4.0)
Requirement already satisfied: aiosignal>=1.1.2 in c:\users\vasim\anaconda3\lib\site-packages (from aiohttp->torch-geometric==2.7.0) (1.2.0)
Requirement already satisfied: attrs>=17.3.0 in c:\users\vasim\anaconda3\lib\site-packages (from aiohttp->torch-geometric==2.7.0) (23.1.0)
Requirement already satisfied: frozenlist>=1.1.1 in c:\users\vasim\anaconda3\lib\site-packages (from aiohttp->torch-geometric==2.7.0) (1.4.0)
Requirement already satisfied: multidict<7.0,>=4.5 in c:\users\vasim\anaconda3\lib\site-packages (from aiohttp->torch-geometric==2.7.0) (6.0.4)
Requirement already satisfied: yarl<2.0,>=1.0 in c:\users\vasim\anaconda3\lib\site-packages (from aiohttp->torch-geometric==2.7.0) (1.11.0)
Requirement already satisfied: MarkupSafe>=2.0 in c:\users\vasim\anaconda3\lib\site-packages (from jinja2->torch-geometric==2.7.0) (2.1.3)
Requirement already satisfied: charset-normalizer<4,>=2 in c:\users\vasim\anaconda3\lib\site-packages (from requests->torch-geometric==2.7.0) (3.3.2)
Requirement already satisfied: idna<4,>=2.5 in c:\users\vasim\anaconda3\lib\site-packages (from requests->torch-geometric==2.7.0)
```

(3.7)

Requirement already satisfied: urllib3<3,>=1.21.1 in c:\users\vasim\anaconda3\lib\site-packages (from requests->torch-geometric==2.7.0)

(2.2.3)

Requirement already satisfied: certifi>=2017.4.17 in c:\users\vasim\anaconda3\lib\site-packages (from requests->torch-geometric==2.7.0)

(2024.8.30)

Requirement already satisfied: colorama in c:\users\vasim\anaconda3\lib\site-packages (from tqdm->torch-geometric==2.7.0) (0.4.6)

Running command git clone --filter=blob:none --quiet
https://github.com/pyg-team/pytorch_geometric.git 'C:\Users\vasim\AppData\Local\Temp\pip-req-build-ur_4ud15'

Requirement already satisfied: xgboost in c:\users\vasim\anaconda3\lib\site-packages (2.1.3)

Requirement already satisfied: numpy in c:\users\vasim\anaconda3\lib\site-packages (from xgboost) (1.26.4)

Requirement already satisfied: scipy in c:\users\vasim\anaconda3\lib\site-packages (from xgboost) (1.14.1)

Requirement already satisfied: catboost in c:\users\vasim\anaconda3\lib\site-packages (1.2.7)

Requirement already satisfied: graphviz in c:\users\vasim\anaconda3\lib\site-packages (from catboost) (0.20.3)

Requirement already satisfied: matplotlib in c:\users\vasim\anaconda3\lib\site-packages (from catboost) (3.9.3)

Requirement already satisfied: numpy<2.0,>=1.16.0 in c:\users\vasim\anaconda3\lib\site-packages (from catboost) (1.26.4)

Requirement already satisfied: pandas>=0.24 in c:\users\vasim\anaconda3\lib\site-packages (from catboost) (2.2.3)

Requirement already satisfied: scipy in c:\users\vasim\anaconda3\lib\site-packages (from catboost) (1.14.1)

Requirement already satisfied: plotly in c:\users\vasim\anaconda3\lib\site-packages (from catboost) (5.24.1)

Requirement already satisfied: six in c:\users\vasim\anaconda3\lib\site-packages (from catboost) (1.16.0)

Requirement already satisfied: python-dateutil>=2.8.2 in c:\users\vasim\anaconda3\lib\site-packages (from pandas>=0.24->catboost) (2.9.0.post0)

Requirement already satisfied: pytz>=2020.1 in c:\users\vasim\anaconda3\lib\site-packages (from pandas>=0.24->catboost) (2024.1)

Requirement already satisfied: tzdata>=2022.7 in c:\users\vasim\anaconda3\lib\site-packages (from pandas>=0.24->catboost) (2023.3)

Requirement already satisfied: contourpy>=1.0.1 in c:\users\vasim\anaconda3\lib\site-packages (from matplotlib->catboost) (1.3.1)

Requirement already satisfied: cycler>=0.10 in c:\users\vasim\anaconda3\lib\site-packages (from matplotlib->catboost) (0.12.1)

Requirement already satisfied: fonttools>=4.22.0 in c:\users\vasim\anaconda3\lib\site-packages (from matplotlib->catboost) (4.55.2)

Requirement already satisfied: kiwisolver>=1.3.1 in c:\users\vasim\

```

anaconda3\lib\site-packages (from matplotlib->catboost) (1.4.7)
Requirement already satisfied: packaging>=20.0 in c:\users\vasim\
anaconda3\lib\site-packages (from matplotlib->catboost) (24.1)
Requirement already satisfied: pillow>=8 in c:\users\vasim\anaconda3\
lib\site-packages (from matplotlib->catboost) (10.4.0)
Requirement already satisfied: pyparsing>=2.3.1 in c:\users\vasim\
anaconda3\lib\site-packages (from matplotlib->catboost) (3.2.0)
Requirement already satisfied: tenacity>=6.2.0 in c:\users\vasim\
anaconda3\lib\site-packages (from plotly->catboost) (9.0.0)

```

Import libs

```

import numpy as np
import pandas as pd
from fcapy.context import FormalContext
from fcapy.lattice import ConceptLattice
from sklearn.model_selection import GridSearchCV, StratifiedKFold
from sklearn.pipeline import Pipeline
from sklearn.ensemble import RandomForestClassifier
from sklearn.feature_selection import RFECV
from sklearn.metrics import accuracy_score, precision_score,
recall_score, f1_score, log_loss, roc_curve, roc_auc_score
import xgboost as xgb
from catboost import CatBoostClassifier
from sklearn.tree import DecisionTreeClassifier
from sklearn import preprocessing
from sklearn.neighbors import KNeighborsClassifier
import sympy

import sys
sys.path.append(r'C:\Users\vasim\Downloads')

import neural_lib as nl

```

Prepare Data

```

df_bin = pd.read_csv(r'C:\Users\vasim\Downloads\
TravelInsurancePrediction_binarized_2.csv', index_col=0)
df_bin.columns = [f.split('_')[-1] for f in df_bin.columns]
df_bin.head()

```

	target	is-age-ng-25	is-age-ng-26	is-age-ng-27	is-age-ng-
28 \					
id					
person1	False	False	False	False	
False					

person2	False	False	False	False
False				
person3	True	False	False	False
False				
person4	False	False	False	False
True				
person5	False	False	False	False
True				

is-age-ng-29 is-age-ng-30 is-age-ng-31 is-age-ng-32 is-age-ng-33 \ id

person1	False	False	True	True
True				
person2	False	False	True	True
True				
person3	False	False	False	False
False				
person4	True	True	True	True
True				
person5	True	True	True	True
True				

... is-nof-ng-3 is-nof-ng-4 is-nof-ng-5 is-nof-ng-6 is-nof-ng-7 \ id ...

person1	...	False	False	False	True
True					
person2	...	False	False	False	False
True					
person3	...	False	True	True	True
True					
person4	...	True	True	True	True
True					
person5	...	False	False	False	False
False					

is-nof-ng-8 is-nof-g-8 is-chronic-disease is-frequent-flyer \ id

person1	True	False	True
False			
person2	True	False	False
False			
person3	True	False	True
False			
person4	True	False	True

```
False
person5      True      False      True
True
```

```
ever-travelled
```

```
id
person1      False
person2      False
person3      False
person4      False
person5      False
```

```
[5 rows x 30 columns]
```

```
df = pd.read_csv(r'C:\Users\vasim\Downloads\
TravelInsurancePrediction_numeric.csv', index_col=0)
df.columns = [f.split('_')[-1] for f in df.columns]
df.head()
```

	Age	Employment	Type	GraduateOrOt	AnnualIncome	FamilyMembers	\
0	31		1	1	400000	6	
1	31		0	1	1250000	7	
2	34		0	1	500000	4	
3	28		0	1	700000	3	
4	28		0	1	700000	8	

```
ChronicDiseases  FrequentFlyer  EverTravelledAbroad
TravelInsurance
```

0	1	0	0
0			
1	0	0	0
0			
2	1	0	0
1			
3	1	0	0
0			
4	1	1	0
0			

```
scaler = preprocessing.MinMaxScaler()
arr_scaled = scaler.fit_transform(df)
df = pd.DataFrame(arr_scaled, columns=df.columns)
df.head()
```

	Age	Employment	Type	GraduateOrOt	AnnualIncome	FamilyMembers	\
0	0.6		1.0	1.0	0.066667	0.571429	
1	0.6		0.0	1.0	0.633333	0.714286	
2	0.9		0.0	1.0	0.133333	0.285714	
3	0.3		0.0	1.0	0.266667	0.142857	
4	0.3		0.0	1.0	0.266667	0.857143	

	ChronicDiseases	FrequentFlyer	EverTravelledAbroad
TravelInsurance			
0	1.0	0.0	0.0
0.0			
1	0.0	0.0	0.0
0.0			
2	1.0	0.0	0.0
1.0			
3	1.0	0.0	0.0
0.0			
4	1.0	1.0	0.0
0.0			

```

y_feat_numeric = 'TravelInsurance'
df_test_numeric = df[600:750]
df_train_numeric = df[0:600]

X_train_num, y_train_num = df_train_numeric.drop(y_feat_numeric,
axis=1), df_train_numeric[y_feat_numeric]
X_test_num, y_test_num = df_test_numeric.drop(y_feat_numeric, axis=1),
df_test_numeric[y_feat_numeric]

y_feat = 'target'
df_train = df_bin[0:600]
df_test = df_bin[600:750]

X_train, y_train = df_train.drop(y_feat, axis=1), df_train[y_feat]
X_test, y_test = df_test.drop(y_feat, axis=1), df_test[y_feat]

```

Build Monotone Concept Lattice

```

K_train = FormalContext.from_pandas(X_train)
K_train

FormalContext (600 objects, 29 attributes, 8318 connections)
      |is-age-ng-25|is-age-ng-26|is-age-ng-27|is-age-ng-28|is-age-
ng-29|...|is-nof-ng-8|is-nof-g-8|is-chronic-disease|is-frequent-flyer|
ever-travelled|
person1 |          |          |          |          |          |
|...|          |X|          |          |          |X|          |
|
person2 |          |          |          |          |          |
|...|          |X|          |          |          |          |
|
person3 |          |          |          |          |          |
|...|          |X|          |          |          |X|          |
|
person4 |          |          |          |          |          |
X|...|          |X|          |          |          |X|          |

```

person5							X	
X ...		X				X		X
person6			X		X		X	X
X ...		X						
person7								
...		X						
person8								
...		X						X
X								
person9							X	
X ...		X				X		X
X								
person10								
...		X						X

.....

.....

.....

.....

.....

person591							X	
X ...		X						
person592			X		X		X	X
X ...		X				X		
person593			X		X		X	X
X ...		X						X
person594								X
X ...		X						
person595								
...		X						X
person596			X		X		X	X
X ...		X				X		X
person597								
...		X						
X								
person598								
...		X						

```

person599|          |          |          |          |
|...|          X|          |          |          |          X|
|
person600|          |          |          |          |          |
|...|          X|          |          |          X|          |
|

L = ConceptLattice.from_context(K_train, algo='Sofia',
is_monotone=True)
len(L)

97

for c in L:
    y_preds = np.zeros(K_train.n_objects)
    y_preds[list(c.extent_i)] = 1
    c.measures['accuracy'] = accuracy_score(y_train, y_preds)

best_concepts = list(L.measures['accuracy'].argsort()[::-1][:80])

assert len({g_i for c in L[best_concepts] for g_i in
c.extent_i})==K_train.n_objects, "Selected concepts do not cover all
train objects"

cn = nl.ConceptNetwork.from_lattice(L, best_concepts,
sorted(set(y_train)))

cn.fit(X_train, y_train)

y_pred = cn.predict(X_test).numpy()
accuracy = accuracy_score(y_test, y_pred)
print("Accuracy Score on test data: ", accuracy)

Accuracy Score on test data:  0.66

```

Decision Tree

```

cn_DT = DecisionTreeClassifier()

param_grid_DT = {'max_features': ['sqrt', 'log2'],
                  'ccp_alpha': [0.1, .01, .001],
                  'max_depth' : [3, 4, 5, 6, 7, 8, 9, 10, 11],
                  'criterion' :['gini', 'entropy']}

grid_search_DT_as = GridSearchCV(estimator=cn_DT,
param_grid=param_grid_DT, cv=5, scoring='accuracy', n_jobs=-1)
grid_search_DT_as.fit(X_train_num, y_train_num)
print("Best parameters found: ", grid_search_DT_as.best_params_)
print("Best cross-validation score: ", grid_search_DT_as.best_score_)

```

```
Best parameters found: {'ccp_alpha': 0.01, 'criterion': 'entropy',  
'max_depth': 11, 'max_features': 'log2'}  
Best cross-validation score: 0.8116666666666668
```

```
grid_search_DT_ps = GridSearchCV(estimator=cn_DT,  
param_grid=param_grid_DT, cv=5, scoring='precision', n_jobs=-1)  
grid_search_DT_ps.fit(X_train_num, y_train_num)  
print("Best parameters found: ", grid_search_DT_ps.best_params_)  
print("Best cross-validation score: ", grid_search_DT_ps.best_score_)
```

```
Best parameters found: {'ccp_alpha': 0.01, 'criterion': 'gini',  
'max_depth': 11, 'max_features': 'log2'}  
Best cross-validation score: 0.9046494355317884
```

```
grid_search_DT_rs = GridSearchCV(estimator=cn_DT,  
param_grid=param_grid_DT, cv=5, scoring='recall', n_jobs=-1)  
grid_search_DT_rs.fit(X_train_num, y_train_num)  
print("Best parameters found: ", grid_search_DT_rs.best_params_)  
print("Best cross-validation score: ", grid_search_DT_rs.best_score_)
```

```
Best parameters found: {'ccp_alpha': 0.001, 'criterion': 'gini',  
'max_depth': 9, 'max_features': 'log2'}  
Best cross-validation score: 0.5842044134727062
```

```
grid_search_DT_fls = GridSearchCV(estimator=cn_DT,  
param_grid=param_grid_DT, cv=5, scoring='f1', n_jobs=-1)  
grid_search_DT_fls.fit(X_train_num, y_train_num)  
print("Best parameters found: ", grid_search_DT_fls.best_params_)  
print("Best cross-validation score: ", grid_search_DT_fls.best_score_)
```

```
Best parameters found: {'ccp_alpha': 0.01, 'criterion': 'entropy',  
'max_depth': 5, 'max_features': 'log2'}  
Best cross-validation score: 0.680813751194972
```

```
grid_search_DT_ras = GridSearchCV(estimator=cn_DT,  
param_grid=param_grid_DT, cv=5, scoring='roc_auc_ovr', n_jobs=-1)  
grid_search_DT_ras.fit(X_train_num, y_train_num)  
print("Best parameters found: ", grid_search_DT_ras.best_params_)  
print("Best cross-validation score: ", grid_search_DT_ras.best_score_)
```

```
Best parameters found: {'ccp_alpha': 0.01, 'criterion': 'entropy',  
'max_depth': 4, 'max_features': 'log2'}  
Best cross-validation score: 0.7753567913339448
```

```
y_DT_pred_as = grid_search_DT_as.predict(X_test_num)  
y_DT_pred_ps = grid_search_DT_ps.predict(X_test_num)  
y_DT_pred_rs = grid_search_DT_rs.predict(X_test_num)  
y_DT_pred_fls = grid_search_DT_fls.predict(X_test_num)  
y_DT_pred_ras = grid_search_DT_ras.predict(X_test_num)
```

```

accuracy_DT = accuracy_score(y_test_num, y_DT_pred_as)
print("Accuracy Score on test data: ", accuracy_DT)
precision_DT = precision_score(y_test_num, y_DT_pred_ps)
print("Precision Score on test data: ", precision_DT)
recall_DT = recall_score(y_test_num, y_DT_pred_rs)
print("Recall Score on test data: ", recall_DT)
f1_DT = f1_score(y_test_num, y_DT_pred_fls)
print("F1 Score on test data: ", f1_DT)
roc_auc_DT = roc_auc_score(y_test_num, y_DT_pred_ras)
print("ROC AUC Score on test data: ", roc_auc_DT)

```

```

Accuracy Score on test data:  0.84
Precision Score on test data:  0.75
Recall Score on test data:  0.7058823529411765
F1 Score on test data:  0.7415730337078652
ROC AUC Score on test data:  0.6746880570409983

```

Random Forest

```

clf_RF = RandomForestClassifier(class_weight="balanced")

param_grid_RF = {
    'n_estimators': [100, 200, 300, 400, 500],
    'max_features': ['sqrt', 'log2'],
    'max_depth': [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15],
    'criterion': ['gini', 'entropy', 'log_loss']
}

```

```

grid_search_RF_as = GridSearchCV(estimator=clf_RF,
    param_grid=param_grid_RF, cv=3, scoring='accuracy', n_jobs=-1)
grid_search_RF_as.fit(X_train_num, y_train_num)
print("Best parameters found: ", grid_search_RF_as.best_params_)
print("Best cross-validation score: ", grid_search_RF_as.best_score_)

```

```

C:\Users\vasim\anaconda3\Lib\site-packages\numpy\ma\core.py:2820:
RuntimeWarning: invalid value encountered in cast
    _data = np.array(data, dtype=dtype, copy=copy,

```

```

Best parameters found: {'criterion': 'entropy', 'max_depth': 4,
    'max_features': 'log2', 'n_estimators': 200}
Best cross-validation score:  0.8316666666666667

```

```

grid_search_RF_ps = GridSearchCV(estimator=clf_RF,
    param_grid=param_grid_RF, cv=3, scoring='precision', n_jobs=-1)
grid_search_RF_ps.fit(X_train_num, y_train_num)
print("Best parameters found: ", grid_search_RF_ps.best_params_)
print("Best cross-validation score: ", grid_search_RF_ps.best_score_)

```

```
Best parameters found: {'criterion': 'entropy', 'max_depth': 4,
'max_features': 'sqrt', 'n_estimators': 100}
Best cross-validation score: 0.8851851851851853
```

```
grid_search_RF_rs = GridSearchCV(estimator=clf_RF,
param_grid=param_grid_RF, cv=3, scoring='recall', n_jobs=-1)
grid_search_RF_rs.fit(X_train_num, y_train_num)
print("Best parameters found: ", grid_search_RF_rs.best_params_)
print("Best cross-validation score: ", grid_search_RF_rs.best_score_)
```

```
Best parameters found: {'criterion': 'entropy', 'max_depth': 15,
'max_features': 'sqrt', 'n_estimators': 400}
Best cross-validation score: 0.6135265700483092
```

```
grid_search_RF_fls = GridSearchCV(estimator=clf_RF,
param_grid=param_grid_RF, cv=3, scoring='f1', n_jobs=-1)
grid_search_RF_fls.fit(X_train_num, y_train_num)
print("Best parameters found: ", grid_search_RF_fls.best_params_)
print("Best cross-validation score: ", grid_search_RF_fls.best_score_)
```

```
Best parameters found: {'criterion': 'entropy', 'max_depth': 4,
'max_features': 'log2', 'n_estimators': 500}
Best cross-validation score: 0.7070332660015518
```

```
grid_search_RF_ras = GridSearchCV(estimator=clf_RF,
param_grid=param_grid_RF, cv=3, scoring='roc_auc_ovr', n_jobs=-1)
grid_search_RF_ras.fit(X_train_num, y_train_num)
print("Best parameters found: ", grid_search_RF_ras.best_params_)
print("Best cross-validation score: ", grid_search_RF_ras.best_score_)
```

```
Best parameters found: {'criterion': 'log_loss', 'max_depth': 5,
'max_features': 'log2', 'n_estimators': 100}
Best cross-validation score: 0.7853929269461961
```

```
y_RF_pred_as = grid_search_RF_as.predict(X_test_num)
y_RF_pred_ps = grid_search_RF_ps.predict(X_test_num)
y_RF_pred_rs = grid_search_RF_rs.predict(X_test_num)
y_RF_pred_fls = grid_search_RF_fls.predict(X_test_num)
y_RF_pred_ras = grid_search_RF_ras.predict(X_test_num)
```

```
accuracy_RF = accuracy_score(y_test_num, y_RF_pred_as)
print("Accuracy Score on test data: ", accuracy_RF)
precision_RF = precision_score(y_test_num, y_RF_pred_ps)
print("Precision Score on test data: ", precision_RF)
recall_RF = recall_score(y_test_num, y_RF_pred_rs)
print("Recall Score on test data: ", recall_RF)
f1_RF = f1_score(y_test_num, y_RF_pred_fls)
print("F1 Score on test data: ", f1_DT)
roc_auc_RF = roc_auc_score(y_test_num, y_RF_pred_ras)
print("ROC AUC Score on test data: ", roc_auc_RF)
```

Accuracy Score on test data: 0.8666666666666667
Precision Score on test data: 0.8604651162790697
Recall Score on test data: 0.7450980392156863
F1 Score on test data: 0.7415730337078652
ROC AUC Score on test data: 0.8475935828877006

XGBoost

```
clf_XG = xgb.XGBClassifier()

param_grid_XG = {'nthread': [10],
                 'colsample_bytree': [0.5, 0.6, 0.7, 0.8, 0.9],
                 'max_depth': [3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13,
                                14, 15, 16],
                 'subsample': [0.5, 0.6, 0.7, 0.8, 0.9],
                 'n_estimators': [100, 200, 300, 400, 500, 600]}

grid_search_XG_as = GridSearchCV(estimator=clf_XG,
                                 param_grid=param_grid_XG, cv=3, scoring='accuracy', n_jobs=-1)
grid_search_XG_as.fit(X_train_num, y_train_num)
print("Best parameters found: ", grid_search_XG_as.best_params_)
print("Best cross-validation score: ", grid_search_XG_as.best_score_)

Best parameters found: {'colsample_bytree': 0.5, 'max_depth': 3,
                        'n_estimators': 100, 'nthread': 10, 'subsample': 0.9}
Best cross-validation score: 0.8033333333333333

grid_search_XG_ps = GridSearchCV(estimator=clf_XG,
                                 param_grid=param_grid_XG, cv=3, scoring='precision', n_jobs=-1)
grid_search_XG_ps.fit(X_train_num, y_train_num)
print("Best parameters found: ", grid_search_XG_ps.best_params_)
print("Best cross-validation score: ", grid_search_XG_ps.best_score_)

Best parameters found: {'colsample_bytree': 0.5, 'max_depth': 3,
                        'n_estimators': 100, 'nthread': 10, 'subsample': 0.9}
Best cross-validation score: 0.7758251448727639

grid_search_XG_rs = GridSearchCV(estimator=clf_XG,
                                 param_grid=param_grid_XG, cv=3, scoring='recall', n_jobs=-1)
grid_search_XG_rs.fit(X_train_num, y_train_num)
print("Best parameters found: ", grid_search_XG_rs.best_params_)
print("Best cross-validation score: ", grid_search_XG_rs.best_score_)

Best parameters found: {'colsample_bytree': 0.7, 'max_depth': 9,
                        'n_estimators': 100, 'nthread': 10, 'subsample': 0.7}
Best cross-validation score: 0.6425120772946861

grid_search_XG_fls = GridSearchCV(estimator=clf_XG,
                                   param_grid=param_grid_XG, cv=3, scoring='f1', n_jobs=-1)
```

```

grid_search_XG_fls.fit(X_train_num, y_train_num)
print("Best parameters found: ", grid_search_XG_fls.best_params_)
print("Best cross-validation score: ", grid_search_XG_fls.best_score_)

Best parameters found: {'colsample_bytree': 0.5, 'max_depth': 3,
'n_estimators': 100, 'nthread': 10, 'subsample': 0.9}
Best cross-validation score: 0.6809987256356599

grid_search_XG_ras = GridSearchCV(estimator=clf_XG,
param_grid=param_grid_XG, cv=3, scoring='roc_auc_ovr', n_jobs=-1)
grid_search_XG_ras.fit(X_train_num, y_train_num)
print("Best parameters found: ", grid_search_XG_ras.best_params_)
print("Best cross-validation score: ", grid_search_XG_ras.best_score_)

Best parameters found: {'colsample_bytree': 0.8, 'max_depth': 5,
'n_estimators': 100, 'nthread': 10, 'subsample': 0.6}
Best cross-validation score: 0.7717667883615444

y_XG_pred_as = grid_search_XG_as.predict(X_test_num)
y_XG_pred_ps = grid_search_XG_ps.predict(X_test_num)
y_XG_pred_rs = grid_search_XG_rs.predict(X_test_num)
y_XG_pred_fls = grid_search_XG_fls.predict(X_test_num)
y_XG_pred_ras = grid_search_XG_ras.predict(X_test_num)

accuracy_XG = accuracy_score(y_test_num, y_XG_pred_as)
print("Accuracy Score on test data: ", accuracy_XG)
precision_XG = precision_score(y_test_num, y_XG_pred_ps)
print("Precision Score on test data: ", precision_XG)
recall_XG = recall_score(y_test_num, y_XG_pred_rs)
print("Recall Score on test data: ", recall_XG)
f1_XG = f1_score(y_test_num, y_XG_pred_fls)
print("F1 Score on test data: ", f1_DT)
roc_auc_XG = roc_auc_score(y_test_num, y_XG_pred_ras)
print("ROC AUC Score on test data: ", roc_auc_XG)

Accuracy Score on test data: 0.8533333333333334
Precision Score on test data: 0.8536585365853658
Recall Score on test data: 0.7254901960784313
F1 Score on test data: 0.7415730337078652
ROC AUC Score on test data: 0.812537136066548

```

CatBoost

```

clf_CB=CatBoostClassifier(loss_function='Logloss', random_state=42)

param_grid_CB = {
    'iterations': [100, 200, 300, 400, 500, 600],
    'learning_rate': [0.2, 0.1, 0.05, 0.01],

```



```

    'depth': [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11]
}

grid_search_CB_as = GridSearchCV(estimator=clf_CB,
param_grid=param_grid_CB, cv=3, scoring='accuracy', n_jobs=-1)
grid_search_CB_as.fit(X_train_num, y_train_num)
print("Best parameters found: ", grid_search_CB_as.best_params_)
print("Best cross-validation score: ", grid_search_CB_as.best_score_)

```

```

0:   learn: 0.6276470 total: 53.7ms   remaining: 5.31s
1:   learn: 0.5847199 total: 54ms     remaining: 2.65s
2:   learn: 0.5532408 total: 54.2ms   remaining: 1.75s
3:   learn: 0.5333715 total: 54.4ms   remaining: 1.31s
4:   learn: 0.5192353 total: 54.6ms   remaining: 1.04s
5:   learn: 0.5077749 total: 54.8ms   remaining: 859ms
6:   learn: 0.5022489 total: 55ms     remaining: 731ms
7:   learn: 0.4958642 total: 55.2ms   remaining: 635ms
8:   learn: 0.4878928 total: 55.4ms   remaining: 560ms
9:   learn: 0.4843846 total: 55.6ms   remaining: 500ms
10:  learn: 0.4802313 total: 55.7ms   remaining: 451ms
11:  learn: 0.4791065 total: 55.9ms   remaining: 410ms
12:  learn: 0.4768860 total: 56.1ms   remaining: 375ms
13:  learn: 0.4703731 total: 56.2ms   remaining: 346ms
14:  learn: 0.4681357 total: 56.4ms   remaining: 320ms
15:  learn: 0.4659176 total: 56.6ms   remaining: 297ms
16:  learn: 0.4630902 total: 56.8ms   remaining: 277ms
17:  learn: 0.4598043 total: 57ms      remaining: 259ms
18:  learn: 0.4582510 total: 57.1ms   remaining: 244ms
19:  learn: 0.4571182 total: 57.3ms   remaining: 229ms
20:  learn: 0.4548098 total: 57.5ms   remaining: 216ms
21:  learn: 0.4537404 total: 57.7ms   remaining: 204ms
22:  learn: 0.4531709 total: 57.8ms   remaining: 194ms
23:  learn: 0.4519392 total: 58ms      remaining: 184ms
24:  learn: 0.4509585 total: 58.2ms   remaining: 175ms
25:  learn: 0.4494856 total: 58.3ms   remaining: 166ms
26:  learn: 0.4486960 total: 58.5ms   remaining: 158ms
27:  learn: 0.4461007 total: 58.7ms   remaining: 151ms
28:  learn: 0.4441502 total: 58.8ms   remaining: 144ms
29:  learn: 0.4425209 total: 59ms      remaining: 138ms
30:  learn: 0.4417994 total: 59.2ms   remaining: 132ms
31:  learn: 0.4410726 total: 59.3ms   remaining: 126ms
32:  learn: 0.4396076 total: 59.5ms   remaining: 121ms
33:  learn: 0.4385452 total: 59.7ms   remaining: 116ms
34:  learn: 0.4378752 total: 59.9ms   remaining: 111ms
35:  learn: 0.4377054 total: 60ms      remaining: 107ms
36:  learn: 0.4376724 total: 60.2ms   remaining: 102ms
37:  learn: 0.4370485 total: 60.3ms   remaining: 98.5ms
38:  learn: 0.4362376 total: 60.5ms   remaining: 94.6ms
39:  learn: 0.4357493 total: 60.7ms   remaining: 91ms
40:  learn: 0.4348155 total: 60.8ms   remaining: 87.6ms

```

41:	learn: 0.4340378	total: 61ms	remaining: 84.3ms
42:	learn: 0.4324768	total: 61.2ms	remaining: 81.1ms
43:	learn: 0.4318184	total: 61.3ms	remaining: 78.1ms
44:	learn: 0.4309399	total: 61.5ms	remaining: 75.2ms
45:	learn: 0.4308908	total: 61.7ms	remaining: 72.4ms
46:	learn: 0.4308134	total: 61.8ms	remaining: 69.7ms
47:	learn: 0.4302045	total: 62ms	remaining: 67.2ms
48:	learn: 0.4301610	total: 62.2ms	remaining: 64.7ms
49:	learn: 0.4293160	total: 62.3ms	remaining: 62.3ms
50:	learn: 0.4292664	total: 62.5ms	remaining: 60ms
51:	learn: 0.4292167	total: 62.7ms	remaining: 57.8ms
52:	learn: 0.4277321	total: 62.8ms	remaining: 55.7ms
53:	learn: 0.4262064	total: 63ms	remaining: 53.7ms
54:	learn: 0.4254772	total: 63.2ms	remaining: 51.7ms
55:	learn: 0.4254133	total: 63.3ms	remaining: 49.8ms
56:	learn: 0.4248461	total: 63.5ms	remaining: 47.9ms
57:	learn: 0.4236742	total: 63.7ms	remaining: 46.1ms
58:	learn: 0.4236281	total: 63.8ms	remaining: 44.3ms
59:	learn: 0.4233132	total: 64ms	remaining: 42.7ms
60:	learn: 0.4227022	total: 64.2ms	remaining: 41ms
61:	learn: 0.4221701	total: 64.3ms	remaining: 39.4ms
62:	learn: 0.4217224	total: 64.5ms	remaining: 37.9ms
63:	learn: 0.4212130	total: 64.7ms	remaining: 36.4ms
64:	learn: 0.4206512	total: 64.8ms	remaining: 34.9ms
65:	learn: 0.4202259	total: 65ms	remaining: 33.5ms
66:	learn: 0.4199014	total: 65.2ms	remaining: 32.1ms
67:	learn: 0.4193975	total: 65.3ms	remaining: 30.7ms
68:	learn: 0.4193482	total: 65.5ms	remaining: 29.4ms
69:	learn: 0.4191463	total: 65.6ms	remaining: 28.1ms
70:	learn: 0.4190988	total: 65.8ms	remaining: 26.9ms
71:	learn: 0.4181470	total: 66ms	remaining: 25.6ms
72:	learn: 0.4181008	total: 66.1ms	remaining: 24.5ms
73:	learn: 0.4176992	total: 66.3ms	remaining: 23.3ms
74:	learn: 0.4169678	total: 66.4ms	remaining: 22.1ms
75:	learn: 0.4158516	total: 66.6ms	remaining: 21ms
76:	learn: 0.4155048	total: 66.8ms	remaining: 19.9ms
77:	learn: 0.4152551	total: 67ms	remaining: 18.9ms
78:	learn: 0.4144023	total: 67.1ms	remaining: 17.8ms
79:	learn: 0.4143550	total: 67.3ms	remaining: 16.8ms
80:	learn: 0.4139945	total: 67.5ms	remaining: 15.8ms
81:	learn: 0.4139499	total: 67.6ms	remaining: 14.8ms
82:	learn: 0.4135492	total: 67.8ms	remaining: 13.9ms
83:	learn: 0.4133455	total: 67.9ms	remaining: 12.9ms
84:	learn: 0.4133018	total: 68.1ms	remaining: 12ms
85:	learn: 0.4126827	total: 68.3ms	remaining: 11.1ms
86:	learn: 0.4124547	total: 68.4ms	remaining: 10.2ms
87:	learn: 0.4122294	total: 68.6ms	remaining: 9.35ms
88:	learn: 0.4112565	total: 68.8ms	remaining: 8.5ms
89:	learn: 0.4112125	total: 68.9ms	remaining: 7.66ms

```
90: learn: 0.4104615 total: 69.1ms remaining: 6.83ms
91: learn: 0.4101789 total: 69.3ms remaining: 6.02ms
92: learn: 0.4094236 total: 69.4ms remaining: 5.22ms
93: learn: 0.4093545 total: 69.6ms remaining: 4.44ms
94: learn: 0.4092884 total: 69.7ms remaining: 3.67ms
95: learn: 0.4086227 total: 69.9ms remaining: 2.91ms
96: learn: 0.4086013 total: 70.1ms remaining: 2.17ms
97: learn: 0.4085394 total: 70.2ms remaining: 1.43ms
98: learn: 0.4084995 total: 70.4ms remaining: 710us
99: learn: 0.4079941 total: 70.5ms remaining: 0us
```

```
Best parameters found: {'depth': 2, 'iterations': 100,
'learning_rate': 0.2}
```

```
Best cross-validation score: 0.835
```

```
grid_search_CB_ps = GridSearchCV(estimator=clf_CB,
param_grid=param_grid_CB, cv=3, scoring='precision', n_jobs=-1)
grid_search_CB_ps.fit(X_train_num, y_train_num)
print("Best parameters found: ", grid_search_CB_ps.best_params_)
print("Best cross-validation score: ", grid_search_CB_ps.best_score_)
```

```
0: learn: 0.6889666 total: 434us remaining: 86.5ms
1: learn: 0.6855075 total: 1.11ms remaining: 110ms
2: learn: 0.6814872 total: 1.61ms remaining: 106ms
3: learn: 0.6775547 total: 2.09ms remaining: 102ms
4: learn: 0.6737052 total: 2.56ms remaining: 99.8ms
5: learn: 0.6699466 total: 3.04ms remaining: 98.2ms
6: learn: 0.6662675 total: 3.5ms remaining: 96.4ms
7: learn: 0.6626690 total: 3.99ms remaining: 95.8ms
8: learn: 0.6591503 total: 4.46ms remaining: 94.8ms
9: learn: 0.6569652 total: 4.92ms remaining: 93.4ms
10: learn: 0.6535730 total: 5.41ms remaining: 93ms
11: learn: 0.6507490 total: 5.85ms remaining: 91.7ms
12: learn: 0.6474867 total: 6.33ms remaining: 91.1ms
13: learn: 0.6443005 total: 6.8ms remaining: 90.4ms
14: learn: 0.6417884 total: 7.27ms remaining: 89.7ms
15: learn: 0.6391842 total: 7.73ms remaining: 88.9ms
16: learn: 0.6372934 total: 8.18ms remaining: 88ms
17: learn: 0.6343318 total: 8.63ms remaining: 87.3ms
18: learn: 0.6325184 total: 9.07ms remaining: 86.4ms
19: learn: 0.6296617 total: 9.56ms remaining: 86ms
20: learn: 0.6268671 total: 10ms remaining: 85.6ms
21: learn: 0.6245376 total: 10.5ms remaining: 85.1ms
22: learn: 0.6218559 total: 11ms remaining: 84.5ms
23: learn: 0.6192346 total: 11.4ms remaining: 83.8ms
24: learn: 0.6166683 total: 11.9ms remaining: 83.3ms
25: learn: 0.6141649 total: 12.4ms remaining: 82.7ms
26: learn: 0.6120659 total: 12.8ms remaining: 82.1ms
27: learn: 0.6096594 total: 13.3ms remaining: 81.6ms
28: learn: 0.6076538 total: 13.7ms remaining: 81ms
29: learn: 0.6056872 total: 14.2ms remaining: 80.4ms
```

30:	learn: 0.6038801	total: 14.7ms	remaining: 80ms
31:	learn: 0.6016496	total: 15.1ms	remaining: 79.4ms
32:	learn: 0.5994686	total: 15.6ms	remaining: 78.9ms
33:	learn: 0.5981448	total: 16ms	remaining: 78.3ms
34:	learn: 0.5963553	total: 16.5ms	remaining: 77.6ms
35:	learn: 0.5942844	total: 16.9ms	remaining: 77.1ms
36:	learn: 0.5922650	total: 17.4ms	remaining: 76.5ms
37:	learn: 0.5910465	total: 17.8ms	remaining: 75.9ms
38:	learn: 0.5893889	total: 18.2ms	remaining: 75.3ms
39:	learn: 0.5874692	total: 18.7ms	remaining: 75ms
40:	learn: 0.5855943	total: 19.2ms	remaining: 74.5ms
41:	learn: 0.5840359	total: 19.7ms	remaining: 74ms
42:	learn: 0.5833741	total: 20.2ms	remaining: 73.6ms
43:	learn: 0.5815758	total: 20.6ms	remaining: 73.2ms
44:	learn: 0.5798206	total: 21.1ms	remaining: 72.7ms
45:	learn: 0.5781034	total: 21.6ms	remaining: 72.2ms
46:	learn: 0.5767927	total: 22ms	remaining: 71.8ms
47:	learn: 0.5759785	total: 22.5ms	remaining: 71.2ms
48:	learn: 0.5743509	total: 23ms	remaining: 70.8ms
49:	learn: 0.5727591	total: 23.4ms	remaining: 70.3ms
50:	learn: 0.5718784	total: 23.9ms	remaining: 69.9ms
51:	learn: 0.5705618	total: 24.4ms	remaining: 69.4ms
52:	learn: 0.5696422	total: 24.8ms	remaining: 68.8ms
53:	learn: 0.5681436	total: 25.3ms	remaining: 68.4ms
54:	learn: 0.5666759	total: 25.7ms	remaining: 67.8ms
55:	learn: 0.5658111	total: 26.2ms	remaining: 67.3ms
56:	learn: 0.5643976	total: 26.6ms	remaining: 66.9ms
57:	learn: 0.5632220	total: 27.1ms	remaining: 66.3ms
58:	learn: 0.5626756	total: 27.5ms	remaining: 65.8ms
59:	learn: 0.5618678	total: 28ms	remaining: 65.2ms
60:	learn: 0.5610780	total: 28.4ms	remaining: 64.7ms
61:	learn: 0.5599650	total: 28.8ms	remaining: 64.1ms
62:	learn: 0.5594713	total: 29.3ms	remaining: 63.6ms
63:	learn: 0.5581779	total: 29.7ms	remaining: 63.1ms
64:	learn: 0.5576747	total: 30.1ms	remaining: 62.6ms
65:	learn: 0.5564150	total: 30.6ms	remaining: 62.2ms
66:	learn: 0.5551842	total: 31.1ms	remaining: 61.8ms
67:	learn: 0.5544840	total: 31.6ms	remaining: 61.3ms
68:	learn: 0.5535777	total: 32.1ms	remaining: 60.9ms
69:	learn: 0.5525947	total: 32.5ms	remaining: 60.4ms
70:	learn: 0.5519319	total: 33ms	remaining: 59.9ms
71:	learn: 0.5507967	total: 33.5ms	remaining: 59.5ms
72:	learn: 0.5501595	total: 33.9ms	remaining: 59.1ms
73:	learn: 0.5496025	total: 34.4ms	remaining: 58.6ms
74:	learn: 0.5489834	total: 34.9ms	remaining: 58.1ms
75:	learn: 0.5479061	total: 35.3ms	remaining: 57.7ms
76:	learn: 0.5473095	total: 35.8ms	remaining: 57.1ms
77:	learn: 0.5464417	total: 36.2ms	remaining: 56.6ms
78:	learn: 0.5458681	total: 36.7ms	remaining: 56.1ms

79:	learn: 0.5453069	total: 37.1ms	remaining: 55.6ms
80:	learn: 0.5443071	total: 37.6ms	remaining: 55.2ms
81:	learn: 0.5437680	total: 38ms	remaining: 54.7ms
82:	learn: 0.5432582	total: 38.4ms	remaining: 54.2ms
83:	learn: 0.5422947	total: 38.9ms	remaining: 53.7ms
84:	learn: 0.5413553	total: 39.4ms	remaining: 53.2ms
85:	learn: 0.5405889	total: 39.8ms	remaining: 52.8ms
86:	learn: 0.5400992	total: 40.2ms	remaining: 52.3ms
87:	learn: 0.5392001	total: 40.7ms	remaining: 51.8ms
88:	learn: 0.5383209	total: 41.2ms	remaining: 51.3ms
89:	learn: 0.5379110	total: 41.6ms	remaining: 50.9ms
90:	learn: 0.5374525	total: 42ms	remaining: 50.4ms
91:	learn: 0.5366105	total: 42.5ms	remaining: 49.9ms
92:	learn: 0.5357857	total: 43ms	remaining: 49.4ms
93:	learn: 0.5349807	total: 43.4ms	remaining: 49ms
94:	learn: 0.5345177	total: 43.9ms	remaining: 48.5ms
95:	learn: 0.5338631	total: 44.3ms	remaining: 48ms
96:	learn: 0.5330905	total: 44.8ms	remaining: 47.5ms
97:	learn: 0.5323355	total: 45.2ms	remaining: 47.1ms
98:	learn: 0.5320142	total: 45.6ms	remaining: 46.6ms
99:	learn: 0.5312791	total: 46.1ms	remaining: 46.1ms
100:	learn: 0.5306786	total: 46.5ms	remaining: 45.6ms
101:	learn: 0.5305043	total: 47ms	remaining: 45.1ms
102:	learn: 0.5301569	total: 47.4ms	remaining: 44.7ms
103:	learn: 0.5295763	total: 47.9ms	remaining: 44.2ms
104:	learn: 0.5291501	total: 48.3ms	remaining: 43.7ms
105:	learn: 0.5287967	total: 48.8ms	remaining: 43.3ms
106:	learn: 0.5285017	total: 49.2ms	remaining: 42.8ms
107:	learn: 0.5279481	total: 49.6ms	remaining: 42.3ms
108:	learn: 0.5276069	total: 50.1ms	remaining: 41.8ms
109:	learn: 0.5269468	total: 50.6ms	remaining: 41.4ms
110:	learn: 0.5267933	total: 51ms	remaining: 40.9ms
111:	learn: 0.5261482	total: 51.4ms	remaining: 40.4ms
112:	learn: 0.5256990	total: 51.9ms	remaining: 40ms
113:	learn: 0.5250803	total: 52.4ms	remaining: 39.5ms
114:	learn: 0.5246508	total: 52.9ms	remaining: 39.1ms
115:	learn: 0.5243515	total: 53.3ms	remaining: 38.6ms
116:	learn: 0.5240416	total: 53.7ms	remaining: 38.1ms
117:	learn: 0.5236526	total: 54.2ms	remaining: 37.6ms
118:	learn: 0.5230680	total: 54.6ms	remaining: 37.2ms
119:	learn: 0.5224972	total: 55.1ms	remaining: 36.7ms
120:	learn: 0.5219390	total: 55.5ms	remaining: 36.3ms
121:	learn: 0.5215594	total: 56ms	remaining: 35.8ms
122:	learn: 0.5212984	total: 56.4ms	remaining: 35.3ms
123:	learn: 0.5207552	total: 56.9ms	remaining: 34.9ms
124:	learn: 0.5203874	total: 57.3ms	remaining: 34.4ms
125:	learn: 0.5201064	total: 57.7ms	remaining: 33.9ms
126:	learn: 0.5195792	total: 58.2ms	remaining: 33.4ms
127:	learn: 0.5191572	total: 58.6ms	remaining: 33ms

128:	learn: 0.5189113	total: 59.1ms	remaining: 32.5ms
129:	learn: 0.5184092	total: 59.5ms	remaining: 32ms
130:	learn: 0.5180587	total: 59.9ms	remaining: 31.6ms
131:	learn: 0.5177145	total: 60.4ms	remaining: 31.1ms
132:	learn: 0.5172251	total: 60.8ms	remaining: 30.6ms
133:	learn: 0.5170977	total: 61.3ms	remaining: 30.2ms
134:	learn: 0.5167637	total: 61.7ms	remaining: 29.7ms
135:	learn: 0.5162880	total: 62.2ms	remaining: 29.3ms
136:	learn: 0.5160509	total: 62.7ms	remaining: 28.8ms
137:	learn: 0.5158662	total: 63.1ms	remaining: 28.3ms
138:	learn: 0.5155544	total: 63.6ms	remaining: 27.9ms
139:	learn: 0.5151877	total: 64ms	remaining: 27.4ms
140:	learn: 0.5148886	total: 64.5ms	remaining: 27ms
141:	learn: 0.5145674	total: 64.9ms	remaining: 26.5ms
142:	learn: 0.5142658	total: 65.4ms	remaining: 26.1ms
143:	learn: 0.5141350	total: 65.8ms	remaining: 25.6ms
144:	learn: 0.5138240	total: 66.3ms	remaining: 25.1ms
145:	learn: 0.5133927	total: 66.7ms	remaining: 24.7ms
146:	learn: 0.5130540	total: 67.1ms	remaining: 24.2ms
147:	learn: 0.5129467	total: 67.6ms	remaining: 23.7ms
148:	learn: 0.5126624	total: 68ms	remaining: 23.3ms
149:	learn: 0.5123627	total: 68.5ms	remaining: 22.8ms
150:	learn: 0.5120368	total: 68.9ms	remaining: 22.4ms
151:	learn: 0.5118226	total: 69.3ms	remaining: 21.9ms
152:	learn: 0.5114176	total: 69.8ms	remaining: 21.4ms
153:	learn: 0.5111301	total: 70.2ms	remaining: 21ms
154:	learn: 0.5108201	total: 70.6ms	remaining: 20.5ms
155:	learn: 0.5104310	total: 71.1ms	remaining: 20ms
156:	learn: 0.5100502	total: 71.6ms	remaining: 19.6ms
157:	learn: 0.5098408	total: 72ms	remaining: 19.1ms
158:	learn: 0.5094698	total: 72.4ms	remaining: 18.7ms
159:	learn: 0.5093697	total: 72.9ms	remaining: 18.2ms
160:	learn: 0.5092897	total: 73.3ms	remaining: 17.8ms
161:	learn: 0.5089459	total: 73.8ms	remaining: 17.3ms
162:	learn: 0.5089026	total: 74.2ms	remaining: 16.8ms
163:	learn: 0.5087023	total: 74.6ms	remaining: 16.4ms
164:	learn: 0.5085418	total: 75ms	remaining: 15.9ms
165:	learn: 0.5083470	total: 75.4ms	remaining: 15.4ms
166:	learn: 0.5079926	total: 75.9ms	remaining: 15ms
167:	learn: 0.5077228	total: 76.3ms	remaining: 14.5ms
168:	learn: 0.5074581	total: 76.8ms	remaining: 14.1ms
169:	learn: 0.5071884	total: 77.2ms	remaining: 13.6ms
170:	learn: 0.5071191	total: 77.6ms	remaining: 13.2ms
171:	learn: 0.5069318	total: 78ms	remaining: 12.7ms
172:	learn: 0.5066098	total: 78.5ms	remaining: 12.3ms
173:	learn: 0.5062771	total: 79ms	remaining: 11.8ms
174:	learn: 0.5060164	total: 79.4ms	remaining: 11.3ms
175:	learn: 0.5057604	total: 79.8ms	remaining: 10.9ms
176:	learn: 0.5055095	total: 80.3ms	remaining: 10.4ms

```

177: learn: 0.5051851 total: 80.7ms remaining: 9.97ms
178: learn: 0.5050048 total: 81.1ms remaining: 9.52ms
179: learn: 0.5048254 total: 81.6ms remaining: 9.06ms
180: learn: 0.5045210 total: 82ms remaining: 8.61ms
181: learn: 0.5042063 total: 82.5ms remaining: 8.16ms
182: learn: 0.5040315 total: 82.9ms remaining: 7.71ms
183: learn: 0.5037915 total: 83.4ms remaining: 7.25ms
184: learn: 0.5034850 total: 83.8ms remaining: 6.8ms
185: learn: 0.5033959 total: 84.3ms remaining: 6.34ms
186: learn: 0.5031710 total: 84.7ms remaining: 5.89ms
187: learn: 0.5029372 total: 85.1ms remaining: 5.43ms
188: learn: 0.5028598 total: 85.6ms remaining: 4.98ms
189: learn: 0.5026944 total: 86ms remaining: 4.53ms
190: learn: 0.5025326 total: 86.4ms remaining: 4.07ms
191: learn: 0.5023102 total: 86.9ms remaining: 3.62ms
192: learn: 0.5021433 total: 87.3ms remaining: 3.17ms
193: learn: 0.5020287 total: 87.7ms remaining: 2.71ms
194: learn: 0.5018115 total: 88.2ms remaining: 2.26ms
195: learn: 0.5015220 total: 88.7ms remaining: 1.81ms
196: learn: 0.5013586 total: 89.1ms remaining: 1.36ms
197: learn: 0.5011996 total: 89.5ms remaining: 904us
198: learn: 0.5011297 total: 90ms remaining: 452us
199: learn: 0.5009234 total: 90.5ms remaining: 0us

```

```

Best parameters found: {'depth': 1, 'iterations': 200,
'learning_rate': 0.01}

```

```

Best cross-validation score: 0.9036414565826331

```

```

grid_search_CB_rs = GridSearchCV(estimator=clf_CB,
param_grid=param_grid_CB, cv=3, scoring='recall', n_jobs=-1)
grid_search_CB_rs.fit(X_train_num, y_train_num)
print("Best parameters found: ", grid_search_CB_rs.best_params_)
print("Best cross-validation score: ", grid_search_CB_rs.best_score_)

```

```

0: learn: 0.6080944 total: 523us remaining: 261ms
1: learn: 0.5635495 total: 1.19ms remaining: 296ms
2: learn: 0.5313326 total: 1.68ms remaining: 278ms
3: learn: 0.5126376 total: 2.19ms remaining: 272ms
4: learn: 0.5046608 total: 2.7ms remaining: 267ms
5: learn: 0.4956921 total: 3.21ms remaining: 264ms
6: learn: 0.4862675 total: 3.7ms remaining: 261ms
7: learn: 0.4771353 total: 4.22ms remaining: 259ms
8: learn: 0.4679050 total: 4.73ms remaining: 258ms
9: learn: 0.4632111 total: 5.25ms remaining: 257ms
10: learn: 0.4606159 total: 5.76ms remaining: 256ms
11: learn: 0.4594676 total: 6.28ms remaining: 255ms
12: learn: 0.4582547 total: 6.79ms remaining: 255ms
13: learn: 0.4570740 total: 7.31ms remaining: 254ms
14: learn: 0.4557564 total: 7.83ms remaining: 253ms
15: learn: 0.4533308 total: 8.31ms remaining: 252ms
16: learn: 0.4516063 total: 8.83ms remaining: 251ms

```

17:	learn: 0.4509584	total: 9.34ms	remaining: 250ms
18:	learn: 0.4447666	total: 9.86ms	remaining: 249ms
19:	learn: 0.4442269	total: 10.3ms	remaining: 248ms
20:	learn: 0.4436941	total: 10.9ms	remaining: 248ms
21:	learn: 0.4420930	total: 11.3ms	remaining: 246ms
22:	learn: 0.4410218	total: 11.8ms	remaining: 246ms
23:	learn: 0.4399521	total: 12.3ms	remaining: 245ms
24:	learn: 0.4391560	total: 12.8ms	remaining: 244ms
25:	learn: 0.4386493	total: 13.4ms	remaining: 244ms
26:	learn: 0.4379955	total: 13.9ms	remaining: 243ms
27:	learn: 0.4355700	total: 14.4ms	remaining: 242ms
28:	learn: 0.4346552	total: 14.9ms	remaining: 242ms
29:	learn: 0.4344191	total: 15.4ms	remaining: 241ms
30:	learn: 0.4322325	total: 15.9ms	remaining: 241ms
31:	learn: 0.4307451	total: 16.4ms	remaining: 240ms
32:	learn: 0.4279581	total: 17ms	remaining: 240ms
33:	learn: 0.4269209	total: 17.5ms	remaining: 240ms
34:	learn: 0.4254515	total: 18ms	remaining: 239ms
35:	learn: 0.4251831	total: 18.5ms	remaining: 239ms
36:	learn: 0.4237840	total: 19ms	remaining: 238ms
37:	learn: 0.4228480	total: 19.5ms	remaining: 237ms
38:	learn: 0.4200340	total: 20.1ms	remaining: 237ms
39:	learn: 0.4181988	total: 20.6ms	remaining: 237ms
40:	learn: 0.4172258	total: 21.1ms	remaining: 236ms
41:	learn: 0.4153269	total: 21.6ms	remaining: 235ms
42:	learn: 0.4137167	total: 22.1ms	remaining: 235ms
43:	learn: 0.4124183	total: 22.6ms	remaining: 234ms
44:	learn: 0.4117368	total: 23.1ms	remaining: 234ms
45:	learn: 0.4106157	total: 23.6ms	remaining: 233ms
46:	learn: 0.4100874	total: 24.1ms	remaining: 233ms
47:	learn: 0.4099776	total: 24.6ms	remaining: 232ms
48:	learn: 0.4080710	total: 25.2ms	remaining: 232ms
49:	learn: 0.4066856	total: 25.6ms	remaining: 231ms
50:	learn: 0.4056038	total: 26.1ms	remaining: 230ms
51:	learn: 0.4045576	total: 26.6ms	remaining: 229ms
52:	learn: 0.4043447	total: 27.1ms	remaining: 229ms
53:	learn: 0.4034067	total: 27.6ms	remaining: 228ms
54:	learn: 0.4033459	total: 28.2ms	remaining: 228ms
55:	learn: 0.4024266	total: 28.7ms	remaining: 227ms
56:	learn: 0.4017956	total: 29.2ms	remaining: 227ms
57:	learn: 0.4012425	total: 29.8ms	remaining: 227ms
58:	learn: 0.3999582	total: 30.3ms	remaining: 226ms
59:	learn: 0.3991505	total: 30.8ms	remaining: 226ms
60:	learn: 0.3982058	total: 31.4ms	remaining: 226ms
61:	learn: 0.3981633	total: 31.9ms	remaining: 225ms
62:	learn: 0.3973923	total: 32.4ms	remaining: 225ms
63:	learn: 0.3971759	total: 32.9ms	remaining: 224ms
64:	learn: 0.3966608	total: 33.4ms	remaining: 223ms
65:	learn: 0.3960559	total: 33.9ms	remaining: 223ms

66:	learn: 0.3955406	total: 34.4ms	remaining: 222ms
67:	learn: 0.3952387	total: 34.9ms	remaining: 222ms
68:	learn: 0.3946242	total: 35.4ms	remaining: 221ms
69:	learn: 0.3944717	total: 35.9ms	remaining: 221ms
70:	learn: 0.3943541	total: 36.4ms	remaining: 220ms
71:	learn: 0.3935114	total: 36.9ms	remaining: 219ms
72:	learn: 0.3931366	total: 37.4ms	remaining: 219ms
73:	learn: 0.3924591	total: 38ms	remaining: 218ms
74:	learn: 0.3918851	total: 38.5ms	remaining: 218ms
75:	learn: 0.3917353	total: 39ms	remaining: 218ms
76:	learn: 0.3913468	total: 39.5ms	remaining: 217ms
77:	learn: 0.3909261	total: 39.9ms	remaining: 216ms
78:	learn: 0.3908241	total: 40.4ms	remaining: 216ms
79:	learn: 0.3905827	total: 40.9ms	remaining: 215ms
80:	learn: 0.3897086	total: 41.5ms	remaining: 214ms
81:	learn: 0.3890386	total: 42ms	remaining: 214ms
82:	learn: 0.3883395	total: 42.4ms	remaining: 213ms
83:	learn: 0.3882095	total: 43ms	remaining: 213ms
84:	learn: 0.3881077	total: 43.5ms	remaining: 212ms
85:	learn: 0.3880279	total: 44ms	remaining: 212ms
86:	learn: 0.3874198	total: 44.5ms	remaining: 211ms
87:	learn: 0.3869374	total: 45ms	remaining: 211ms
88:	learn: 0.3864011	total: 45.5ms	remaining: 210ms
89:	learn: 0.3857442	total: 46ms	remaining: 210ms
90:	learn: 0.3856535	total: 46.5ms	remaining: 209ms
91:	learn: 0.3849127	total: 47ms	remaining: 209ms
92:	learn: 0.3845553	total: 47.5ms	remaining: 208ms
93:	learn: 0.3841638	total: 48ms	remaining: 207ms
94:	learn: 0.3837450	total: 48.5ms	remaining: 207ms
95:	learn: 0.3836655	total: 49ms	remaining: 206ms
96:	learn: 0.3835009	total: 49.5ms	remaining: 206ms
97:	learn: 0.3829070	total: 50ms	remaining: 205ms
98:	learn: 0.3823742	total: 50.5ms	remaining: 204ms
99:	learn: 0.3819900	total: 51.1ms	remaining: 204ms
100:	learn: 0.3814339	total: 51.6ms	remaining: 204ms
101:	learn: 0.3812399	total: 52.1ms	remaining: 203ms
102:	learn: 0.3811637	total: 52.7ms	remaining: 203ms
103:	learn: 0.3806828	total: 53.2ms	remaining: 203ms
104:	learn: 0.3797338	total: 53.7ms	remaining: 202ms
105:	learn: 0.3787953	total: 54.3ms	remaining: 202ms
106:	learn: 0.3786025	total: 54.8ms	remaining: 201ms
107:	learn: 0.3785209	total: 55.3ms	remaining: 201ms
108:	learn: 0.3784559	total: 55.8ms	remaining: 200ms
109:	learn: 0.3783993	total: 56.4ms	remaining: 200ms
110:	learn: 0.3779553	total: 56.9ms	remaining: 199ms
111:	learn: 0.3776496	total: 57.3ms	remaining: 199ms
112:	learn: 0.3772878	total: 57.9ms	remaining: 198ms
113:	learn: 0.3766692	total: 58.4ms	remaining: 198ms
114:	learn: 0.3762267	total: 58.9ms	remaining: 197ms

115:	learn:	0.3759237	total:	59.5ms	remaining:	197ms
116:	learn:	0.3756632	total:	60ms	remaining:	196ms
117:	learn:	0.3751062	total:	60.5ms	remaining:	196ms
118:	learn:	0.3746897	total:	61ms	remaining:	195ms
119:	learn:	0.3745665	total:	61.5ms	remaining:	195ms
120:	learn:	0.3740276	total:	62ms	remaining:	194ms
121:	learn:	0.3735510	total:	62.5ms	remaining:	194ms
122:	learn:	0.3732202	total:	63ms	remaining:	193ms
123:	learn:	0.3731447	total:	63.6ms	remaining:	193ms
124:	learn:	0.3726389	total:	64.1ms	remaining:	192ms
125:	learn:	0.3722823	total:	64.6ms	remaining:	192ms
126:	learn:	0.3721014	total:	65.1ms	remaining:	191ms
127:	learn:	0.3717465	total:	65.6ms	remaining:	191ms
128:	learn:	0.3712457	total:	66.2ms	remaining:	190ms
129:	learn:	0.3710109	total:	66.6ms	remaining:	190ms
130:	learn:	0.3706278	total:	67.2ms	remaining:	189ms
131:	learn:	0.3702593	total:	67.7ms	remaining:	189ms
132:	learn:	0.3697052	total:	68.2ms	remaining:	188ms
133:	learn:	0.3693530	total:	68.7ms	remaining:	188ms
134:	learn:	0.3689834	total:	69.2ms	remaining:	187ms
135:	learn:	0.3684503	total:	69.7ms	remaining:	187ms
136:	learn:	0.3681185	total:	70.2ms	remaining:	186ms
137:	learn:	0.3678339	total:	70.7ms	remaining:	185ms
138:	learn:	0.3675762	total:	71.2ms	remaining:	185ms
139:	learn:	0.3675686	total:	71.7ms	remaining:	184ms
140:	learn:	0.3674455	total:	72.2ms	remaining:	184ms
141:	learn:	0.3672139	total:	72.7ms	remaining:	183ms
142:	learn:	0.3667601	total:	73.2ms	remaining:	183ms
143:	learn:	0.3665018	total:	73.7ms	remaining:	182ms
144:	learn:	0.3661205	total:	74.2ms	remaining:	182ms
145:	learn:	0.3660528	total:	74.7ms	remaining:	181ms
146:	learn:	0.3659995	total:	75.2ms	remaining:	181ms
147:	learn:	0.3659383	total:	75.8ms	remaining:	180ms
148:	learn:	0.3657178	total:	76.3ms	remaining:	180ms
149:	learn:	0.3652619	total:	76.8ms	remaining:	179ms
150:	learn:	0.3652012	total:	77.4ms	remaining:	179ms
151:	learn:	0.3646429	total:	78ms	remaining:	179ms
152:	learn:	0.3644062	total:	78.5ms	remaining:	178ms
153:	learn:	0.3640997	total:	79.1ms	remaining:	178ms
154:	learn:	0.3636149	total:	79.5ms	remaining:	177ms
155:	learn:	0.3633091	total:	80ms	remaining:	177ms
156:	learn:	0.3630569	total:	80.6ms	remaining:	176ms
157:	learn:	0.3627010	total:	81.1ms	remaining:	176ms
158:	learn:	0.3623846	total:	81.6ms	remaining:	175ms
159:	learn:	0.3618826	total:	82.1ms	remaining:	174ms
160:	learn:	0.3615627	total:	82.6ms	remaining:	174ms
161:	learn:	0.3612236	total:	83.2ms	remaining:	174ms
162:	learn:	0.3607995	total:	83.7ms	remaining:	173ms
163:	learn:	0.3606230	total:	84.2ms	remaining:	173ms

164:	learn:	0.3604677	total:	84.8ms	remaining:	172ms
165:	learn:	0.3601066	total:	85.3ms	remaining:	172ms
166:	learn:	0.3598195	total:	85.8ms	remaining:	171ms
167:	learn:	0.3595169	total:	86.3ms	remaining:	171ms
168:	learn:	0.3591670	total:	86.8ms	remaining:	170ms
169:	learn:	0.3589819	total:	87.3ms	remaining:	170ms
170:	learn:	0.3585896	total:	87.9ms	remaining:	169ms
171:	learn:	0.3585368	total:	88.4ms	remaining:	169ms
172:	learn:	0.3584276	total:	88.9ms	remaining:	168ms
173:	learn:	0.3581944	total:	89.4ms	remaining:	168ms
174:	learn:	0.3578875	total:	89.9ms	remaining:	167ms
175:	learn:	0.3575969	total:	90.4ms	remaining:	166ms
176:	learn:	0.3573242	total:	90.9ms	remaining:	166ms
177:	learn:	0.3571756	total:	91.5ms	remaining:	165ms
178:	learn:	0.3568798	total:	92ms	remaining:	165ms
179:	learn:	0.3568478	total:	92.5ms	remaining:	164ms
180:	learn:	0.3565063	total:	93ms	remaining:	164ms
181:	learn:	0.3563909	total:	93.5ms	remaining:	163ms
182:	learn:	0.3561218	total:	94ms	remaining:	163ms
183:	learn:	0.3558774	total:	94.5ms	remaining:	162ms
184:	learn:	0.3557042	total:	95.1ms	remaining:	162ms
185:	learn:	0.3555702	total:	95.6ms	remaining:	161ms
186:	learn:	0.3553299	total:	96.1ms	remaining:	161ms
187:	learn:	0.3549084	total:	96.7ms	remaining:	160ms
188:	learn:	0.3547000	total:	97.2ms	remaining:	160ms
189:	learn:	0.3545816	total:	97.7ms	remaining:	159ms
190:	learn:	0.3544011	total:	98.2ms	remaining:	159ms
191:	learn:	0.3542293	total:	98.8ms	remaining:	158ms
192:	learn:	0.3541105	total:	99.3ms	remaining:	158ms
193:	learn:	0.3538998	total:	99.7ms	remaining:	157ms
194:	learn:	0.3537154	total:	100ms	remaining:	157ms
195:	learn:	0.3533526	total:	101ms	remaining:	156ms
196:	learn:	0.3531929	total:	101ms	remaining:	156ms
197:	learn:	0.3529909	total:	102ms	remaining:	155ms
198:	learn:	0.3529791	total:	102ms	remaining:	155ms
199:	learn:	0.3526444	total:	103ms	remaining:	154ms
200:	learn:	0.3524352	total:	103ms	remaining:	154ms
201:	learn:	0.3521090	total:	104ms	remaining:	153ms
202:	learn:	0.3518830	total:	104ms	remaining:	153ms
203:	learn:	0.3515917	total:	105ms	remaining:	152ms
204:	learn:	0.3514679	total:	106ms	remaining:	152ms
205:	learn:	0.3512123	total:	106ms	remaining:	151ms
206:	learn:	0.3511803	total:	107ms	remaining:	151ms
207:	learn:	0.3511532	total:	107ms	remaining:	150ms
208:	learn:	0.3508822	total:	108ms	remaining:	150ms
209:	learn:	0.3508734	total:	108ms	remaining:	149ms
210:	learn:	0.3506878	total:	109ms	remaining:	149ms
211:	learn:	0.3506657	total:	109ms	remaining:	148ms
212:	learn:	0.3503544	total:	110ms	remaining:	148ms

213:	learn:	0.3503269	total:	110ms	remaining:	147ms
214:	learn:	0.3502981	total:	111ms	remaining:	147ms
215:	learn:	0.3499058	total:	111ms	remaining:	146ms
216:	learn:	0.3496990	total:	112ms	remaining:	146ms
217:	learn:	0.3495420	total:	112ms	remaining:	145ms
218:	learn:	0.3495221	total:	113ms	remaining:	145ms
219:	learn:	0.3493356	total:	113ms	remaining:	144ms
220:	learn:	0.3493180	total:	114ms	remaining:	144ms
221:	learn:	0.3490742	total:	114ms	remaining:	143ms
222:	learn:	0.3489656	total:	115ms	remaining:	143ms
223:	learn:	0.3488378	total:	115ms	remaining:	142ms
224:	learn:	0.3486743	total:	116ms	remaining:	142ms
225:	learn:	0.3485296	total:	116ms	remaining:	141ms
226:	learn:	0.3481476	total:	117ms	remaining:	140ms
227:	learn:	0.3478041	total:	117ms	remaining:	140ms
228:	learn:	0.3475726	total:	118ms	remaining:	139ms
229:	learn:	0.3473417	total:	118ms	remaining:	139ms
230:	learn:	0.3472060	total:	119ms	remaining:	138ms
231:	learn:	0.3470568	total:	119ms	remaining:	138ms
232:	learn:	0.3468233	total:	120ms	remaining:	137ms
233:	learn:	0.3466757	total:	120ms	remaining:	137ms
234:	learn:	0.3462180	total:	121ms	remaining:	136ms
235:	learn:	0.3460027	total:	121ms	remaining:	136ms
236:	learn:	0.3459705	total:	122ms	remaining:	135ms
237:	learn:	0.3457685	total:	122ms	remaining:	135ms
238:	learn:	0.3457427	total:	123ms	remaining:	134ms
239:	learn:	0.3456156	total:	123ms	remaining:	134ms
240:	learn:	0.3453263	total:	124ms	remaining:	133ms
241:	learn:	0.3450351	total:	124ms	remaining:	133ms
242:	learn:	0.3448881	total:	125ms	remaining:	132ms
243:	learn:	0.3446367	total:	125ms	remaining:	132ms
244:	learn:	0.3443535	total:	126ms	remaining:	131ms
245:	learn:	0.3442284	total:	127ms	remaining:	131ms
246:	learn:	0.3438983	total:	127ms	remaining:	130ms
247:	learn:	0.3435946	total:	128ms	remaining:	130ms
248:	learn:	0.3433937	total:	128ms	remaining:	129ms
249:	learn:	0.3432418	total:	129ms	remaining:	129ms
250:	learn:	0.3430320	total:	129ms	remaining:	128ms
251:	learn:	0.3428596	total:	130ms	remaining:	128ms
252:	learn:	0.3426484	total:	130ms	remaining:	127ms
253:	learn:	0.3424559	total:	131ms	remaining:	127ms
254:	learn:	0.3423401	total:	131ms	remaining:	126ms
255:	learn:	0.3420628	total:	132ms	remaining:	126ms
256:	learn:	0.3418248	total:	132ms	remaining:	125ms
257:	learn:	0.3418178	total:	133ms	remaining:	125ms
258:	learn:	0.3416214	total:	133ms	remaining:	124ms
259:	learn:	0.3414172	total:	134ms	remaining:	124ms
260:	learn:	0.3413295	total:	134ms	remaining:	123ms
261:	learn:	0.3410334	total:	135ms	remaining:	123ms

262:	learn:	0.3408874	total:	135ms	remaining:	122ms
263:	learn:	0.3405891	total:	136ms	remaining:	122ms
264:	learn:	0.3404660	total:	136ms	remaining:	121ms
265:	learn:	0.3404611	total:	137ms	remaining:	121ms
266:	learn:	0.3404323	total:	138ms	remaining:	120ms
267:	learn:	0.3401971	total:	138ms	remaining:	120ms
268:	learn:	0.3401755	total:	139ms	remaining:	119ms
269:	learn:	0.3399885	total:	139ms	remaining:	118ms
270:	learn:	0.3396751	total:	140ms	remaining:	118ms
271:	learn:	0.3394025	total:	140ms	remaining:	117ms
272:	learn:	0.3392740	total:	141ms	remaining:	117ms
273:	learn:	0.3389513	total:	141ms	remaining:	116ms
274:	learn:	0.3387322	total:	142ms	remaining:	116ms
275:	learn:	0.3385927	total:	142ms	remaining:	115ms
276:	learn:	0.3384373	total:	143ms	remaining:	115ms
277:	learn:	0.3383039	total:	143ms	remaining:	114ms
278:	learn:	0.3381922	total:	144ms	remaining:	114ms
279:	learn:	0.3378764	total:	144ms	remaining:	113ms
280:	learn:	0.3377845	total:	145ms	remaining:	113ms
281:	learn:	0.3376141	total:	145ms	remaining:	112ms
282:	learn:	0.3374731	total:	146ms	remaining:	112ms
283:	learn:	0.3373644	total:	146ms	remaining:	111ms
284:	learn:	0.3372553	total:	147ms	remaining:	111ms
285:	learn:	0.3371321	total:	147ms	remaining:	110ms
286:	learn:	0.3369228	total:	148ms	remaining:	110ms
287:	learn:	0.3367683	total:	148ms	remaining:	109ms
288:	learn:	0.3366344	total:	149ms	remaining:	109ms
289:	learn:	0.3365381	total:	149ms	remaining:	108ms
290:	learn:	0.3365279	total:	150ms	remaining:	108ms
291:	learn:	0.3363326	total:	150ms	remaining:	107ms
292:	learn:	0.3361956	total:	151ms	remaining:	107ms
293:	learn:	0.3359454	total:	151ms	remaining:	106ms
294:	learn:	0.3357096	total:	152ms	remaining:	106ms
295:	learn:	0.3357076	total:	152ms	remaining:	105ms
296:	learn:	0.3357064	total:	153ms	remaining:	105ms
297:	learn:	0.3355001	total:	153ms	remaining:	104ms
298:	learn:	0.3351558	total:	154ms	remaining:	104ms
299:	learn:	0.3350860	total:	155ms	remaining:	103ms
300:	learn:	0.3349567	total:	155ms	remaining:	103ms
301:	learn:	0.3347214	total:	156ms	remaining:	102ms
302:	learn:	0.3346949	total:	156ms	remaining:	101ms
303:	learn:	0.3344915	total:	157ms	remaining:	101ms
304:	learn:	0.3343409	total:	157ms	remaining:	100ms
305:	learn:	0.3341780	total:	158ms	remaining:	99.9ms
306:	learn:	0.3340735	total:	158ms	remaining:	99.4ms
307:	learn:	0.3339600	total:	159ms	remaining:	98.9ms
308:	learn:	0.3335195	total:	159ms	remaining:	98.4ms
309:	learn:	0.3333811	total:	160ms	remaining:	97.9ms
310:	learn:	0.3331108	total:	160ms	remaining:	97.4ms

311:	learn:	0.3328763	total:	161ms	remaining:	96.9ms
312:	learn:	0.3327618	total:	161ms	remaining:	96.4ms
313:	learn:	0.3327238	total:	162ms	remaining:	95.9ms
314:	learn:	0.3325711	total:	162ms	remaining:	95.4ms
315:	learn:	0.3324298	total:	163ms	remaining:	94.9ms
316:	learn:	0.3323215	total:	163ms	remaining:	94.3ms
317:	learn:	0.3321788	total:	164ms	remaining:	93.8ms
318:	learn:	0.3320904	total:	164ms	remaining:	93.3ms
319:	learn:	0.3320116	total:	165ms	remaining:	92.8ms
320:	learn:	0.3319846	total:	165ms	remaining:	92.3ms
321:	learn:	0.3318531	total:	166ms	remaining:	91.7ms
322:	learn:	0.3317141	total:	166ms	remaining:	91.2ms
323:	learn:	0.3316116	total:	167ms	remaining:	90.7ms
324:	learn:	0.3315014	total:	167ms	remaining:	90.2ms
325:	learn:	0.3314145	total:	168ms	remaining:	89.7ms
326:	learn:	0.3312427	total:	169ms	remaining:	89.1ms
327:	learn:	0.3310890	total:	169ms	remaining:	88.6ms
328:	learn:	0.3310869	total:	169ms	remaining:	88.1ms
329:	learn:	0.3309794	total:	170ms	remaining:	87.6ms
330:	learn:	0.3308014	total:	171ms	remaining:	87.1ms
331:	learn:	0.3305363	total:	171ms	remaining:	86.5ms
332:	learn:	0.3305150	total:	172ms	remaining:	86ms
333:	learn:	0.3303770	total:	172ms	remaining:	85.5ms
334:	learn:	0.3301918	total:	173ms	remaining:	85ms
335:	learn:	0.3300068	total:	173ms	remaining:	84.5ms
336:	learn:	0.3299815	total:	174ms	remaining:	83.9ms
337:	learn:	0.3298269	total:	174ms	remaining:	83.4ms
338:	learn:	0.3297757	total:	175ms	remaining:	82.9ms
339:	learn:	0.3297565	total:	175ms	remaining:	82.4ms
340:	learn:	0.3296871	total:	176ms	remaining:	81.9ms
341:	learn:	0.3295387	total:	176ms	remaining:	81.4ms
342:	learn:	0.3293625	total:	177ms	remaining:	80.8ms
343:	learn:	0.3291867	total:	177ms	remaining:	80.3ms
344:	learn:	0.3290709	total:	178ms	remaining:	79.8ms
345:	learn:	0.3287346	total:	178ms	remaining:	79.3ms
346:	learn:	0.3284034	total:	179ms	remaining:	78.8ms
347:	learn:	0.3283125	total:	179ms	remaining:	78.3ms
348:	learn:	0.3281978	total:	180ms	remaining:	77.8ms
349:	learn:	0.3280444	total:	180ms	remaining:	77.2ms
350:	learn:	0.3279616	total:	181ms	remaining:	76.7ms
351:	learn:	0.3278696	total:	181ms	remaining:	76.2ms
352:	learn:	0.3278390	total:	182ms	remaining:	75.7ms
353:	learn:	0.3275271	total:	182ms	remaining:	75.2ms
354:	learn:	0.3273034	total:	183ms	remaining:	74.6ms
355:	learn:	0.3272118	total:	183ms	remaining:	74.1ms
356:	learn:	0.3270803	total:	184ms	remaining:	73.6ms
357:	learn:	0.3269667	total:	185ms	remaining:	73.2ms
358:	learn:	0.3267706	total:	185ms	remaining:	72.7ms
359:	learn:	0.3266584	total:	186ms	remaining:	72.2ms

360:	learn:	0.3265110	total:	186ms	remaining:	71.7ms
361:	learn:	0.3264394	total:	187ms	remaining:	71.2ms
362:	learn:	0.3264032	total:	187ms	remaining:	70.7ms
363:	learn:	0.3263894	total:	188ms	remaining:	70.1ms
364:	learn:	0.3262553	total:	188ms	remaining:	69.6ms
365:	learn:	0.3261783	total:	189ms	remaining:	69.1ms
366:	learn:	0.3259777	total:	189ms	remaining:	68.6ms
367:	learn:	0.3258641	total:	190ms	remaining:	68.1ms
368:	learn:	0.3258306	total:	190ms	remaining:	67.6ms
369:	learn:	0.3257572	total:	191ms	remaining:	67ms
370:	learn:	0.3255957	total:	191ms	remaining:	66.5ms
371:	learn:	0.3254806	total:	192ms	remaining:	66ms
372:	learn:	0.3254506	total:	192ms	remaining:	65.5ms
373:	learn:	0.3254449	total:	193ms	remaining:	65ms
374:	learn:	0.3254221	total:	193ms	remaining:	64.5ms
375:	learn:	0.3253237	total:	194ms	remaining:	63.9ms
376:	learn:	0.3251704	total:	194ms	remaining:	63.4ms
377:	learn:	0.3251650	total:	195ms	remaining:	62.9ms
378:	learn:	0.3250729	total:	195ms	remaining:	62.4ms
379:	learn:	0.3249400	total:	196ms	remaining:	61.9ms
380:	learn:	0.3249362	total:	196ms	remaining:	61.4ms
381:	learn:	0.3247724	total:	197ms	remaining:	60.8ms
382:	learn:	0.3245669	total:	197ms	remaining:	60.3ms
383:	learn:	0.3244750	total:	198ms	remaining:	59.8ms
384:	learn:	0.3243214	total:	198ms	remaining:	59.3ms
385:	learn:	0.3241939	total:	199ms	remaining:	58.7ms
386:	learn:	0.3241873	total:	199ms	remaining:	58.2ms
387:	learn:	0.3240517	total:	200ms	remaining:	57.7ms
388:	learn:	0.3239814	total:	200ms	remaining:	57.2ms
389:	learn:	0.3239662	total:	201ms	remaining:	56.7ms
390:	learn:	0.3238743	total:	202ms	remaining:	56.2ms
391:	learn:	0.3237422	total:	202ms	remaining:	55.7ms
392:	learn:	0.3236467	total:	203ms	remaining:	55.1ms
393:	learn:	0.3234668	total:	203ms	remaining:	54.6ms
394:	learn:	0.3234604	total:	204ms	remaining:	54.1ms
395:	learn:	0.3233670	total:	204ms	remaining:	53.6ms
396:	learn:	0.3232740	total:	205ms	remaining:	53.1ms
397:	learn:	0.3230569	total:	205ms	remaining:	52.6ms
398:	learn:	0.3229359	total:	206ms	remaining:	52ms
399:	learn:	0.3227119	total:	206ms	remaining:	51.5ms
400:	learn:	0.3226198	total:	207ms	remaining:	51ms
401:	learn:	0.3226068	total:	207ms	remaining:	50.5ms
402:	learn:	0.3225226	total:	208ms	remaining:	50ms
403:	learn:	0.3223330	total:	208ms	remaining:	49.5ms
404:	learn:	0.3220108	total:	209ms	remaining:	49ms
405:	learn:	0.3218301	total:	209ms	remaining:	48.4ms
406:	learn:	0.3217439	total:	210ms	remaining:	47.9ms
407:	learn:	0.3216402	total:	210ms	remaining:	47.4ms
408:	learn:	0.3215465	total:	211ms	remaining:	46.9ms

409:	learn:	0.3215344	total:	211ms	remaining:	46.4ms
410:	learn:	0.3214247	total:	212ms	remaining:	45.8ms
411:	learn:	0.3213538	total:	212ms	remaining:	45.3ms
412:	learn:	0.3212550	total:	213ms	remaining:	44.8ms
413:	learn:	0.3212425	total:	213ms	remaining:	44.3ms
414:	learn:	0.3211496	total:	214ms	remaining:	43.8ms
415:	learn:	0.3210411	total:	214ms	remaining:	43.3ms
416:	learn:	0.3209816	total:	215ms	remaining:	42.8ms
417:	learn:	0.3209646	total:	215ms	remaining:	42.2ms
418:	learn:	0.3209346	total:	216ms	remaining:	41.7ms
419:	learn:	0.3207276	total:	216ms	remaining:	41.2ms
420:	learn:	0.3206486	total:	217ms	remaining:	40.7ms
421:	learn:	0.3206293	total:	217ms	remaining:	40.2ms
422:	learn:	0.3205024	total:	218ms	remaining:	39.7ms
423:	learn:	0.3203781	total:	218ms	remaining:	39.1ms
424:	learn:	0.3203137	total:	219ms	remaining:	38.6ms
425:	learn:	0.3202981	total:	219ms	remaining:	38.1ms
426:	learn:	0.3202185	total:	220ms	remaining:	37.6ms
427:	learn:	0.3201693	total:	220ms	remaining:	37.1ms
428:	learn:	0.3201118	total:	221ms	remaining:	36.6ms
429:	learn:	0.3200634	total:	221ms	remaining:	36ms
430:	learn:	0.3199833	total:	222ms	remaining:	35.5ms
431:	learn:	0.3199750	total:	222ms	remaining:	35ms
432:	learn:	0.3198192	total:	223ms	remaining:	34.5ms
433:	learn:	0.3197027	total:	223ms	remaining:	34ms
434:	learn:	0.3195717	total:	224ms	remaining:	33.5ms
435:	learn:	0.3194617	total:	224ms	remaining:	32.9ms
436:	learn:	0.3192788	total:	225ms	remaining:	32.4ms
437:	learn:	0.3191986	total:	225ms	remaining:	31.9ms
438:	learn:	0.3191331	total:	226ms	remaining:	31.4ms
439:	learn:	0.3191305	total:	226ms	remaining:	30.9ms
440:	learn:	0.3190295	total:	227ms	remaining:	30.4ms
441:	learn:	0.3190181	total:	227ms	remaining:	29.8ms
442:	learn:	0.3189820	total:	228ms	remaining:	29.3ms
443:	learn:	0.3188587	total:	228ms	remaining:	28.8ms
444:	learn:	0.3187865	total:	229ms	remaining:	28.3ms
445:	learn:	0.3186377	total:	229ms	remaining:	27.8ms
446:	learn:	0.3186331	total:	230ms	remaining:	27.3ms
447:	learn:	0.3185329	total:	230ms	remaining:	26.7ms
448:	learn:	0.3183842	total:	231ms	remaining:	26.2ms
449:	learn:	0.3177105	total:	231ms	remaining:	25.7ms
450:	learn:	0.3176455	total:	232ms	remaining:	25.2ms
451:	learn:	0.3175902	total:	233ms	remaining:	24.7ms
452:	learn:	0.3175490	total:	233ms	remaining:	24.2ms
453:	learn:	0.3174358	total:	234ms	remaining:	23.7ms
454:	learn:	0.3173340	total:	234ms	remaining:	23.2ms
455:	learn:	0.3172049	total:	235ms	remaining:	22.6ms
456:	learn:	0.3171359	total:	235ms	remaining:	22.1ms
457:	learn:	0.3170550	total:	236ms	remaining:	21.6ms


```
458: learn: 0.3168738 total: 236ms remaining: 21.1ms
459: learn: 0.3167736 total: 237ms remaining: 20.6ms
460: learn: 0.3167144 total: 237ms remaining: 20.1ms
461: learn: 0.3166192 total: 238ms remaining: 19.5ms
462: learn: 0.3165891 total: 238ms remaining: 19ms
463: learn: 0.3165219 total: 239ms remaining: 18.5ms
464: learn: 0.3164780 total: 239ms remaining: 18ms
465: learn: 0.3162820 total: 240ms remaining: 17.5ms
466: learn: 0.3162737 total: 240ms remaining: 17ms
467: learn: 0.3162576 total: 241ms remaining: 16.5ms
468: learn: 0.3161288 total: 241ms remaining: 15.9ms
469: learn: 0.3160669 total: 242ms remaining: 15.4ms
470: learn: 0.3158221 total: 242ms remaining: 14.9ms
471: learn: 0.3158176 total: 243ms remaining: 14.4ms
472: learn: 0.3158146 total: 243ms remaining: 13.9ms
473: learn: 0.3157910 total: 244ms remaining: 13.4ms
474: learn: 0.3156625 total: 244ms remaining: 12.9ms
475: learn: 0.3156446 total: 245ms remaining: 12.3ms
476: learn: 0.3155450 total: 245ms remaining: 11.8ms
477: learn: 0.3155288 total: 246ms remaining: 11.3ms
478: learn: 0.3153958 total: 246ms remaining: 10.8ms
479: learn: 0.3153945 total: 247ms remaining: 10.3ms
480: learn: 0.3153255 total: 247ms remaining: 9.77ms
481: learn: 0.3152440 total: 248ms remaining: 9.26ms
482: learn: 0.3151974 total: 248ms remaining: 8.74ms
483: learn: 0.3149876 total: 249ms remaining: 8.23ms
484: learn: 0.3149816 total: 249ms remaining: 7.71ms
485: learn: 0.3149008 total: 250ms remaining: 7.2ms
486: learn: 0.3147986 total: 250ms remaining: 6.68ms
487: learn: 0.3146740 total: 251ms remaining: 6.17ms
488: learn: 0.3146051 total: 251ms remaining: 5.66ms
489: learn: 0.3144591 total: 252ms remaining: 5.14ms
490: learn: 0.3144491 total: 253ms remaining: 4.63ms
491: learn: 0.3143670 total: 253ms remaining: 4.11ms
492: learn: 0.3142247 total: 254ms remaining: 3.6ms
493: learn: 0.3141569 total: 254ms remaining: 3.09ms
494: learn: 0.3140947 total: 255ms remaining: 2.57ms
495: learn: 0.3140855 total: 255ms remaining: 2.06ms
496: learn: 0.3138302 total: 256ms remaining: 1.54ms
497: learn: 0.3138232 total: 256ms remaining: 1.03ms
498: learn: 0.3138026 total: 257ms remaining: 514us
499: learn: 0.3136707 total: 257ms remaining: 0us
```

```
Best parameters found: {'depth': 2, 'iterations': 500,
'learning_rate': 0.2}
```

```
Best cross-validation score: 0.6135265700483091
```

```
grid_search_CB_fls = GridSearchCV(estimator=clf_CB,
param_grid=param_grid_CB, cv=3, scoring='f1', n_jobs=-1)
grid_search_CB_fls.fit(X_train_num, y_train_num)
```

```
print("Best parameters found: ", grid_search_CB_fls.best_params_)
print("Best cross-validation score: ", grid_search_CB_fls.best_score_)
```

0:	learn:	0.6276470	total:	240us	remaining:	23.8ms
1:	learn:	0.5847199	total:	496us	remaining:	24.4ms
2:	learn:	0.5532408	total:	675us	remaining:	21.8ms
3:	learn:	0.5333715	total:	845us	remaining:	20.3ms
4:	learn:	0.5192353	total:	1.04ms	remaining:	19.8ms
5:	learn:	0.5077749	total:	1.22ms	remaining:	19ms
6:	learn:	0.5022489	total:	1.38ms	remaining:	18.3ms
7:	learn:	0.4958642	total:	1.55ms	remaining:	17.9ms
8:	learn:	0.4878928	total:	1.72ms	remaining:	17.4ms
9:	learn:	0.4843846	total:	1.89ms	remaining:	17ms
10:	learn:	0.4802313	total:	2.06ms	remaining:	16.7ms
11:	learn:	0.4791065	total:	2.22ms	remaining:	16.3ms
12:	learn:	0.4768860	total:	2.39ms	remaining:	16ms
13:	learn:	0.4703731	total:	2.55ms	remaining:	15.7ms
14:	learn:	0.4681357	total:	2.71ms	remaining:	15.4ms
15:	learn:	0.4659176	total:	2.88ms	remaining:	15.1ms
16:	learn:	0.4630902	total:	3.05ms	remaining:	14.9ms
17:	learn:	0.4598043	total:	3.22ms	remaining:	14.7ms
18:	learn:	0.4582510	total:	3.39ms	remaining:	14.4ms
19:	learn:	0.4571182	total:	3.56ms	remaining:	14.2ms
20:	learn:	0.4548098	total:	3.72ms	remaining:	14ms
21:	learn:	0.4537404	total:	3.88ms	remaining:	13.8ms
22:	learn:	0.4531709	total:	4.04ms	remaining:	13.5ms
23:	learn:	0.4519392	total:	4.21ms	remaining:	13.3ms
24:	learn:	0.4509585	total:	4.37ms	remaining:	13.1ms
25:	learn:	0.4494856	total:	4.53ms	remaining:	12.9ms
26:	learn:	0.4486960	total:	4.69ms	remaining:	12.7ms
27:	learn:	0.4461007	total:	4.86ms	remaining:	12.5ms
28:	learn:	0.4441502	total:	5.02ms	remaining:	12.3ms
29:	learn:	0.4425209	total:	5.18ms	remaining:	12.1ms
30:	learn:	0.4417994	total:	5.33ms	remaining:	11.9ms
31:	learn:	0.4410726	total:	5.49ms	remaining:	11.7ms
32:	learn:	0.4396076	total:	5.65ms	remaining:	11.5ms
33:	learn:	0.4385452	total:	5.81ms	remaining:	11.3ms
34:	learn:	0.4378752	total:	5.97ms	remaining:	11.1ms
35:	learn:	0.4377054	total:	6.12ms	remaining:	10.9ms
36:	learn:	0.4376724	total:	6.28ms	remaining:	10.7ms
37:	learn:	0.4370485	total:	6.44ms	remaining:	10.5ms
38:	learn:	0.4362376	total:	6.61ms	remaining:	10.3ms
39:	learn:	0.4357493	total:	6.77ms	remaining:	10.2ms
40:	learn:	0.4348155	total:	6.93ms	remaining:	9.97ms
41:	learn:	0.4340378	total:	7.09ms	remaining:	9.79ms
42:	learn:	0.4324768	total:	7.25ms	remaining:	9.61ms
43:	learn:	0.4318184	total:	7.4ms	remaining:	9.42ms
44:	learn:	0.4309399	total:	7.56ms	remaining:	9.24ms
45:	learn:	0.4308908	total:	7.72ms	remaining:	9.07ms
46:	learn:	0.4308134	total:	7.88ms	remaining:	8.89ms

47:	learn: 0.4302045	total: 8.04ms	remaining: 8.71ms
48:	learn: 0.4301610	total: 8.2ms	remaining: 8.54ms
49:	learn: 0.4293160	total: 8.36ms	remaining: 8.36ms
50:	learn: 0.4292664	total: 8.52ms	remaining: 8.18ms
51:	learn: 0.4292167	total: 8.68ms	remaining: 8.01ms
52:	learn: 0.4277321	total: 8.84ms	remaining: 7.84ms
53:	learn: 0.4262064	total: 9.02ms	remaining: 7.68ms
54:	learn: 0.4254772	total: 9.18ms	remaining: 7.51ms
55:	learn: 0.4254133	total: 9.33ms	remaining: 7.33ms
56:	learn: 0.4248461	total: 9.5ms	remaining: 7.16ms
57:	learn: 0.4236742	total: 9.66ms	remaining: 6.99ms
58:	learn: 0.4236281	total: 9.82ms	remaining: 6.82ms
59:	learn: 0.4233132	total: 9.98ms	remaining: 6.65ms
60:	learn: 0.4227022	total: 10.1ms	remaining: 6.48ms
61:	learn: 0.4221701	total: 10.3ms	remaining: 6.31ms
62:	learn: 0.4217224	total: 10.5ms	remaining: 6.14ms
63:	learn: 0.4212130	total: 10.6ms	remaining: 5.97ms
64:	learn: 0.4206512	total: 10.8ms	remaining: 5.8ms
65:	learn: 0.4202259	total: 10.9ms	remaining: 5.63ms
66:	learn: 0.4199014	total: 11.1ms	remaining: 5.46ms
67:	learn: 0.4193975	total: 11.2ms	remaining: 5.29ms
68:	learn: 0.4193482	total: 11.4ms	remaining: 5.12ms
69:	learn: 0.4191463	total: 11.6ms	remaining: 4.95ms
70:	learn: 0.4190988	total: 11.7ms	remaining: 4.79ms
71:	learn: 0.4181470	total: 11.9ms	remaining: 4.63ms
72:	learn: 0.4181008	total: 12.1ms	remaining: 4.46ms
73:	learn: 0.4176992	total: 12.2ms	remaining: 4.29ms
74:	learn: 0.4169678	total: 12.4ms	remaining: 4.13ms
75:	learn: 0.4158516	total: 12.6ms	remaining: 3.96ms
76:	learn: 0.4155048	total: 12.7ms	remaining: 3.8ms
77:	learn: 0.4152551	total: 12.9ms	remaining: 3.63ms
78:	learn: 0.4144023	total: 13.1ms	remaining: 3.47ms
79:	learn: 0.4143550	total: 13.2ms	remaining: 3.3ms
80:	learn: 0.4139945	total: 13.4ms	remaining: 3.14ms
81:	learn: 0.4139499	total: 13.6ms	remaining: 2.97ms
82:	learn: 0.4135492	total: 13.7ms	remaining: 2.81ms
83:	learn: 0.4133455	total: 13.9ms	remaining: 2.64ms
84:	learn: 0.4133018	total: 14ms	remaining: 2.48ms
85:	learn: 0.4126827	total: 14.2ms	remaining: 2.31ms
86:	learn: 0.4124547	total: 14.4ms	remaining: 2.15ms
87:	learn: 0.4122294	total: 14.5ms	remaining: 1.98ms
88:	learn: 0.4112565	total: 14.7ms	remaining: 1.82ms
89:	learn: 0.4112125	total: 14.8ms	remaining: 1.65ms
90:	learn: 0.4104615	total: 15ms	remaining: 1.48ms
91:	learn: 0.4101789	total: 15.2ms	remaining: 1.32ms
92:	learn: 0.4094236	total: 15.3ms	remaining: 1.15ms
93:	learn: 0.4093545	total: 15.5ms	remaining: 988us
94:	learn: 0.4092884	total: 15.6ms	remaining: 822us
95:	learn: 0.4086227	total: 15.8ms	remaining: 657us

```
96: learn: 0.4086013 total: 15.9ms remaining: 493us
97: learn: 0.4085394 total: 16.1ms remaining: 328us
98: learn: 0.4084995 total: 16.3ms remaining: 164us
99: learn: 0.4079941 total: 16.4ms remaining: 0us
```

```
Best parameters found: {'depth': 2, 'iterations': 100,
'learning_rate': 0.2}
```

```
Best cross-validation score: 0.7133003448792922
```

```
grid_search_CB_ras = GridSearchCV(estimator=clf_CB,
param_grid=param_grid_CB, cv=3, scoring='roc_auc_ovr', n_jobs=-1)
grid_search_CB_ras.fit(X_train_num, y_train_num)
print("Best parameters found: ", grid_search_CB_ras.best_params_)
print("Best cross-validation score: ", grid_search_CB_ras.best_score_)
```

```
0: learn: 0.6894531 total: 391us remaining: 38.8ms
1: learn: 0.6862624 total: 822us remaining: 40.3ms
2: learn: 0.6832624 total: 1.17ms remaining: 37.9ms
3: learn: 0.6800204 total: 1.48ms remaining: 35.5ms
4: learn: 0.6770671 total: 1.78ms remaining: 33.9ms
5: learn: 0.6740915 total: 2.09ms remaining: 32.7ms
6: learn: 0.6714896 total: 2.41ms remaining: 32ms
7: learn: 0.6687351 total: 2.71ms remaining: 31.2ms
8: learn: 0.6657163 total: 3.04ms remaining: 30.8ms
9: learn: 0.6630885 total: 3.34ms remaining: 30.1ms
10: learn: 0.6608303 total: 3.65ms remaining: 29.6ms
11: learn: 0.6578313 total: 3.96ms remaining: 29ms
12: learn: 0.6551627 total: 4.26ms remaining: 28.5ms
13: learn: 0.6522997 total: 4.55ms remaining: 28ms
14: learn: 0.6498259 total: 4.86ms remaining: 27.5ms
15: learn: 0.6473324 total: 5.18ms remaining: 27.2ms
16: learn: 0.6448181 total: 5.5ms remaining: 26.8ms
17: learn: 0.6424372 total: 5.81ms remaining: 26.5ms
18: learn: 0.6403244 total: 6.12ms remaining: 26.1ms
19: learn: 0.6379932 total: 6.42ms remaining: 25.7ms
20: learn: 0.6354813 total: 6.73ms remaining: 25.3ms
21: learn: 0.6332918 total: 7.04ms remaining: 25ms
22: learn: 0.6306322 total: 7.35ms remaining: 24.6ms
23: learn: 0.6282617 total: 7.66ms remaining: 24.3ms
24: learn: 0.6257491 total: 7.97ms remaining: 23.9ms
25: learn: 0.6233017 total: 8.29ms remaining: 23.6ms
26: learn: 0.6213025 total: 8.6ms remaining: 23.2ms
27: learn: 0.6188328 total: 8.91ms remaining: 22.9ms
28: learn: 0.6167615 total: 9.22ms remaining: 22.6ms
29: learn: 0.6147249 total: 9.55ms remaining: 22.3ms
30: learn: 0.6125213 total: 9.85ms remaining: 21.9ms
31: learn: 0.6106519 total: 10ms remaining: 21.3ms
32: learn: 0.6088421 total: 10.3ms remaining: 21ms
33: learn: 0.6069171 total: 10.7ms remaining: 20.7ms
34: learn: 0.6050221 total: 11ms remaining: 20.4ms
35: learn: 0.6032607 total: 11.3ms remaining: 20ms
```

36:	learn: 0.6017555	total: 11.6ms	remaining: 19.7ms
37:	learn: 0.6002395	total: 11.9ms	remaining: 19.4ms
38:	learn: 0.5983850	total: 12.2ms	remaining: 19.1ms
39:	learn: 0.5966720	total: 12.5ms	remaining: 18.8ms
40:	learn: 0.5947786	total: 12.8ms	remaining: 18.4ms
41:	learn: 0.5930982	total: 13.1ms	remaining: 18.1ms
42:	learn: 0.5912396	total: 13.4ms	remaining: 17.8ms
43:	learn: 0.5896149	total: 13.7ms	remaining: 17.4ms
44:	learn: 0.5879024	total: 14ms	remaining: 17.1ms
45:	learn: 0.5863052	total: 14.3ms	remaining: 16.8ms
46:	learn: 0.5846471	total: 14.6ms	remaining: 16.5ms
47:	learn: 0.5829613	total: 14.9ms	remaining: 16.2ms
48:	learn: 0.5813454	total: 15.2ms	remaining: 15.9ms
49:	learn: 0.5797543	total: 15.5ms	remaining: 15.5ms
50:	learn: 0.5781521	total: 15.8ms	remaining: 15.2ms
51:	learn: 0.5767197	total: 16.1ms	remaining: 14.9ms
52:	learn: 0.5747702	total: 16.4ms	remaining: 14.6ms
53:	learn: 0.5731821	total: 16.7ms	remaining: 14.2ms
54:	learn: 0.5716903	total: 17ms	remaining: 13.9ms
55:	learn: 0.5701244	total: 17.3ms	remaining: 13.6ms
56:	learn: 0.5683163	total: 17.7ms	remaining: 13.3ms
57:	learn: 0.5670521	total: 18ms	remaining: 13ms
58:	learn: 0.5654323	total: 18.3ms	remaining: 12.7ms
59:	learn: 0.5640238	total: 18.6ms	remaining: 12.4ms
60:	learn: 0.5626267	total: 18.9ms	remaining: 12.1ms
61:	learn: 0.5611685	total: 19.2ms	remaining: 11.8ms
62:	learn: 0.5598292	total: 19.5ms	remaining: 11.5ms
63:	learn: 0.5584868	total: 19.8ms	remaining: 11.2ms
64:	learn: 0.5571838	total: 20.1ms	remaining: 10.8ms
65:	learn: 0.5559585	total: 20.4ms	remaining: 10.5ms
66:	learn: 0.5545719	total: 20.7ms	remaining: 10.2ms
67:	learn: 0.5532962	total: 21ms	remaining: 9.9ms
68:	learn: 0.5521606	total: 21.4ms	remaining: 9.59ms
69:	learn: 0.5506209	total: 21.7ms	remaining: 9.28ms
70:	learn: 0.5493935	total: 22ms	remaining: 8.97ms
71:	learn: 0.5482028	total: 22.3ms	remaining: 8.68ms
72:	learn: 0.5470484	total: 22.6ms	remaining: 8.36ms
73:	learn: 0.5460051	total: 22.9ms	remaining: 8.05ms
74:	learn: 0.5448477	total: 23.2ms	remaining: 7.74ms
75:	learn: 0.5439007	total: 23.5ms	remaining: 7.43ms
76:	learn: 0.5428415	total: 23.8ms	remaining: 7.12ms
77:	learn: 0.5419426	total: 24.2ms	remaining: 6.81ms
78:	learn: 0.5406364	total: 24.5ms	remaining: 6.5ms
79:	learn: 0.5395890	total: 24.8ms	remaining: 6.19ms
80:	learn: 0.5385768	total: 25.1ms	remaining: 5.88ms
81:	learn: 0.5373480	total: 25.4ms	remaining: 5.57ms
82:	learn: 0.5360013	total: 25.7ms	remaining: 5.26ms
83:	learn: 0.5351254	total: 26ms	remaining: 4.95ms
84:	learn: 0.5341118	total: 26.3ms	remaining: 4.64ms

```

85:  learn: 0.5333994 total: 26.6ms    remaining: 4.34ms
86:  learn: 0.5320418 total: 26.9ms    remaining: 4.03ms
87:  learn: 0.5309983 total: 27.2ms    remaining: 3.71ms
88:  learn: 0.5302726 total: 27.5ms    remaining: 3.39ms
89:  learn: 0.5291486 total: 27.8ms    remaining: 3.08ms
90:  learn: 0.5281416 total: 28.1ms    remaining: 2.78ms
91:  learn: 0.5273826 total: 28.4ms    remaining: 2.47ms
92:  learn: 0.5263929 total: 28.7ms    remaining: 2.16ms
93:  learn: 0.5254927 total: 29ms      remaining: 1.85ms
94:  learn: 0.5243930 total: 29.3ms    remaining: 1.54ms
95:  learn: 0.5235557 total: 29.6ms    remaining: 1.23ms
96:  learn: 0.5226483 total: 29.9ms    remaining: 925us
97:  learn: 0.5218078 total: 30.2ms    remaining: 615us
98:  learn: 0.5207112 total: 30.5ms    remaining: 307us
99:  learn: 0.5199688 total: 30.9ms    remaining: 0us
Best parameters found: {'depth': 5, 'iterations': 100,
'learning_rate': 0.01}
Best cross-validation score: 0.7839547147545819

```

```

y_CB_pred_as = grid_search_CB_as.predict(X_test_num)
y_CB_pred_ps = grid_search_CB_ps.predict(X_test_num)
y_CB_pred_rs = grid_search_CB_rs.predict(X_test_num)
y_CB_pred_fls = grid_search_CB_fls.predict(X_test_num)
y_CB_pred_ras = grid_search_CB_ras.predict(X_test_num)

accuracy_CB = accuracy_score(y_test_num, y_CB_pred_as)
print("Accuracy Score on test data: ", accuracy_CB)
precision_CB = precision_score(y_test_num, y_CB_pred_ps)
print("Precision Score on test data: ", precision_CB)
recall_CB = recall_score(y_test_num, y_CB_pred_rs)
print("Recall Score on test data: ", recall_CB)
f1_CB = f1_score(y_test_num, y_CB_pred_fls)
print("F1 Score on test data: ", f1_DT)
roc_auc_CB = roc_auc_score(y_test_num, y_CB_pred_ras)
print("ROC AUC Score on test data: ", roc_auc_CB)

```

```

Accuracy Score on test data: 0.8666666666666667
Precision Score on test data: 0.88
Recall Score on test data: 0.6862745098039216
F1 Score on test data: 0.7415730337078652
ROC AUC Score on test data: 0.7935234699940582

```

KNN

```

clf_KNN = KNeighborsClassifier()

param_grid_KNN = {
    'n_neighbors': [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11],

```

```

    'leaf_size': [1, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50],
    'p': [1, 2],
    'weights': ['uniform', 'distance'],
    'metric': ['minkowski', 'chebyshev']}

grid_search_KNN_as = GridSearchCV(estimator=clf_KNN,
    param_grid=param_grid_KNN, cv=3, scoring='accuracy', n_jobs=-1)
grid_search_KNN_as.fit(X_train_num, y_train_num)
print("Best parameters found: ", grid_search_KNN_as.best_params_)
print("Best cross-validation score: ", grid_search_KNN_as.best_score_)

Best parameters found: {'leaf_size': 1, 'metric': 'minkowski',
    'n_neighbors': 6, 'p': 1, 'weights': 'uniform'}
Best cross-validation score: 0.7766666666666667

grid_search_KNN_ps = GridSearchCV(estimator=clf_KNN,
    param_grid=param_grid_KNN, cv=3, scoring='precision', n_jobs=-1)
grid_search_KNN_ps.fit(X_train_num, y_train_num)
print("Best parameters found: ", grid_search_KNN_ps.best_params_)
print("Best cross-validation score: ", grid_search_KNN_ps.best_score_)

Best parameters found: {'leaf_size': 25, 'metric': 'minkowski',
    'n_neighbors': 4, 'p': 2, 'weights': 'uniform'}
Best cross-validation score: 0.8292448292448292

grid_search_KNN_rs = GridSearchCV(estimator=clf_KNN,
    param_grid=param_grid_KNN, cv=3, scoring='recall', n_jobs=-1)
grid_search_KNN_rs.fit(X_train_num, y_train_num)
print("Best parameters found: ", grid_search_KNN_rs.best_params_)
print("Best cross-validation score: ", grid_search_KNN_rs.best_score_)

Best parameters found: {'leaf_size': 50, 'metric': 'minkowski',
    'n_neighbors': 1, 'p': 1, 'weights': 'uniform'}
Best cross-validation score: 0.5700483091787439

C:\Users\vasim\anaconda3\Lib\site-packages\numpy\ma\core.py:2820:
RuntimeWarning: invalid value encountered in cast
    _data = np.array(data, dtype=dtype, copy=copy,

grid_search_KNN_fls = GridSearchCV(estimator=clf_KNN,
    param_grid=param_grid_KNN, cv=3, scoring='f1', n_jobs=-1)
grid_search_KNN_fls.fit(X_train_num, y_train_num)
print("Best parameters found: ", grid_search_KNN_fls.best_params_)
print("Best cross-validation score: ",
    grid_search_KNN_fls.best_score_)

Best parameters found: {'leaf_size': 1, 'metric': 'minkowski',
    'n_neighbors': 11, 'p': 1, 'weights': 'distance'}
Best cross-validation score: 0.6051215721662406

```



```

grid_search_KNN_ras = GridSearchCV(estimator=clf_KNN,
param_grid=param_grid_KNN, cv=3, scoring='roc_auc_ovr', n_jobs=-1)
grid_search_KNN_ras.fit(X_train_num, y_train_num)
print("Best parameters found: ", grid_search_KNN_ras.best_params_)
print("Best cross-validation score: ",
grid_search_KNN_ras.best_score_)

```

```

Best parameters found: {'leaf_size': 25, 'metric': 'minkowski',
'n_neighbors': 11, 'p': 1, 'weights': 'uniform'}
Best cross-validation score: 0.7495666924807317

```

```

y_KNN_pred_as = grid_search_KNN_as.predict(X_test_num)
y_KNN_pred_ps = grid_search_KNN_ps.predict(X_test_num)
y_KNN_pred_rs = grid_search_KNN_rs.predict(X_test_num)
y_KNN_pred_fls = grid_search_KNN_fls.predict(X_test_num)
y_KNN_pred_ras = grid_search_KNN_ras.predict(X_test_num)

accuracy_KNN = accuracy_score(y_test_num, y_KNN_pred_as)
print("Accuracy Score on test data: ", accuracy_KNN)
precision_KNN = precision_score(y_test_num, y_KNN_pred_ps)
print("Precision Score on test data: ", precision_KNN)
recall_KNN = recall_score(y_test_num, y_KNN_pred_rs)
print("Recall Score on test data: ", recall_KNN)
f1_KNNB = f1_score(y_test_num, y_KNN_pred_fls)
print("F1 Score on test data: ", f1_DT)
roc_auc_KNN = roc_auc_score(y_test_num, y_KNN_pred_ras)
print("ROC AUC Score on test data: ", roc_auc_KNN)

```

```

Accuracy Score on test data: 0.8066666666666666
Precision Score on test data: 0.8064516129032258
Recall Score on test data: 0.6470588235294118
F1 Score on test data: 0.7415730337078652
ROC AUC Score on test data: 0.7540106951871658

```