```
import pandas as pd
pd.set_option('display.max_columns', 3000)
pd.set_option('display.max_rows', 5000)

import warnings
warnings.filterwarnings('ignore')

#Extend cell width
from IPython.core.display import display, HTML
display(HTML("<style>.container { width:90% !important; }</style>"))
```

```
<IPython.core.display.HTML object>
```

```
df =
pd.read_csv("D:/Work/Gre/UTD/Courses/Fall/MIS6341/Softwares/Python/ml-
fall-2023/Project2/SBA_loans_project_2.csv")
df.drop(columns="index",inplace=True)
```

```
df
```

```
                   City State    Zip
Bank  \
0              NEW YORK    NY  10003  JPMORGAN CHASE BANK NATL ASSOC

1             PAWTUCKET    RI   2860        CITIZENS BANK NATL ASSOC

2              ISSAQUAH    WA  98027       FIRST-CITIZENS BK & TR CO

3                 HURST    TX  76053                   WILSHIRE BANK

4                ALPINE    CA  91901         CALIFORNIA BANK & TRUST

...                 ...   ...    ...                             ...

800250          Kenmore    NY  14217    KEYBANK NATIONAL ASSOCIATION

800251  MENOMONEE FALLS    WI  53051             WAUKESHA STATE BANK

800252         LONGVIEW    TX  75604          CAPITAL ONE NATL ASSOC

800253           CAMDEN    NJ   8105      BANK OF AMERICA NATL ASSOC

800254         COVENTRY    RI   2816        CITIZENS BANK NATL ASSOC


       BankState   NAICS  NoEmp  NewExist  CreateJob  RetainedJob  \
0             IL  561439      9       1.0          1            9
1             RI  541810      8       1.0          4           12
2             WA  448210      9       2.0          0            0
3             CA  722213      4       1.0          0            4
4             CA  233210      1       1.0          0            1
```

```
...          ...     ...    ...       ...         ...           ...
800250        OH  561720    112       1.0           0             0
800251        WI  337110     75       1.0           0            75
800252        VA  517310      2       1.0           0             0
800253        RI  447110      4       2.0           0             0
800254        RI  541511      1       1.0           0             1

        FranchiseCode  UrbanRural RevLineCr LowDoc  DisbursementGross
\
0                   1           1         0      N            68000.0

1                   0           1         N      N            90000.0

2                   1           0         N      N           450000.0

3                   1           1         0      N           140000.0

4                   1           2         Y      N            50000.0

...               ...         ...       ...    ...                ...

800250              1           1         N      N            45500.0

800251              1           1         0      N           550000.0

800252              1           1         0      Y           128800.0

800253              1           1         Y      N           100000.0

800254              0           1         N      N            10000.0


        BalanceGross    GrAppv  SBA_Appv  MIS_Status
0                0.0   68000.0   34000.0           0
1                0.0   90000.0   45000.0           1
2                0.0  450000.0  337500.0           0
3                0.0  165000.0   82500.0           0
4                0.0   50000.0   25000.0           0
...              ...       ...       ...         ...
800250           0.0   45500.0   22750.0           0
800251           0.0  550000.0  412500.0           0
800252           0.0  135000.0  114750.0           0
800253           0.0  100000.0   50000.0           0
800254           0.0   10000.0    5000.0           0

[800255 rows x 19 columns]

df.isnull().sum()

City                   26
State                  13
```

```
Zip                     0
Bank                 1381
BankState            1386
NAICS                   0
NoEmp                   0
NewExist              127
CreateJob               0
RetainedJob             0
FranchiseCode           0
UrbanRural              0
RevLineCr            4016
LowDoc               2316
DisbursementGross       0
BalanceGross            0
GrAppv                  0
SBA_Appv                0
MIS_Status              0
dtype: int64
```

```
#show unique values in each column and its data type
for col in df.columns:
    print(f'{col} unique values are {df[col].unique()}')
    print("\n")
    print(f'{col} data type is {df[col].dtype}')
```

```
City unique values are ['NEW YORK' 'PAWTUCKET' 'ISSAQUAH' ... 'ST
FRANCIS' 'Stevens point'
 'Pylesville']


City data type is object
State unique values are ['NY' 'RI' 'WA' 'TX' 'CA' 'NC' 'MN' 'MO' 'FL'
'IA' 'IL' 'DC' 'PA' 'AL'
 'MS' 'OH' 'MA' 'NJ' 'ME' 'NV' 'LA' 'MI' 'IN' 'GA' 'UT' 'VA' 'WI' 'TN'
 'KS' 'NH' 'CO' 'CT' 'KY' 'AZ' 'ID' 'DE' 'SD' 'AR' 'MD' 'OK' 'SC' 'NM'
 'MT' 'NE' 'OR' 'WY' 'AK' 'HI' 'VT' 'ND' 'WV' nan]


State data type is object
Zip unique values are [10003  2860 98027 ... 78944 17814 95812]


Zip data type is int64
Bank unique values are ['JPMORGAN CHASE BANK NATL ASSOC' 'CITIZENS
BANK NATL ASSOC'
 'FIRST-CITIZENS BK & TR CO' ... 'TULSA NATIONAL BANCSHARES, INC'
 'BEACH PLAZA LLC' 'THE LEADERS BANK']


Bank data type is object
```

```
BankState unique values are ['IL' 'RI' 'WA' 'CA' 'NC' 'MN' 'MO' 'OR'
'FL' 'IA' 'SD' 'DC' 'TX' 'PA'
 'VA' 'AL' 'OH' 'MS' 'IN' 'MA' 'ME' 'MI' 'DE' 'UT' 'SC' 'NY' 'KS' 'CO'
 'LA' 'WI' 'CT' 'AZ' 'AR' 'MD' 'OK' 'NM' 'ID' 'MT' 'NJ' 'KY' 'NE' 'WY'
 'GA' 'HI' 'NH' 'VT' 'ND' 'TN' nan 'NV' 'AK' 'WV' 'PR' 'EN' 'GU']


BankState data type is object
NAICS unique values are [561439 541810 448210 ... 922140 221114
333241]


NAICS data type is int64
NoEmp unique values are [   9    8    4    1    3   25   10    2   12
6   21   15   19    7
   70   45   14   57   30   16   13   35    5   17   11   42   33   36
    0   65   20   23  175   18   50   34   60   26   80   40   22   24
   31  300   55   29   44   76 3030   75   32   28   41  135   52  100
   90   51   37  350   46  207   27   64  160   98   92  190   38   47
   39   62   85  985  150   48   79   72  387   84   69 9945   49   68
  124   43   73  200  140   59  120  174   54   71  101  102   56 5000
  142   67  195  185   53  145  435  110  109  115  425  281   58  153
   95   63   61  750  133   81   74   83   82  700  111  132  114   93
   78  146   89   77  170  250  205  125  130  184   94  105   97   99
   86  104  158  220  155  163  247  246  137  106  450  113  151   96
  500  116 1000  118  280  141 5149   66  126   88  400  188  108  154
  223  325  900  127  189  222  360   91  107  498  131   87  230  421
  162  218  515  180  271  138  128  122  386  179  345  129  165  240
  117 3400 1644  315  182  134  123  112  275  139  210  232  260  288
 6000  245  119  215 1150  600  258  227  261  206  257 1382  270  203
  256  499  144  285  161  295 1400  375  608 1010 1500  177 1200  103
  173 4000  121 1700  314  340  192  307  147  329  339 1451 8041  226
 1003  225  231  254  148  344  191  712  967  149  187  403  152  520
 2202  420  299  351 1524  212  136  156  166 7231  323 5921  208  290
  202 7538 5812  143  197  213  550  310  305 3900 1112  233  761  241
  521  228 3200 2200  317  249 2000  346  243  178  840  167  475  172
  248 3000 1515 1800  330  237 1461  214  625  740  186  211 2151  204
  255  217 2400 5680  196 1005 7389  306  171 5211  265  168  157  327
 1100  427  390 2401  394  236 3100  216  289  458  850  176 1600 8000
  169  221  720 2501  760  430  384 1981  253 2725  234  277  510  194
  224  263  463  259 9090 3737  268  365  488  283  278  342  332  404
  484  423  198 1940  318 3713  530  235  433  273  353 4100  455  304
  382  276  267  424  193  640  606  456 3089  164  407  336  362 1706
  585  560  252  355  576 4685  308  251  320  396 7212  442  380 3500
  385  808 1300  183  376 4005  605  454  312  209  505 9999 1233 1711
  181 5947  523  479 7000  279  301  262 3334  358 2300 2100  448  602
  713 7941  413  780 4012  635  302 2020  685 2120  575  294  540  238
  369  405  313 2510 1900 5555 1020  395 4847  377  525  445 2610  401
  354  322 7241 2500 5013  287 3009  242  266  465  688 2700 4658 1073
 1340  717  410  229  269 5200  282 9992 1520 1235  274  480  485 1980
```

```
 1050  296  383  426  408 1920 6501 7216  544  298  368  782  476  324
 1629 1550  609  363  680 1542  827 7111  357 1012 2232  800 1101  464
  447  735  284 2010  341 5084  828  495  370  538  319 7991 1603 7999
 3732 8018 2121  199  535  244 1250 1280 9000  292 1145  293 2520  650
  356  159 1030 4800 7007  328 4300 3170  570  660  414  441  429  823
  367  348  858]


NoEmp data type is int64
NewExist unique values are [ 1.  2.  0. nan]


NewExist data type is float64
CreateJob unique values are [   1    4    0   15    3    6    8    9
2   20    7   10   12    5
   26   35   30   13   23   11   45   40   65   29   25   16   46   21
  458   14   73   70 8800   43  120   38   28   22   49   41   59   33
   80   19   17   48   60   50  250   24   18  150   37   57  100   31
   44   39   32   79   96   89  118   27   75  451   71  450   85   42
   36  456   52  105  135  125  452  200  300   54   63   61   90   34
  154   64   47   76   82  171   56  175  256   55  198   58  110  138
 3000  264   98  158   69   95  162   68  124   66  119  860   72   92
  115   83  168  206   78  116   62  500   53   67   84  255  600   51
  400  137  104  130  152  140  454  226   77  453  225   97  270  123
  126 3100  240  108  160  102 1530  235   99  189  114   87  106  165
  112  179  101   88  141  167  183  131   81  455   94  433  205  136
 1618 1100  223  146  457 5199 1000   74 3500  121  409  750  220 1711
 5085  148  155  184 1027 2515  186  280 5621 1016  145  310  129  360
  386   86  375  169  109  170   93  182  397  195  365  180  128  190
 1011  221  103  350  157  174  222  127  149 1150  480  363 2140  214
  252  569 2020  320  144  164  153 1118  139  151  163  210]


CreateJob data type is int64
RetainedJob unique values are [   9   12    0    4    1   40   10    2
6    8    5   20   30   13
   35   11    3   14   19    7   34   21   23   18   50   22   85   80
   60   45   15  330   25   65   33   29   17   16   44   32   31   28
   41   27   90   24  207  160   92  190   38   46 8800   26   48   72
   84   36   70  200  140  120   54   52   71   53   47  102   55   75
  150  142   37   43   64  300  117   42   95   39  281   49   58   96
  212  100   63   79   82   57  111   69   62  135  250   61   56  155
   78  104  158   67  163  270  350  151  500  116   51  118  275  141
  450  126   74   86  223  387   76  498  189   87  130  115   59  145
  205  175  125  256  138  105   93  137  164  180  219  139   77  110
   68   81  103  210  109  167  230   83   99  162  185  171   91   97
  119  304  101   98  107  285  240  257  170   73  165  229  161  149
  173  750  113  231  114  168  156  362  967   88  128  122  127   89
  220  129  251  404  375   66  203  550  267  177  133  123  263  143
   94 3900  182  121 1300  384 2200  254  900  243  112  178  310  226
```

```
  184  237  515  146  154  192  265  157  327  245  108  400  194  172
  169  134  186  153  216  106  152 4441  360  124  259  187  131  202
  316  600  472  371  278  342  206  214  484  204  390  318  225 3225
  286 1700  428  176  147  497  268  585  312  393  148  280  290  475
  235  291  320  369  132 1711  197  523  195  144  448  602  217 3100
  302  136  685  540  295  215  366  322  287  315  485  266  610  292
  476  208  430  410  247  191 1600  420  325 4000  233  188 5000  355
  196  260  274  480  544  298  262  609  363  199  815  277  403  166
 7250  720  370  548 3200  911  183  221 1500 1000  675  535  232  236
  198  159  255  252  356  394 1111  201 9500  328  297  660  700
317]


RetainedJob data type is int64
FranchiseCode unique values are [    1     0 78760 ... 21424 41418
29580]


FranchiseCode data type is int64
UrbanRural unique values are [1 0 2]


UrbanRural data type is int64
RevLineCr unique values are ['0' 'N' 'Y' 'T' nan '1' 'A' '`' '4' 'R'
'2' '.' '5' 'C' ',' '-' 'Q' '7'
 '3']


RevLineCr data type is object
LowDoc unique values are ['N' 'Y' '0' nan 'C' 'A' 'S' 'R' '1']


LowDoc data type is object
DisbursementGross unique values are [ 68000.  90000. 450000. ...
199123.  67516.  97203.]


DisbursementGross data type is float64
BalanceGross unique values are [0.00000e+00 4.15090e+04 3.95476e+05
9.11100e+03 8.46170e+04 8.27875e+05
 1.27500e+04 9.96262e+05 9.69080e+04 2.50000e+04 1.15820e+05
1.76000e+03
 3.71000e+04 6.00000e+02 4.31270e+04]


BalanceGross data type is float64
GrAppv unique values are [  68000.   90000.  450000. ... 1853900.
32916.   35224.]


GrAppv data type is float64
```

```
SBA_Appv unique values are [  34000.   45000.  337500. ...   26333.
1609000.   17612.]


SBA_Appv data type is float64
MIS_Status unique values are [0 1]


MIS_Status data type is int64

df

                    City State    Zip
Bank  \
0               NEW YORK    NY  10003  JPMORGAN CHASE BANK NATL ASSOC

1              PAWTUCKET    RI   2860        CITIZENS BANK NATL ASSOC

2               ISSAQUAH    WA  98027       FIRST-CITIZENS BK & TR CO

3                  HURST    TX  76053                    WILSHIRE BANK

4                 ALPINE    CA  91901         CALIFORNIA BANK & TRUST

...                  ...   ...    ...                             ...

800250           Kenmore    NY  14217    KEYBANK NATIONAL ASSOCIATION

800251  MENOMONEE FALLS    WI  53051             WAUKESHA STATE BANK

800252          LONGVIEW    TX  75604          CAPITAL ONE NATL ASSOC

800253            CAMDEN    NJ   8105      BANK OF AMERICA NATL ASSOC

800254          COVENTRY    RI   2816        CITIZENS BANK NATL ASSOC


       BankState   NAICS  NoEmp  NewExist  CreateJob  RetainedJob  \
0             IL  561439      9       1.0          1            9
1             RI  541810      8       1.0          4           12
2             WA  448210      9       2.0          0            0
3             CA  722213      4       1.0          0            4
4             CA  233210      1       1.0          0            1
...          ...     ...    ...       ...        ...          ...
800250        OH  561720    112       1.0          0            0
800251        WI  337110     75       1.0          0           75
800252        VA  517310      2       1.0          0            0
800253        RI  447110      4       2.0          0            0
800254        RI  541511      1       1.0          0            1

        FranchiseCode  UrbanRural RevLineCr LowDoc  DisbursementGross
```

```
\
0                    1            1          0      N             68000.0

1                    0            1          N      N             90000.0

2                    1            0          N      N            450000.0

3                    1            1          0      N            140000.0

4                    1            2          Y      N             50000.0

...                ...          ...        ...    ...                ...

800250               1            1          N      N             45500.0

800251               1            1          0      N            550000.0

800252               1            1          0      Y            128800.0

800253               1            1          Y      N            100000.0

800254               0            1          N      N             10000.0


        BalanceGross    GrAppv  SBA_Appv  MIS_Status
0                0.0   68000.0   34000.0           0
1                0.0   90000.0   45000.0           1
2                0.0  450000.0  337500.0           0
3                0.0  165000.0   82500.0           0
4                0.0   50000.0   25000.0           0
...              ...       ...       ...         ...
800250           0.0   45500.0   22750.0           0
800251           0.0  550000.0  412500.0           0
800252           0.0  135000.0  114750.0           0
800253           0.0  100000.0   50000.0           0
800254           0.0   10000.0    5000.0           0

[800255 rows x 19 columns]
```

```python
for i in df['RevLineCr']:
    if i not in ['Y','N']:
        df['RevLineCr'].replace(i,'N',inplace=True)
print("RevLineCr",df['RevLineCr'].unique())

for i in df['LowDoc']:
    if i not in ['Y','N']:
        df['LowDoc'].replace(i,'N',inplace=True)
print("LowDoc",df['LowDoc'].unique())

for i in df['NewExist']:
    if i not in [1,2]:
```

```
        df['NewExist'].replace(i,None,inplace=True)
print("NewExist",df['NewExist'].unique())
```

```
RevLineCr ['N' 'Y']
LowDoc ['N' 'Y']
NewExist [1.0 2.0 None]
```

```
df.isnull().sum()
```

```
City                   26
State                  13
Zip                     0
Bank                 1381
BankState            1386
NAICS                   0
NoEmp                   0
NewExist             1057
CreateJob               0
RetainedJob             0
FranchiseCode           0
UrbanRural              0
RevLineCr               0
LowDoc                  0
DisbursementGross       0
BalanceGross            0
GrAppv                  0
SBA_Appv                0
MIS_Status              0
dtype: int64
```

```
category_cols=['City', 'State', 'Bank', 'BankState', 'RevLineCr',
'LowDoc','NewExist']
for column in category_cols:
  df[column]=df[column].fillna(df[column].mode()[0])
```

```
df.isnull().sum()
```

```
City                 0
State                0
Zip                  0
Bank                 0
BankState            0
NAICS                0
NoEmp                0
NewExist             0
CreateJob            0
RetainedJob          0
FranchiseCode        0
UrbanRural           0
RevLineCr            0
LowDoc               0
```

```
DisbursementGross    0
BalanceGross         0
GrAppv               0
SBA_Appv             0
MIS_Status           0
dtype: int64
```

```
from sklearn.model_selection import train_test_split

train,test = train_test_split(df,test_size=0.2,random_state=42)
train.shape, test.shape
```

```
((640204, 19), (160051, 19))
```

Target Encoding (Categorical Variables into Numerical)

``` Training set has 560178 rows and testing set has 240077 samples

Target encoding is a data preprocessing technique used to convert categorical variables into numerical values that can be used by machine learning algorithms. It works by replacing each category with the average value of the target variable for that category. This can be helpful for algorithms that cannot handle categorical variables directly.

In this case the target variable is "MIS_Status"```

```
#target encoder
import category_encoders as ce
import warnings
warnings.filterwarnings("ignore", category=FutureWarning)
categorical_columns = ['City', 'State', 'Bank', 'BankState',
'RevLineCr', 'LowDoc','NewExist', 'UrbanRural']

encoder = ce.TargetEncoder(cols=categorical_columns)
encoder.fit(train, train['MIS_Status'])

train_encoded = encoder.transform(train)

# Renaming the columns
train_encoded = train_encoded.add_suffix('_trg')
train_encoded = pd.concat([train_encoded, train], axis=1)
for column in categorical_columns:
    train_encoded[column + "_trg"].fillna(train_encoded[column +
"_trg"].mean(), inplace=True)

train_encoded.drop(columns=categorical_columns, inplace=True)
```
```

```
train_encoded.drop(columns='MIS_Status_trg', inplace=True)
train_encoded.head()
```

```
        City_trg  State_trg  Zip_trg  Bank_trg  BankState_trg
NAICS_trg  \
473658  0.311896   0.165712    43110  0.276163       0.223360
541921
778431  0.148794   0.165712    45371  0.175041       0.159471
541320
509938  0.152428   0.186924    92123  0.084951       0.219710
447110
651625  0.144928   0.188710    75081  0.142174       0.179305
0
526142  0.134538   0.147593    96817  0.549263       0.219710
713940

        NoEmp_trg  NewExist_trg  CreateJob_trg  RetainedJob_trg  \
473658          2      0.170871              0                2
778431          3      0.170871              0                3
509938          1      0.170871              4                4
651625         15      0.186933              0                0
526142         10      0.170871              1               10

        FranchiseCode_trg  UrbanRural_trg  RevLineCr_trg
LowDoc_trg  \
473658                  0        0.244557       0.152838    0.187475

778431                  0        0.187843       0.253428    0.187475

509938              85304        0.244557       0.152838    0.187475

651625              24957        0.244557       0.152838    0.187475

526142                  1        0.244557       0.152838    0.187475


        DisbursementGross_trg  BalanceGross_trg  GrAppv_trg
SBA_Appv_trg  \
473658                25400.0               0.0     25400.0
12700.0
778431                41882.0               0.0     25000.0
12500.0
509938               602000.0               0.0    602000.0
451500.0
651625               183500.0               0.0    183500.0
137625.0
526142                 5000.0               0.0      5000.0
4250.0

          Zip   NAICS  NoEmp  CreateJob  RetainedJob  FranchiseCode  \
```

```
473658  43110  541921      2          0            2               0
778431  45371  541320      3          0            3               0
509938  92123  447110      1          4            4           85304
651625  75081       0     15          0            0           24957
526142  96817  713940     10          1           10               1

        DisbursementGross  BalanceGross    GrAppv  SBA_Appv
MIS_Status
473658            25400.0           0.0   25400.0   12700.0
0
778431            41882.0           0.0   25000.0   12500.0
0
509938           602000.0           0.0  602000.0  451500.0
0
651625           183500.0           0.0  183500.0  137625.0
0
526142             5000.0           0.0    5000.0    4250.0
1


test_encoded = encoder.transform(test)
test_encoded = test_encoded.add_suffix('_trg')
test_encoded = pd.concat([test_encoded, test], axis=1)
for column in categorical_columns:
    test_encoded[column + "_trg"].fillna(test_encoded[column +
"_trg"].mean(), inplace=True)

test_encoded.drop(columns=categorical_columns, inplace=True)
test_encoded.drop(columns='MIS_Status_trg', inplace=True)
test_encoded.head()

        City_trg  State_trg  Zip_trg  Bank_trg  BankState_trg
NAICS_trg  \
384386  0.140612   0.197919    12953  0.367531       0.168015
0
662652  0.136187   0.197919    14850  0.094340       0.168015
235920
269020  0.149920   0.138693    98004  0.175041       0.159471
0
752306  0.224138   0.275144    33905  0.112576       0.293824
541940
675193  0.335998   0.275144    33172  0.000000       0.160260
811111

        NoEmp_trg  NewExist_trg  CreateJob_trg  RetainedJob_trg  \
384386          5      0.170871              0                0
662652          7      0.170871              0                0
269020         17      0.170871              0                0
752306         15      0.186933             15                0
675193          4      0.170871              7                0
```

```
        FranchiseCode_trg  UrbanRural_trg  RevLineCr_trg
LowDoc_trg  \
384386                  1        0.070732       0.152838    0.187475

662652                  0        0.070732       0.152838    0.187475

269020                  1        0.070732       0.152838    0.187475

752306                  1        0.244557       0.152838    0.187475

675193                  1        0.070732       0.152838    0.187475


        DisbursementGross_trg  BalanceGross_trg  GrAppv_trg
SBA_Appv_trg  \
384386               420000.0               0.0    420000.0
315000.0
662652               165000.0               0.0    165000.0
140250.0
269020                65000.0               0.0     65000.0
52000.0
752306              1125000.0               0.0   1125000.0
843750.0
675193               240000.0               0.0    240000.0
240000.0

          Zip   NAICS  NoEmp  CreateJob  RetainedJob  FranchiseCode  \
384386  12953       0      5          0            0              1
662652  14850  235920      7          0            0              0
269020  98004       0     17          0            0              1
752306  33905  541940     15         15            0              1
675193  33172  811111      4          7            0              1

        DisbursementGross  BalanceGross     GrAppv  SBA_Appv
MIS_Status
384386           420000.0           0.0   420000.0  315000.0
0
662652           165000.0           0.0   165000.0  140250.0
0
269020            65000.0           0.0    65000.0   52000.0
0
752306          1125000.0           0.0  1125000.0  843750.0
1
675193           240000.0           0.0   240000.0  240000.0
0
```

Feature Engineering

Log_DisbursementGross: This feature calculates the natural logarithm of the 'DisbursementGross' column values after adding 1 (np.log1p). Log transformation is commonly used to reduce the skewness of data or make it more normally distributed.

Log_NoEmp: Similar to the first feature, it computes the natural logarithm of the 'NoEmp' column values.

Log_GrAppv: Computes the natural logarithm of the 'GrAppv' column values.

(4) Log_SBA_Appv: Computes the natural logarithm of the 'SBA_Appv' column values

(5) Log_BalanceGross: Performs a log transformation on the 'BalanceGross' column values. (6) Disbursement_Bins: Creates categorical bins based on the 'DisbursementGross' values. It categorizes 'DisbursementGross' into three bins: 'Low', 'Medium', and 'High' based on predefined bins.

(7) Loan_Efficiency: Calculates the efficiency of the loan by dividing 'DisbursementGross' by the sum of 'CreateJob', 'RetainedJob', and 1. The addition of 1 prevents division by zero.

(8) Guarantee_Ratio: Computes the ratio between 'SBA_Appv' and 'GrAppv', which represents the proportion of the SBA-approved amount to the gross amount approved.

(9) Loan_Guarantee_Interaction: Multiplies 'SBA_Appv' and 'GrAppv', providing an interaction feature capturing the interaction between these two variables.

(10) Disbursement_Squared: Computes the square of 'DisbursementGross', which might capture non-linear relationships in the data.

```
# Adding Features
import numpy as np
train_encoded['Log_DisbursementGross'] =
np.log1p(train_encoded['DisbursementGross'])
train_encoded['Log_NoEmp'] = np.log1p(train_encoded['NoEmp'])
train_encoded['Log_GrAppv'] = np.log1p(train_encoded['GrAppv'])
train_encoded['Log_SBA_Appv'] = np.log1p(train_encoded['SBA_Appv'])
train_encoded['Log_BalanceGross'] =
np.log1p(train_encoded['BalanceGross'])

# Binning
train_encoded['Disbursement_Bins'] =
pd.cut(train_encoded['DisbursementGross'],
                                          bins=[-np.inf, 50000,
```

```
150000, np.inf],
                                          labels=['Low', 'Medium',
'High'])

# Loan Efficiency
train_encoded['Loan_Efficiency'] = train_encoded['DisbursementGross']
/ (train_encoded['CreateJob'] + train_encoded['RetainedJob'] + 1)  #
Adding 1 to avoid division by zero

# Guarantee Ratio
train_encoded['Guarantee_Ratio'] = train_encoded['SBA_Appv'] /
train_encoded['GrAppv']

# Loan Guarantee Interaction
train_encoded['Loan_Guarantee_Interaction'] =
train_encoded['SBA_Appv'] * train_encoded['GrAppv']

# Disbursement Squared
train_encoded['Disbursement_Squared'] =
train_encoded['DisbursementGross'] ** 2

# Displaying the newly created features
train_encoded[['Log_DisbursementGross', 'Log_NoEmp', 'Log_GrAppv',
'Log_SBA_Appv','Disbursement_Bins', 'Loan_Efficiency',
'Guarantee_Ratio', 'Loan_Guarantee_Interaction',
'Disbursement_Squared']].head()
```

```
        Log_DisbursementGross  Log_NoEmp  Log_GrAppv  Log_SBA_Appv  \
473658              10.142544   1.098612   10.142544      9.449436
778431              10.642635   1.386294   10.126671      9.433564
509938              13.308014   0.693147   13.308014     13.020333
651625              12.119975   2.772589   12.119975     11.832295
526142               8.517393   2.397895    8.517393      8.354910

       Disbursement_Bins  Loan_Efficiency  Guarantee_Ratio  \
473658               Low      8466.666667             0.50
778431               Low     10470.500000             0.50
509938              High     66888.888889             0.75
651625              High    183500.000000             0.75
526142               Low       416.666667             0.85

        Loan_Guarantee_Interaction  Disbursement_Squared
473658                3.225800e+08          6.451600e+08
778431                3.125000e+08          1.754102e+09
509938                2.718030e+11          3.624040e+11
651625                2.525419e+10          3.367225e+10
526142                2.125000e+07          2.500000e+07
```

```
# Creating log-based features for the test dataset
```

```
test_encoded['Log_DisbursementGross'] =
np.log1p(test_encoded['DisbursementGross'])
test_encoded['Log_NoEmp'] = np.log1p(test_encoded['NoEmp'])
test_encoded['Log_GrAppv'] = np.log1p(test_encoded['GrAppv'])
test_encoded['Log_SBA_Appv'] = np.log1p(test_encoded['SBA_Appv'])
test_encoded['Log_BalanceGross'] =
np.log1p(test_encoded['BalanceGross'])

# Binning

test_encoded['Disbursement_Bins'] =
pd.cut(test_encoded['DisbursementGross'],
                                          bins=[-np.inf, 50000,
150000, np.inf],
                                          labels=['Low', 'Medium',
'High'])

# Loan Efficiency
test_encoded['Loan_Efficiency'] = test_encoded['DisbursementGross'] /
(test_encoded['CreateJob'] + test_encoded['RetainedJob'] + 1)  #
Adding 1 to avoid division by zero

# Guarantee Ratio
test_encoded['Guarantee_Ratio'] = test_encoded['SBA_Appv'] /
test_encoded['GrAppv']

# Loan Guarantee Interaction
test_encoded['Loan_Guarantee_Interaction'] = test_encoded['SBA_Appv']
* test_encoded['GrAppv']

# Disbursement Squared
test_encoded['Disbursement_Squared'] =
test_encoded['DisbursementGross'] ** 2

# Displaying the newly created features
test_encoded[['Log_DisbursementGross', 'Log_NoEmp', 'Log_GrAppv',
'Log_SBA_Appv','Disbursement_Bins', 'Loan_Efficiency',
'Guarantee_Ratio', 'Loan_Guarantee_Interaction',
'Disbursement_Squared']].head()
```

```
        Log_DisbursementGross  Log_NoEmp  Log_GrAppv  Log_SBA_Appv  \
384386              12.948012   1.791759   12.948012     12.660331
662652              12.013707   2.079442   12.013707     11.851189
269020              11.082158   2.890372   11.082158     10.859018
752306              13.933294   2.772589   13.933294     13.645613
675193              12.388398   1.609438   12.388398     12.388398

       Disbursement_Bins  Loan_Efficiency  Guarantee_Ratio  \
384386              High         420000.0             0.75
662652              High         165000.0             0.85
```

```
269020             Medium          65000.0              0.80
752306               High          70312.5              0.75
675193               High          30000.0              1.00

        Loan_Guarantee_Interaction  Disbursement_Squared
384386                1.323000e+11          1.764000e+11
662652                2.314125e+10          2.722500e+10
269020                3.380000e+09          4.225000e+09
752306                9.492188e+11          1.265625e+12
675193                5.760000e+10          5.760000e+10
```

Scaling

StandardScaler in scikit-learn is a preprocessing technique that centers and scales numerical features such that they have a mean of zero and a standard deviation of one.

We will make use of the StandardScaler, which is used to transform both the training and test data in the same way, ensuring that the features have the same mean and standard deviation in both datasets.

Here we will scale it on the training set and transform on both training and testing

```
from sklearn.preprocessing import StandardScaler

numerical_columns = [ 'NoEmp', 'CreateJob', 'RetainedJob', 'GrAppv',
'SBA_Appv', 'DisbursementGross', 'BalanceGross',
'Log_DisbursementGross', 'Log_NoEmp', 'Log_GrAppv', 'Log_SBA_Appv',
'Log_BalanceGross', 'Loan_Efficiency', 'Guarantee_Ratio',
'Loan_Guarantee_Interaction', 'Disbursement_Squared']
scaler = StandardScaler()
train_encoded[numerical_columns] =
scaler.fit_transform(train_encoded[numerical_columns])
train_encoded.head()

test_encoded[numerical_columns] =
scaler.transform(test_encoded[numerical_columns])
test_encoded.head()
```

```
        City_trg  State_trg  Zip_trg  Bank_trg  BankState_trg
NAICS_trg  \
384386  0.140612   0.197919    12953  0.367531       0.168015
0
662652  0.136187   0.197919    14850  0.094340       0.168015
235920
269020  0.149920   0.138693    98004  0.175041       0.159471
0
752306  0.224138   0.275144    33905  0.112576       0.293824
541940
```

```
675193  0.335998   0.275144    33172  0.000000       0.160260
811111

        NoEmp_trg  NewExist_trg  CreateJob_trg  RetainedJob_trg  \
384386          5      0.170871              0                0
662652          7      0.170871              0                0
269020         17      0.170871              0                0
752306         15      0.186933             15                0
675193          4      0.170871              7                0

        FranchiseCode_trg  UrbanRural_trg  RevLineCr_trg
LowDoc_trg  \
384386                  1        0.070732       0.152838    0.187475

662652                  0        0.070732       0.152838    0.187475

269020                  1        0.070732       0.152838    0.187475

752306                  1        0.244557       0.152838    0.187475

675193                  1        0.070732       0.152838    0.187475


        DisbursementGross_trg  BalanceGross_trg  GrAppv_trg
SBA_Appv_trg  \
384386               420000.0               0.0    420000.0
315000.0
662652               165000.0               0.0    165000.0
140250.0
269020                65000.0               0.0     65000.0
52000.0
752306              1125000.0               0.0   1125000.0
843750.0
675193               240000.0               0.0    240000.0
240000.0

          Zip   NAICS     NoEmp  CreateJob  RetainedJob  FranchiseCode
\
384386  12953       0 -0.086398  -0.035203    -0.045349              1

662652  14850  235920 -0.059623  -0.035203    -0.045349              0

269020  98004       0  0.074252  -0.035203    -0.045349              1

752306  33905  541940  0.047477   0.029733    -0.045349              1

675193  33172  811111 -0.099785  -0.004899    -0.045349              1


        DisbursementGross  BalanceGross    GrAppv  SBA_Appv
MIS_Status  \
```

```
384386           0.761437     -0.002347  0.802282  0.725015
0
662652          -0.125062     -0.002347 -0.097242 -0.039847
0
269020          -0.472708     -0.002347 -0.449997 -0.426107
0
752306           3.212347     -0.002347  3.289204  3.039296
1
675193           0.135673     -0.002347  0.167324  0.396748
0

        Log_DisbursementGross  Log_NoEmp  Log_GrAppv  Log_SBA_Appv  \
384386               1.157104  -0.048393    1.205831      1.159638
662652               0.423160   0.246620    0.488425      0.593798
269020              -0.308620   1.078217   -0.226864     -0.100035
752306               1.931094   0.957432    1.962379      1.848654
675193               0.717499  -0.235361    0.776132      0.969473

        Log_BalanceGross Disbursement_Bins  Loan_Efficiency
Guarantee_Ratio  \
384386         -0.004091               High         1.648470
0.234647
662652         -0.004091               High         0.324071
0.810093
269020         -0.004091             Medium        -0.195301
0.522370
752306         -0.004091               High        -0.167710
0.234647
675193         -0.004091               High        -0.377082
1.673261

        Loan_Guarantee_Interaction  Disbursement_Squared
384386                    0.106400              0.090669
662652                   -0.180743             -0.163246
269020                   -0.232725             -0.202395
752306                    2.255308              1.944665
675193                   -0.090099             -0.111544

train_encoded.columns
test_encoded.columns

Index(['City_trg', 'State_trg', 'Zip_trg', 'Bank_trg',
'BankState_trg',
       'NAICS_trg', 'NoEmp_trg', 'NewExist_trg', 'CreateJob_trg',
       'RetainedJob_trg', 'FranchiseCode_trg', 'UrbanRural_trg',
       'RevLineCr_trg', 'LowDoc_trg', 'DisbursementGross_trg',
       'BalanceGross_trg', 'GrAppv_trg', 'SBA_Appv_trg', 'Zip',
'NAICS',
       'NoEmp', 'CreateJob', 'RetainedJob', 'FranchiseCode',
       'DisbursementGross', 'BalanceGross', 'GrAppv', 'SBA_Appv',
```

```
'MIS_Status',
       'Log_DisbursementGross', 'Log_NoEmp', 'Log_GrAppv',
'Log_SBA_Appv',
       'Log_BalanceGross', 'Disbursement_Bins', 'Loan_Efficiency',
       'Guarantee_Ratio', 'Loan_Guarantee_Interaction',
       'Disbursement_Squared'],
      dtype='object')

X_train = train_encoded.copy()
X_test = test_encoded.copy()

y_train = X_train['MIS_Status']
X_train.drop(columns='MIS_Status', axis=1, inplace=True)
y_test = X_test['MIS_Status']
X_test.drop(columns='MIS_Status', axis=1, inplace=True)

import lightgbm as lgb
from sklearn.metrics import roc_auc_score

train_data = lgb.Dataset(data=X_train, label=y_train,
params={"verbose":-1})
test_data = lgb.Dataset(data=X_test, label=y_test, params={"verbose":-
1})
lgb_clf = lgb.train(params={"verbose":-1},
                    train_set=train_data)

from sklearn.metrics import roc_auc_score
print("AUC score on Test dataset:", roc_auc_score(y_test,
lgb_clf.predict(X_test)))
print("AUC score on Train dataset:", roc_auc_score(y_train,
lgb_clf.predict(X_train)))

AUC score on Test dataset: 0.8225855591034863
AUC score on Train dataset: 0.8473599291272692

from optuna.integration import LightGBMPruningCallback
import tqdm as notebook_tqdm
from sklearn.model_selection import StratifiedKFold
import lightgbm as lgb
from sklearn.metrics import roc_auc_score
import matplotlib.pyplot as plt
import optuna
import warnings

warnings.filterwarnings("ignore", category=UserWarning)
study_model_iteractions = {}

def objective(trial, X, y):
    param_grid = {
        # Refer to the Official guide :
https://lightgbm.readthedocs.io/en/latest/Parameters-Tuning.html
```

```
        "num_iterations": 10000,
        "num_threads": 16,
        "learning_rate": trial.suggest_float("learning_rate", 1e-1,
0.8, log=True),
        #"num_leaves": trial.suggest_int("num_leaves", 50, 150,
step=5),
        "num_leaves": trial.suggest_int("num_leaves", 20, 700,
step=10),
        #"num_leaves": trial.suggest_int("num_leaves", 2, 2**8,
step=2),
        "max_depth": trial.suggest_int("max_depth", 10, 17, step=2),
        #"max_depth": trial.suggest_int("max_depth", 3, 12),
        "min_data_in_leaf": trial.suggest_int("min_data_in_leaf", 100,
1000, step=100),
        ##############################
        'lambda_l1': trial.suggest_float('lambda_l1', 1e-1, 10.0,
log=True),
        'lambda_l2': trial.suggest_float('lambda_l2', 1e-1, 10.0,
log=True),
        #"lambda_l1": trial.suggest_int("lambda_l1", 0, 100, step=5),
        #"lambda_l2": trial.suggest_int("lambda_l2", 0, 100, step=5),
        #"lambda_l1": trial.suggest_float("lambda_l1", 0.01, 0.1,
step=0.01),
        #"lambda_l2": trial.suggest_float("lambda_l2", 0.01, 0.1,
step=0.01),
        ##########################
        "bagging_fraction": trial.suggest_float("bagging_fraction",
0.8, 1.0, step=0.1),
        "bagging_freq": trial.suggest_categorical("bagging_freq",
[5]),
        #"bagging_freq": 1,
        "feature_fraction": trial.suggest_float("feature_fraction",
0.8, 1.0, step=0.1),
        ########################
        "is_unbalance": trial.suggest_categorical("is_unbalance",
[True, False]),
        ##########################
        "verbose": -1,
        "objective":"binary",
        "metric":"auc",
        "num_threads": 16
    }

    cv = StratifiedKFold(n_splits=5, shuffle=True,
random_state=1121218)

    cv_scores = np.empty(5)
    cv_iteractions = np.empty(5)
    for idx, (train_idx, test_idx) in enumerate(cv.split(X, y)):
```

```
        X_train, X_valid = X.iloc[train_idx], X.iloc[test_idx]
        y_train, y_valid = y.iloc[train_idx], y.iloc[test_idx]

        train_data = lgb.Dataset(data=X_train, label=y_train,
params={"verbose":-1})
        valid_data = lgb.Dataset(data=X_valid, label=y_valid,
params={"verbose":-1})
        lgb_clf = lgb.train(params=param_grid,
                            train_set=train_data,
                            valid_sets=[valid_data],
                            #categorical_feature=categorical_columns,
                            callbacks=[LightGBMPruningCallback(trial,
"auc"),

lgb.early_stopping(stopping_rounds=5)]
                            )
        preds = lgb_clf.predict(X_valid)
        cv_scores[idx] = roc_auc_score(y_valid, preds)
        cv_iteractions[idx] = lgb_clf.best_iteration

    study_model_iteractions[trial.number] = np.mean(cv_iteractions)

    return np.mean(cv_scores)
```

Hyper Tuning Parameters in LGBM Optuna

Below are some important terminologies mentioned in the OPTUNA docs, understanding which will make our jobs easier:

```
Trial: A single call of the objective function
Study: An optimization session, which is a set of trials
Parameter: A variable whose value is to be optimized, such as x in the
above example
```

`num_leaves: This is the main parameter to control the complexity of the tree model. Theoretically, we can set num_leaves = 2^(max_depth) to obtain the same number of leaves as depth-wise tree. However, this simple conversion is not good in practice. The reason is that a leaf-wise tree is typically much deeper than a depth-wise tree for a fixed number of leaves. Unconstrained depth can induce over-fitting. Thus, when trying to tune the num_leaves, we should let it be smaller than 2^(max_depth)`

`min_data_in_leaf: In order to keep a leaf-wise tree from over-fitting, this value is crucial. The ideal value is determined by num_leaves and the quantity of training samples.`

max_depth: The maximum depth of a tree. Limits the number of nodes in the tree

learning_rate: Controls the step size during each boosting iteration. A smaller learning rate requires more iterations but can help improve generalization.

lambda_l1: L1 regularization term on weights. Controls overfitting by penalizing large weights.

lambda_l2: L2 regularization term on weights. Similar to L1 but penalizes large weights differently.

bagging_fraction: The fraction of samples used for each boosting iteration. Helps in preventing overfitting by using subsets of the data.

bagging_freq: Frequency for bagging. Specifies how often to perform bagging.

is_unbalance: Controls whether the training data is unbalanced. Useful for imbalanced classification problems.

verbose: Controls the level of LightGBM's verbosity during training.
objective: Specifies the learning task and the corresponding objective function.

Metric

The metric we have used here is AUCPR

```
study = optuna.create_study(direction="maximize", study_name="LGBM
Classifier")
func = lambda trial: objective(trial, X_train, y_train)
study.optimize(func, n_trials=200)

print('Best hyperparameters:', study.best_params)
print('Best AUCPR:', study.best_value)


[I 2023-12-10 17:25:21,641] A new study created in memory with name:
LGBM Classifier

Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[252] valid_0's auc: 0.859028
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[256] valid_0's auc: 0.861669
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[244] valid_0's auc: 0.861667
```

```
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[238] valid_0's auc: 0.858122
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[263] valid_0's auc: 0.859648

[I 2023-12-10 17:26:05,278] Trial 0 finished with value:
0.8600267399226471 and parameters: {'learning_rate':
0.13238993755297335, 'num_leaves': 700, 'max_depth': 10,
'min_data_in_leaf': 900, 'lambda_l1': 0.16858915562508314,
'lambda_l2': 1.773650587284315, 'bagging_fraction': 1.0,
'bagging_freq': 5, 'feature_fraction': 1.0, 'is_unbalance': False}.
Best is trial 0 with value: 0.8600267399226471.

Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[30]  valid_0's auc: 0.848891
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[27]  valid_0's auc: 0.851833
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[35]  valid_0's auc: 0.85095
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[33]  valid_0's auc: 0.849136
Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:26:15,427] Trial 1 finished with value:
0.8502537125600433 and parameters: {'learning_rate':
0.7436492718856647, 'num_leaves': 520, 'max_depth': 10,
'min_data_in_leaf': 600, 'lambda_l1': 1.313723007210879, 'lambda_l2':
1.784435998219494, 'bagging_fraction': 1.0, 'bagging_freq': 5,
'feature_fraction': 0.9, 'is_unbalance': False}. Best is trial 0 with
value: 0.8600267399226471.

Early stopping, best iteration is:
[42]  valid_0's auc: 0.850459
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[83]  valid_0's auc: 0.85502
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[63]  valid_0's auc: 0.85736
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[73]  valid_0's auc: 0.857762
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
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[74]  valid_0's auc: 0.853933
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[61]  valid_0's auc: 0.85476

[I 2023-12-10 17:26:35,763] Trial 2 finished with value:
0.8557669284482972 and parameters: {'learning_rate':
0.3016891434351898, 'num_leaves': 550, 'max_depth': 14,
'min_data_in_leaf': 700, 'lambda_l1': 0.11684490843813285,
'lambda_l2': 2.982441050587382, 'bagging_fraction': 0.8,
'bagging_freq': 5, 'feature_fraction': 1.0, 'is_unbalance': False}.
Best is trial 0 with value: 0.8600267399226471.

Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[65]  valid_0's auc: 0.857133
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[71]  valid_0's auc: 0.859384
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[73]  valid_0's auc: 0.860878
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[71]  valid_0's auc: 0.85655
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[71]  valid_0's auc: 0.857918

[I 2023-12-10 17:26:53,475] Trial 3 finished with value:
0.8583724375258941 and parameters: {'learning_rate':
0.2734516356146528, 'num_leaves': 170, 'max_depth': 14,
'min_data_in_leaf': 400, 'lambda_l1': 2.718636491445507, 'lambda_l2':
2.7628707703013027, 'bagging_fraction': 1.0, 'bagging_freq': 5,
'feature_fraction': 0.9, 'is_unbalance': True}. Best is trial 0 with
value: 0.8600267399226471.

Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[51]  valid_0's auc: 0.855257
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[47]  valid_0's auc: 0.858153
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[43]  valid_0's auc: 0.85714
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[48]  valid_0's auc: 0.854524
Training until validation scores don't improve for 5 rounds
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Early stopping, best iteration is:
[54]  valid_0's auc: 0.855835

[I 2023-12-10 17:27:08,853] Trial 4 finished with value:
0.856181662864914 and parameters: {'learning_rate':
0.3735895355354363, 'num_leaves': 410, 'max_depth': 14,
'min_data_in_leaf': 500, 'lambda_l1': 0.5090871825191621, 'lambda_l2':
0.531245124226821, 'bagging_fraction': 1.0, 'bagging_freq': 5,
'feature_fraction': 0.9, 'is_unbalance': False}. Best is trial 0 with
value: 0.8600267399226471.
[I 2023-12-10 17:27:09,637] Trial 5 pruned. Trial was pruned at
iteration 1.

Training until validation scores don't improve for 5 rounds
Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:27:10,726] Trial 6 pruned. Trial was pruned at
iteration 5.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:27:12,027] Trial 7 pruned. Trial was pruned at
iteration 7.
[I 2023-12-10 17:27:12,887] Trial 8 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:27:13,653] Trial 9 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:27:14,436] Trial 10 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:27:15,170] Trial 11 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:27:15,936] Trial 12 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:27:17,007] Trial 13 pruned. Trial was pruned at
iteration 2.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:27:17,903] Trial 14 pruned. Trial was pruned at
iteration 0.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:27:19,078] Trial 15 pruned. Trial was pruned at
iteration 3.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:27:20,102] Trial 16 pruned. Trial was pruned at
iteration 4.
[I 2023-12-10 17:27:20,869] Trial 17 pruned. Trial was pruned at
iteration 0.
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[I 2023-12-10 17:27:21,619] Trial 18 pruned. Trial was pruned at
iteration 0.

Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[65]  valid_0's auc: 0.855475
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[36]  valid_0's auc: 0.856565
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[41]  valid_0's auc: 0.85752
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[56]  valid_0's auc: 0.853472
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[42]  valid_0's auc: 0.854518

[I 2023-12-10 17:27:36,817] Trial 19 finished with value:
0.855509731207119 and parameters: {'learning_rate':
0.41315793118346655, 'num_leaves': 430, 'max_depth': 16,
'min_data_in_leaf': 800, 'lambda_l1': 0.11105789306722862,
'lambda_l2': 4.149993200595819, 'bagging_fraction': 1.0,
'bagging_freq': 5, 'feature_fraction': 0.9, 'is_unbalance': True}.
Best is trial 0 with value: 0.8600267399226471.
[I 2023-12-10 17:27:37,567] Trial 20 pruned. Trial was pruned at
iteration 0.

Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[50]  valid_0's auc: 0.856273
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[46]  valid_0's auc: 0.857241
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[42]  valid_0's auc: 0.856982
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[53]  valid_0's auc: 0.854656
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[33]  valid_0's auc: 0.85531

[I 2023-12-10 17:27:52,217] Trial 21 finished with value:
0.8560922939506106 and parameters: {'learning_rate':
0.3606751433904208, 'num_leaves': 440, 'max_depth': 14,
'min_data_in_leaf': 500, 'lambda_l1': 0.4242577206111134, 'lambda_l2':
0.6236188814917167, 'bagging_fraction': 1.0, 'bagging_freq': 5,
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'feature_fraction': 0.9, 'is_unbalance': False}. Best is trial 0 with
value: 0.8600267399226471.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:27:53,298] Trial 22 pruned. Trial was pruned at
iteration 5.

Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[29]  valid_0's auc: 0.854369
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[42]  valid_0's auc: 0.858053
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[46]  valid_0's auc: 0.856802
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[31]  valid_0's auc: 0.853167
Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:28:07,946] Trial 23 finished with value:
0.8553562983404829 and parameters: {'learning_rate':
0.35548283718523926, 'num_leaves': 630, 'max_depth': 14,
'min_data_in_leaf': 200, 'lambda_l1': 0.3669035174335385, 'lambda_l2':
2.3545911018066503, 'bagging_fraction': 1.0, 'bagging_freq': 5,
'feature_fraction': 0.9, 'is_unbalance': False}. Best is trial 0 with
value: 0.8600267399226471.

Early stopping, best iteration is:
[28]  valid_0's auc: 0.85439

[I 2023-12-10 17:28:08,696] Trial 24 pruned. Trial was pruned at
iteration 0.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:28:09,764] Trial 25 pruned. Trial was pruned at
iteration 4.
[I 2023-12-10 17:28:10,563] Trial 26 pruned. Trial was pruned at
iteration 1.

Training until validation scores don't improve for 5 rounds
Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:28:11,663] Trial 27 pruned. Trial was pruned at
iteration 3.

Training until validation scores don't improve for 5 rounds
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[I 2023-12-10 17:28:13,263] Trial 28 pruned. Trial was pruned at
iteration 8.
[I 2023-12-10 17:28:14,173] Trial 29 pruned. Trial was pruned at
iteration 0.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:28:15,564] Trial 30 pruned. Trial was pruned at
iteration 10.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:28:16,899] Trial 31 pruned. Trial was pruned at
iteration 10.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:28:18,063] Trial 32 pruned. Trial was pruned at
iteration 5.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:28:19,979] Trial 33 pruned. Trial was pruned at
iteration 23.
[I 2023-12-10 17:28:20,812] Trial 34 pruned. Trial was pruned at
iteration 1.

Training until validation scores don't improve for 5 rounds
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[53]  valid_0's auc: 0.856224
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[58]  valid_0's auc: 0.858721
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[69]  valid_0's auc: 0.859245
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[62]  valid_0's auc: 0.855408
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[51]  valid_0's auc: 0.856654

[I 2023-12-10 17:28:38,084] Trial 35 finished with value:
0.8572504651278974 and parameters: {'learning_rate':
0.30505581107657376, 'num_leaves': 600, 'max_depth': 14,
'min_data_in_leaf': 400, 'lambda_l1': 0.10013083446554812,
'lambda_l2': 0.5546600078233036, 'bagging_fraction': 1.0,
'bagging_freq': 5, 'feature_fraction': 0.8, 'is_unbalance': False}.
Best is trial 0 with value: 0.8600267399226471.
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Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:28:39,342] Trial 36 pruned. Trial was pruned at
iteration 5.

Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[52]  valid_0's auc: 0.856363
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[44]  valid_0's auc: 0.857707
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[52]  valid_0's auc: 0.858883
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[45]  valid_0's auc: 0.855493
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[31]  valid_0's auc: 0.854442

[I 2023-12-10 17:28:54,023] Trial 37 finished with value:
0.856577701475546 and parameters: {'learning_rate':
0.30115618160830354, 'num_leaves': 660, 'max_depth': 12,
'min_data_in_leaf': 200, 'lambda_l1': 0.14408510725111, 'lambda_l2':
0.5363533871386492, 'bagging_fraction': 1.0, 'bagging_freq': 5,
'feature_fraction': 0.8, 'is_unbalance': True}. Best is trial 0 with
value: 0.8600267399226471.
[I 2023-12-10 17:28:54,773] Trial 38 pruned. Trial was pruned at
iteration 0.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:28:56,207] Trial 39 pruned. Trial was pruned at
iteration 9.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:28:57,606] Trial 40 pruned. Trial was pruned at
iteration 6.

Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[43]  valid_0's auc: 0.856108
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[49]  valid_0's auc: 0.857994
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[43]  valid_0's auc: 0.858098
Training until validation scores don't improve for 5 rounds
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Early stopping, best iteration is:
[51]  valid_0's auc: 0.855488
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[38]  valid_0's auc: 0.855524

[I 2023-12-10 17:29:12,673] Trial 41 finished with value:
0.8566424258970674 and parameters: {'learning_rate':
0.31489877209609646, 'num_leaves': 550, 'max_depth': 14,
'min_data_in_leaf': 400, 'lambda_l1': 0.18890883726714694,
'lambda_l2': 0.5551464222116601, 'bagging_fraction': 1.0,
'bagging_freq': 5, 'feature_fraction': 0.8, 'is_unbalance': True}.
Best is trial 0 with value: 0.8600267399226471.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:29:15,021] Trial 42 pruned. Trial was pruned at
iteration 34.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:29:17,671] Trial 43 pruned. Trial was pruned at
iteration 41.

Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[41]  valid_0's auc: 0.856517
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[51]  valid_0's auc: 0.858748
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[57]  valid_0's auc: 0.858636
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[51]  valid_0's auc: 0.856003
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[45]  valid_0's auc: 0.856417

[I 2023-12-10 17:29:34,388] Trial 44 finished with value:
0.8572643178949694 and parameters: {'learning_rate':
0.25842766531567857, 'num_leaves': 670, 'max_depth': 12,
'min_data_in_leaf': 100, 'lambda_l1': 0.17604097785891978,
'lambda_l2': 1.0298613173801736, 'bagging_fraction': 1.0,
'bagging_freq': 5, 'feature_fraction': 0.8, 'is_unbalance': True}.
Best is trial 0 with value: 0.8600267399226471.
[I 2023-12-10 17:29:35,152] Trial 45 pruned. Trial was pruned at
iteration 0.
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Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[53]  valid_0's auc: 0.857431
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[53]  valid_0's auc: 0.858712
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[45]  valid_0's auc: 0.860398
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[39]  valid_0's auc: 0.855277
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[45]  valid_0's auc: 0.856885

[I 2023-12-10 17:29:55,339] Trial 46 finished with value:
0.8577406381859136 and parameters: {'learning_rate':
0.2207044919301121, 'num_leaves': 620, 'max_depth': 16,
'min_data_in_leaf': 100, 'lambda_l1': 0.25755330059530596,
'lambda_l2': 1.103837111135766, 'bagging_fraction': 1.0,
'bagging_freq': 5, 'feature_fraction': 0.8, 'is_unbalance': True}.
Best is trial 0 with value: 0.8600267399226471.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:29:56,749] Trial 47 pruned. Trial was pruned at
iteration 8.

Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[54]  valid_0's auc: 0.858165
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[53]  valid_0's auc: 0.859705
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[54]  valid_0's auc: 0.860175
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[42]  valid_0's auc: 0.856034
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[33]  valid_0's auc: 0.858082

[I 2023-12-10 17:30:18,598] Trial 48 finished with value:
0.8584320772606407 and parameters: {'learning_rate':
0.2095452004911264, 'num_leaves': 670, 'max_depth': 16,
'min_data_in_leaf': 100, 'lambda_l1': 0.28314817208521775,
'lambda_l2': 1.433930597487384, 'bagging_fraction': 1.0,
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'bagging_freq': 5, 'feature_fraction': 0.8, 'is_unbalance': True}.
Best is trial 0 with value: 0.8600267399226471.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:30:20,447] Trial 49 pruned. Trial was pruned at
iteration 10.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:30:22,147] Trial 50 pruned. Trial was pruned at
iteration 10.

Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[52]  valid_0's auc: 0.857849
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[44]  valid_0's auc: 0.858475
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[51]  valid_0's auc: 0.859954
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[45]  valid_0's auc: 0.855764
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[42]  valid_0's auc: 0.857167

[I 2023-12-10 17:30:41,008] Trial 51 finished with value:
0.8578416679516139 and parameters: {'learning_rate':
0.23038623934695204, 'num_leaves': 580, 'max_depth': 16,
'min_data_in_leaf': 100, 'lambda_l1': 0.24724207410438123,
'lambda_l2': 1.03690673597857, 'bagging_fraction': 1.0,
'bagging_freq': 5, 'feature_fraction': 0.8, 'is_unbalance': True}.
Best is trial 0 with value: 0.8600267399226471.

Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[33]  valid_0's auc: 0.857064
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[45]  valid_0's auc: 0.858556
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[44]  valid_0's auc: 0.859488
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[42]  valid_0's auc: 0.856191
Training until validation scores don't improve for 5 rounds
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Early stopping, best iteration is:
[36]  valid_0's auc: 0.856971

[I 2023-12-10 17:30:58,677] Trial 52 finished with value:
0.8576539369000242 and parameters: {'learning_rate':
0.216330340312591, 'num_leaves': 680, 'max_depth': 16,
'min_data_in_leaf': 100, 'lambda_l1': 0.26481735906713755,
'lambda_l2': 1.6499115015776231, 'bagging_fraction': 1.0,
'bagging_freq': 5, 'feature_fraction': 0.8, 'is_unbalance': True}.
Best is trial 0 with value: 0.8600267399226471.

Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[41]  valid_0's auc: 0.857068
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[51]  valid_0's auc: 0.858512
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[61]  valid_0's auc: 0.859234
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[47]  valid_0's auc: 0.856054
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[39]  valid_0's auc: 0.856734

[I 2023-12-10 17:31:18,498] Trial 53 finished with value:
0.8575202723630518 and parameters: {'learning_rate':
0.21964100928249483, 'num_leaves': 700, 'max_depth': 16,
'min_data_in_leaf': 100, 'lambda_l1': 0.3268412725929073, 'lambda_l2':
1.7484319981568937, 'bagging_fraction': 1.0, 'bagging_freq': 5,
'feature_fraction': 0.8, 'is_unbalance': True}. Best is trial 0 with
value: 0.8600267399226471.

Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[39]  valid_0's auc: 0.857857
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[68]  valid_0's auc: 0.860204
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[62]  valid_0's auc: 0.860278
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[68]  valid_0's auc: 0.856673
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[52]  valid_0's auc: 0.85845
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[I 2023-12-10 17:31:39,493] Trial 54 finished with value:
0.8586923397643037 and parameters: {'learning_rate':
0.229939794828962, 'num_leaves': 570, 'max_depth': 16,
'min_data_in_leaf': 200, 'lambda_l1': 0.25837022271094495,
'lambda_l2': 2.6921996585359778, 'bagging_fraction': 1.0,
'bagging_freq': 5, 'feature_fraction': 0.8, 'is_unbalance': True}.
Best is trial 0 with value: 0.8600267399226471.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:31:40,785] Trial 55 pruned. Trial was pruned at
iteration 8.
[I 2023-12-10 17:31:41,680] Trial 56 pruned. Trial was pruned at
iteration 1.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:31:42,433] Trial 57 pruned. Trial was pruned at
iteration 0.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:31:43,646] Trial 58 pruned. Trial was pruned at
iteration 6.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:31:44,770] Trial 59 pruned. Trial was pruned at
iteration 5.
[I 2023-12-10 17:31:45,570] Trial 60 pruned. Trial was pruned at
iteration 0.

Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[54]  valid_0's auc: 0.85787
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[45]  valid_0's auc: 0.8589
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[43]  valid_0's auc: 0.860407
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[49]  valid_0's auc: 0.856594
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[43]  valid_0's auc: 0.857425

[I 2023-12-10 17:32:03,926] Trial 61 finished with value:
0.8582391854567282 and parameters: {'learning_rate':
0.2198862869582215, 'num_leaves': 560, 'max_depth': 16,
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'min_data_in_leaf': 100, 'lambda_l1': 0.2546565213106376, 'lambda_l2':
1.637293359042712, 'bagging_fraction': 1.0, 'bagging_freq': 5,
'feature_fraction': 0.8, 'is_unbalance': True}. Best is trial 0 with
value: 0.8600267399226471.

Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[45]  valid_0's auc: 0.857329
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[51]  valid_0's auc: 0.859049
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[43]  valid_0's auc: 0.859986
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[53]  valid_0's auc: 0.856346
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[32]  valid_0's auc: 0.856642

[I 2023-12-10 17:32:21,001] Trial 62 finished with value:
0.8578702930181457 and parameters: {'learning_rate':
0.2452055239572739, 'num_leaves': 530, 'max_depth': 16,
'min_data_in_leaf': 100, 'lambda_l1': 0.22427863427813713,
'lambda_l2': 1.55778096583017, 'bagging_fraction': 1.0,
'bagging_freq': 5, 'feature_fraction': 0.8, 'is_unbalance': True}.
Best is trial 0 with value: 0.8600267399226471.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:32:24,066] Trial 63 pruned. Trial was pruned at
iteration 46.
[I 2023-12-10 17:32:24,841] Trial 64 pruned. Trial was pruned at
iteration 0.

Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[52]  valid_0's auc: 0.857684
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[67]  valid_0's auc: 0.85959
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[46]  valid_0's auc: 0.85985
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[65]  valid_0's auc: 0.857271
Training until validation scores don't improve for 5 rounds
```

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Early stopping, best iteration is:
[45]  valid_0's auc: 0.857681

[I 2023-12-10 17:32:44,296] Trial 65 finished with value:
0.858415210250409 and parameters: {'learning_rate':
0.2281533272578777, 'num_leaves': 570, 'max_depth': 16,
'min_data_in_leaf': 200, 'lambda_l1': 0.40152968716734017,
'lambda_l2': 2.7788672204360996, 'bagging_fraction': 1.0,
'bagging_freq': 5, 'feature_fraction': 0.8, 'is_unbalance': True}.
Best is trial 0 with value: 0.8600267399226471.
[I 2023-12-10 17:32:45,258] Trial 66 pruned. Trial was pruned at
iteration 2.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:32:46,051] Trial 67 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:32:46,853] Trial 68 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:32:47,637] Trial 69 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:32:48,507] Trial 70 pruned. Trial was pruned at
iteration 0.

Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[45]  valid_0's auc: 0.858552
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[44]  valid_0's auc: 0.858114
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[37]  valid_0's auc: 0.86028
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[52]  valid_0's auc: 0.856498
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[31]  valid_0's auc: 0.857021

[I 2023-12-10 17:33:07,188] Trial 71 finished with value:
0.8580930682562986 and parameters: {'learning_rate':
0.2310814994093488, 'num_leaves': 520, 'max_depth': 16,
'min_data_in_leaf': 100, 'lambda_l1': 0.24031192480026378,
'lambda_l2': 1.2718415240922005, 'bagging_fraction': 1.0,
'bagging_freq': 5, 'feature_fraction': 0.8, 'is_unbalance': True}.
Best is trial 0 with value: 0.8600267399226471.

Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[47]  valid_0's auc: 0.858129
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Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[42]  valid_0's auc: 0.85902
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[46]  valid_0's auc: 0.860031
Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:33:23,027] Trial 72 pruned. Trial was pruned at
iteration 59.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:33:24,275] Trial 73 pruned. Trial was pruned at
iteration 6.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:33:25,541] Trial 74 pruned. Trial was pruned at
iteration 4.
[I 2023-12-10 17:33:26,474] Trial 75 pruned. Trial was pruned at
iteration 2.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:33:27,485] Trial 76 pruned. Trial was pruned at
iteration 2.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:33:28,389] Trial 77 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:33:29,170] Trial 78 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:33:30,023] Trial 79 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:33:30,860] Trial 80 pruned. Trial was pruned at
iteration 0.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:33:34,144] Trial 81 pruned. Trial was pruned at
iteration 34.

Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[47]  valid_0's auc: 0.857532
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[41]  valid_0's auc: 0.858725
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
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[41]  valid_0's auc: 0.85948
Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:33:50,880] Trial 82 pruned. Trial was pruned at
iteration 58.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:33:52,309] Trial 83 pruned. Trial was pruned at
iteration 6.

Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[39]  valid_0's auc: 0.85717
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[51]  valid_0's auc: 0.85868
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[51]  valid_0's auc: 0.859928
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[50]  valid_0's auc: 0.856799
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[42]  valid_0's auc: 0.857377

[I 2023-12-10 17:34:13,592] Trial 84 finished with value:
0.8579908024249354 and parameters: {'learning_rate':
0.22321724033063936, 'num_leaves': 550, 'max_depth': 16,
'min_data_in_leaf': 100, 'lambda_l1': 0.22308339726954923,
'lambda_l2': 0.9826618592024223, 'bagging_fraction': 1.0,
'bagging_freq': 5, 'feature_fraction': 0.8, 'is_unbalance': True}.
Best is trial 0 with value: 0.8600267399226471.
[I 2023-12-10 17:34:14,373] Trial 85 pruned. Trial was pruned at
iteration 0.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:34:17,515] Trial 86 pruned. Trial was pruned at
iteration 34.
[I 2023-12-10 17:34:18,359] Trial 87 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:34:19,187] Trial 88 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:34:20,145] Trial 89 pruned. Trial was pruned at
iteration 1.

Training until validation scores don't improve for 5 rounds
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[I 2023-12-10 17:34:21,040] Trial 90 pruned. Trial was pruned at
iteration 0.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:34:25,122] Trial 91 pruned. Trial was pruned at
iteration 48.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:34:26,898] Trial 92 pruned. Trial was pruned at
iteration 11.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:34:31,442] Trial 93 pruned. Trial was pruned at
iteration 59.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:34:32,743] Trial 94 pruned. Trial was pruned at
iteration 6.
[I 2023-12-10 17:34:33,568] Trial 95 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:34:34,477] Trial 96 pruned. Trial was pruned at
iteration 1.

Training until validation scores don't improve for 5 rounds
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[42]  valid_0's auc: 0.857651
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[52]  valid_0's auc: 0.859147
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[45]  valid_0's auc: 0.859115
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[44]  valid_0's auc: 0.855746
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[30]  valid_0's auc: 0.856928

[I 2023-12-10 17:34:54,921] Trial 97 finished with value:
0.8577173080557025 and parameters: {'learning_rate':
0.24128628890339518, 'num_leaves': 610, 'max_depth': 16,
'min_data_in_leaf': 100, 'lambda_l1': 0.2986261823363801, 'lambda_l2':
3.2402991033265622, 'bagging_fraction': 1.0, 'bagging_freq': 5,
'feature_fraction': 0.8, 'is_unbalance': True}. Best is trial 0 with
value: 0.8600267399226471.
```

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[I 2023-12-10 17:34:55,739] Trial 98 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:34:56,585] Trial 99 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:34:57,470] Trial 100 pruned. Trial was pruned at
iteration 0.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:34:59,557] Trial 101 pruned. Trial was pruned at
iteration 15.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:35:01,444] Trial 102 pruned. Trial was pruned at
iteration 12.
[I 2023-12-10 17:35:02,296] Trial 103 pruned. Trial was pruned at
iteration 0.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:35:05,519] Trial 104 pruned. Trial was pruned at
iteration 34.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:35:08,620] Trial 105 pruned. Trial was pruned at
iteration 34.
[I 2023-12-10 17:35:09,442] Trial 106 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:35:10,255] Trial 107 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:35:11,070] Trial 108 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:35:11,849] Trial 109 pruned. Trial was pruned at
iteration 0.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:35:13,069] Trial 110 pruned. Trial was pruned at
iteration 3.

Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[40]  valid_0's auc: 0.857153
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[51]  valid_0's auc: 0.859023
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[48]  valid_0's auc: 0.85939
Training until validation scores don't improve for 5 rounds
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Early stopping, best iteration is:
[46]  valid_0's auc: 0.855585
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[37]  valid_0's auc: 0.856789

[I 2023-12-10 17:35:33,113] Trial 111 finished with value:
0.8575881799997888 and parameters: {'learning_rate':
0.24018627076187027, 'num_leaves': 620, 'max_depth': 16,
'min_data_in_leaf': 100, 'lambda_l1': 0.28997489270314836,
'lambda_l2': 2.8657443474302977, 'bagging_fraction': 1.0,
'bagging_freq': 5, 'feature_fraction': 0.8, 'is_unbalance': True}.
Best is trial 0 with value: 0.8600267399226471.
[I 2023-12-10 17:35:33,899] Trial 112 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:35:34,671] Trial 113 pruned. Trial was pruned at
iteration 0.

Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[46]  valid_0's auc: 0.857837
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[40]  valid_0's auc: 0.858969
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[44]  valid_0's auc: 0.859718
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[33]  valid_0's auc: 0.855319
Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:35:52,621] Trial 114 pruned. Trial was pruned at
iteration 59.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:35:53,808] Trial 115 pruned. Trial was pruned at
iteration 4.
[I 2023-12-10 17:35:54,702] Trial 116 pruned. Trial was pruned at
iteration 1.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:35:55,477] Trial 117 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:35:56,289] Trial 118 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:35:57,116] Trial 119 pruned. Trial was pruned at
iteration 0.
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Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:35:58,100] Trial 120 pruned. Trial was pruned at
iteration 3.

Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[45]  valid_0's auc: 0.858311
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[48]  valid_0's auc: 0.859551
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[56]  valid_0's auc: 0.860616
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[60]  valid_0's auc: 0.856483
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[51]  valid_0's auc: 0.858295

[I 2023-12-10 17:36:17,597] Trial 121 finished with value:
0.8586513512179579 and parameters: {'learning_rate':
0.21120290065107622, 'num_leaves': 520, 'max_depth': 16,
'min_data_in_leaf': 100, 'lambda_l1': 0.2652789238432754, 'lambda_l2':
1.5931577517819755, 'bagging_fraction': 1.0, 'bagging_freq': 5,
'feature_fraction': 0.8, 'is_unbalance': True}. Best is trial 0 with
value: 0.8600267399226471.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:36:18,806] Trial 122 pruned. Trial was pruned at
iteration 5.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:36:20,938] Trial 123 pruned. Trial was pruned at
iteration 18.
[I 2023-12-10 17:36:21,918] Trial 124 pruned. Trial was pruned at
iteration 2.

Training until validation scores don't improve for 5 rounds
Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:36:23,756] Trial 125 pruned. Trial was pruned at
iteration 18.

Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[46]  valid_0's auc: 0.858135
Training until validation scores don't improve for 5 rounds
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Early stopping, best iteration is:
[45]  valid_0's auc: 0.858859
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[53]  valid_0's auc: 0.86086
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[45]  valid_0's auc: 0.85654
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[33]  valid_0's auc: 0.856953

[I 2023-12-10 17:36:41,629] Trial 126 finished with value:
0.8582692721611821 and parameters: {'learning_rate':
0.21431363741395956, 'num_leaves': 550, 'max_depth': 16,
'min_data_in_leaf': 100, 'lambda_l1': 0.16215023780566265,
'lambda_l2': 1.3346542761479314, 'bagging_fraction': 1.0,
'bagging_freq': 5, 'feature_fraction': 0.8, 'is_unbalance': True}.
Best is trial 0 with value: 0.8600267399226471.
[I 2023-12-10 17:36:42,379] Trial 127 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:36:43,145] Trial 128 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:36:43,926] Trial 129 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:36:44,875] Trial 130 pruned. Trial was pruned at
iteration 2.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:36:45,801] Trial 131 pruned. Trial was pruned at
iteration 2.

Training until validation scores don't improve for 5 rounds
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[47]  valid_0's auc: 0.857982
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[50]  valid_0's auc: 0.859833
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[52]  valid_0's auc: 0.860173
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[44]  valid_0's auc: 0.856019
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[45]  valid_0's auc: 0.857202
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[I 2023-12-10 17:37:05,175] Trial 132 finished with value:
0.8582419326312326 and parameters: {'learning_rate':
0.21622211493513482, 'num_leaves': 600, 'max_depth': 16,
'min_data_in_leaf': 100, 'lambda_l1': 0.3515894238914401, 'lambda_l2':
1.4066870541085763, 'bagging_fraction': 1.0, 'bagging_freq': 5,
'feature_fraction': 0.8, 'is_unbalance': True}. Best is trial 0 with
value: 0.8600267399226471.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:37:06,663] Trial 133 pruned. Trial was pruned at
iteration 11.
[I 2023-12-10 17:37:07,611] Trial 134 pruned. Trial was pruned at
iteration 2.

Training until validation scores don't improve for 5 rounds
Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:37:09,165] Trial 135 pruned. Trial was pruned at
iteration 11.
[I 2023-12-10 17:37:09,939] Trial 136 pruned. Trial was pruned at
iteration 0.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:37:11,188] Trial 137 pruned. Trial was pruned at
iteration 5.
[I 2023-12-10 17:37:11,962] Trial 138 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:37:12,770] Trial 139 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:37:13,548] Trial 140 pruned. Trial was pruned at
iteration 0.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:37:16,019] Trial 141 pruned. Trial was pruned at
iteration 28.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:37:18,801] Trial 142 pruned. Trial was pruned at
iteration 34.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:37:20,739] Trial 143 pruned. Trial was pruned at
iteration 20.

Training until validation scores don't improve for 5 rounds
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[I 2023-12-10 17:37:23,793] Trial 144 pruned. Trial was pruned at
iteration 37.
[I 2023-12-10 17:37:24,669] Trial 145 pruned. Trial was pruned at
iteration 0.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:37:27,192] Trial 146 pruned. Trial was pruned at
iteration 27.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:37:29,867] Trial 147 pruned. Trial was pruned at
iteration 31.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:37:30,842] Trial 148 pruned. Trial was pruned at
iteration 3.
[I 2023-12-10 17:37:31,830] Trial 149 pruned. Trial was pruned at
iteration 2.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:37:32,595] Trial 150 pruned. Trial was pruned at
iteration 0.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:37:36,811] Trial 151 pruned. Trial was pruned at
iteration 59.

Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[41]  valid_0's auc: 0.857607
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[55]  valid_0's auc: 0.858816
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[45]  valid_0's auc: 0.859945
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[48]  valid_0's auc: 0.856108
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[37]  valid_0's auc: 0.85659

[I 2023-12-10 17:37:56,053] Trial 152 finished with value:
0.8578132675219319 and parameters: {'learning_rate':
0.2172934088339664, 'num_leaves': 700, 'max_depth': 16,
'min_data_in_leaf': 100, 'lambda_l1': 0.2963999652857492, 'lambda_l2':
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1.926468336748035, 'bagging_fraction': 1.0, 'bagging_freq': 5,
'feature_fraction': 0.8, 'is_unbalance': True}. Best is trial 0 with
value: 0.8600267399226471.
[I 2023-12-10 17:37:56,845] Trial 153 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:37:57,831] Trial 154 pruned. Trial was pruned at
iteration 2.

Training until validation scores don't improve for 5 rounds
Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:38:00,260] Trial 155 pruned. Trial was pruned at
iteration 22.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:38:02,270] Trial 156 pruned. Trial was pruned at
iteration 18.
[I 2023-12-10 17:38:03,110] Trial 157 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:38:03,981] Trial 158 pruned. Trial was pruned at
iteration 0.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:38:05,321] Trial 159 pruned. Trial was pruned at
iteration 8.
[I 2023-12-10 17:38:06,132] Trial 160 pruned. Trial was pruned at
iteration 0.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:38:07,880] Trial 161 pruned. Trial was pruned at
iteration 14.
[I 2023-12-10 17:38:08,662] Trial 162 pruned. Trial was pruned at
iteration 0.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:38:10,112] Trial 163 pruned. Trial was pruned at
iteration 8.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:38:11,229] Trial 164 pruned. Trial was pruned at
iteration 5.
[I 2023-12-10 17:38:12,031] Trial 165 pruned. Trial was pruned at
iteration 0.

Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[30]  valid_0's auc: 0.856725
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Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[46]  valid_0's auc: 0.858271
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[44]  valid_0's auc: 0.859158
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[31]  valid_0's auc: 0.854915
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[37]  valid_0's auc: 0.857283

[I 2023-12-10 17:38:28,718] Trial 166 finished with value:
0.8572704676834231 and parameters: {'learning_rate':
0.23910527203278434, 'num_leaves': 640, 'max_depth': 16,
'min_data_in_leaf': 100, 'lambda_l1': 0.15282603635993006,
'lambda_l2': 1.5099726784671146, 'bagging_fraction': 1.0,
'bagging_freq': 5, 'feature_fraction': 0.8, 'is_unbalance': True}.
Best is trial 0 with value: 0.8600267399226471.
[I 2023-12-10 17:38:29,614] Trial 167 pruned. Trial was pruned at
iteration 1.

Training until validation scores don't improve for 5 rounds
Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:38:31,630] Trial 168 pruned. Trial was pruned at
iteration 22.
[I 2023-12-10 17:38:32,452] Trial 169 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:38:33,249] Trial 170 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:38:34,097] Trial 171 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:38:34,890] Trial 172 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:38:35,839] Trial 173 pruned. Trial was pruned at
iteration 1.

Training until validation scores don't improve for 5 rounds
Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:38:36,966] Trial 174 pruned. Trial was pruned at
iteration 4.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:38:39,550] Trial 175 pruned. Trial was pruned at
iteration 31.
[I 2023-12-10 17:38:40,323] Trial 176 pruned. Trial was pruned at
iteration 0.
```

```
[I 2023-12-10 17:38:41,190] Trial 177 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:38:41,946] Trial 178 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:38:42,775] Trial 179 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:38:43,556] Trial 180 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:38:44,343] Trial 181 pruned. Trial was pruned at
iteration 0.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:38:46,897] Trial 182 pruned. Trial was pruned at
iteration 26.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:38:51,094] Trial 183 pruned. Trial was pruned at
iteration 59.
[I 2023-12-10 17:38:52,061] Trial 184 pruned. Trial was pruned at
iteration 2.

Training until validation scores don't improve for 5 rounds
Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:38:53,898] Trial 185 pruned. Trial was pruned at
iteration 15.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:38:56,146] Trial 186 pruned. Trial was pruned at
iteration 22.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:38:57,534] Trial 187 pruned. Trial was pruned at
iteration 7.

Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[50]  valid_0's auc: 0.858128
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[47]  valid_0's auc: 0.85947
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[46]  valid_0's auc: 0.860317
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[48]  valid_0's auc: 0.856571
Training until validation scores don't improve for 5 rounds
```

```
Early stopping, best iteration is:
[37]  valid_0's auc: 0.856957

[I 2023-12-10 17:39:16,617] Trial 188 finished with value:
0.8582884438598674 and parameters: {'learning_rate':
0.22810765425630575, 'num_leaves': 560, 'max_depth': 16,
'min_data_in_leaf': 100, 'lambda_l1': 0.31227773853598395,
'lambda_l2': 1.476097762039324, 'bagging_fraction': 1.0,
'bagging_freq': 5, 'feature_fraction': 0.8, 'is_unbalance': True}.
Best is trial 0 with value: 0.8600267399226471.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:39:18,494] Trial 189 pruned. Trial was pruned at
iteration 17.
[I 2023-12-10 17:39:19,294] Trial 190 pruned. Trial was pruned at
iteration 0.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:39:20,364] Trial 191 pruned. Trial was pruned at
iteration 4.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:39:22,149] Trial 192 pruned. Trial was pruned at
iteration 14.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:39:23,302] Trial 193 pruned. Trial was pruned at
iteration 4.
[I 2023-12-10 17:39:24,107] Trial 194 pruned. Trial was pruned at
iteration 0.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:39:26,601] Trial 195 pruned. Trial was pruned at
iteration 27.
[I 2023-12-10 17:39:27,599] Trial 196 pruned. Trial was pruned at
iteration 2.

Training until validation scores don't improve for 5 rounds
Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:39:29,703] Trial 197 pruned. Trial was pruned at
iteration 20.
[I 2023-12-10 17:39:30,656] Trial 198 pruned. Trial was pruned at
iteration 1.

Training until validation scores don't improve for 5 rounds
```

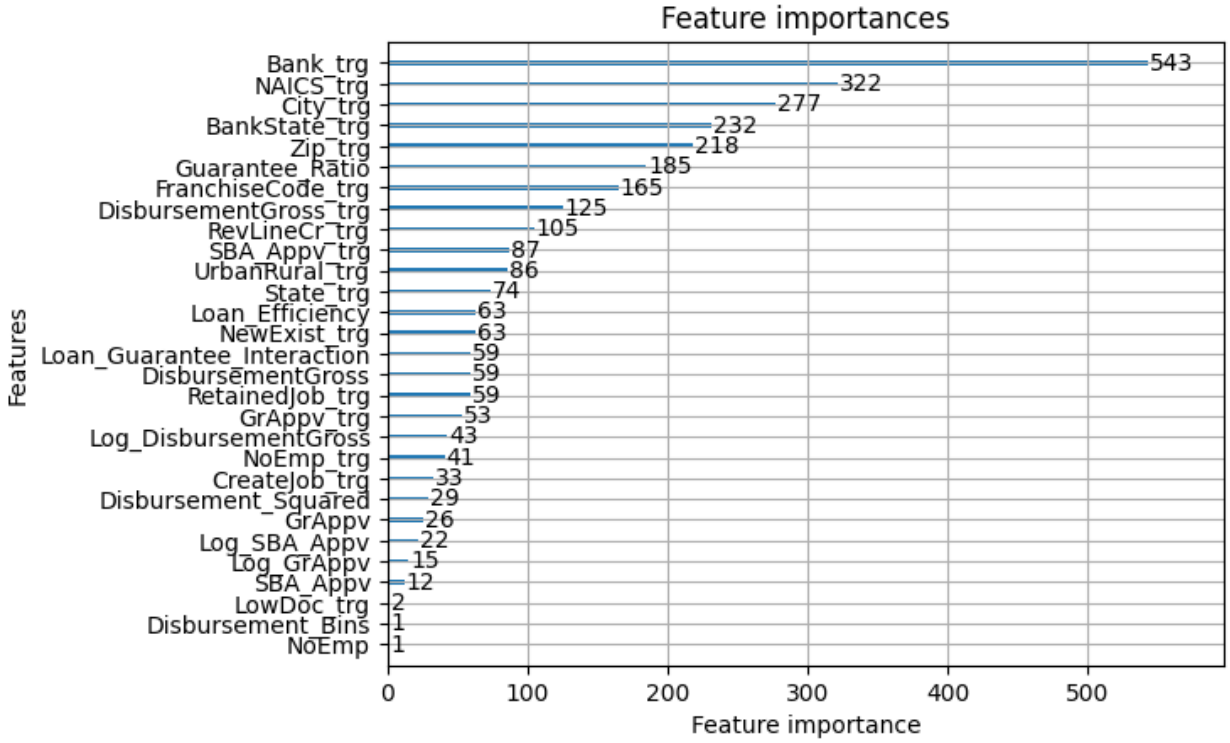
```
[I 2023-12-10 17:39:31,450] Trial 199 pruned. Trial was pruned at
iteration 0.

Best hyperparameters: {'learning_rate': 0.13238993755297335,
'num_leaves': 700, 'max_depth': 10, 'min_data_in_leaf': 900,
'lambda_l1': 0.16858915562508314, 'lambda_l2': 1.773650587284315,
'bagging_fraction': 1.0, 'bagging_freq': 5, 'feature_fraction': 1.0,
'is_unbalance': False}
Best AUCPR: 0.8600267399226471
```

```
print('Best hyperparameters:', study.best_params)
print('Best AUCPR:', study.best_value)
plt.figure(figsize=(12,6))
lgb.plot_importance(lgb_clf, max_num_features=30)
plt.title("Feature importances")
plt.show()
```

```
Best hyperparameters: {'learning_rate': 0.13238993755297335,
'num_leaves': 700, 'max_depth': 10, 'min_data_in_leaf': 900,
'lambda_l1': 0.16858915562508314, 'lambda_l2': 1.773650587284315,
'bagging_fraction': 1.0, 'bagging_freq': 5, 'feature_fraction': 1.0,
'is_unbalance': False}
Best AUCPR: 0.8600267399226471

<Figure size 1200x600 with 0 Axes>
```



Permutation feature by Optuna

As we can see Variable Bank(encoded) is the top most feature, followed by NAICS(encoded) -> Industry type

Then we have Bank State and Zip, both encoded , and then Gaureentee ratio.

```
optuna.visualization.plot_optimization_history(study)
```


```
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Optimization Score History

As we can see the model gets us the best base score value as 0.86

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Hyperparameter Tuning and individual effect

As we can see learning_rate parameter contributes to 80% model tunining Followed by max_depth 11% , and then lambda_l1 (Lasso) 6% and rest follow suits

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import shap
explainer = shap.TreeExplainer(lgb_clf)
shap_values = explainer.shap_values(X_test)

# Plot SHAP summary plot (for all features)
shap.summary_plot(shap_values, X_test)
plt.show()
```

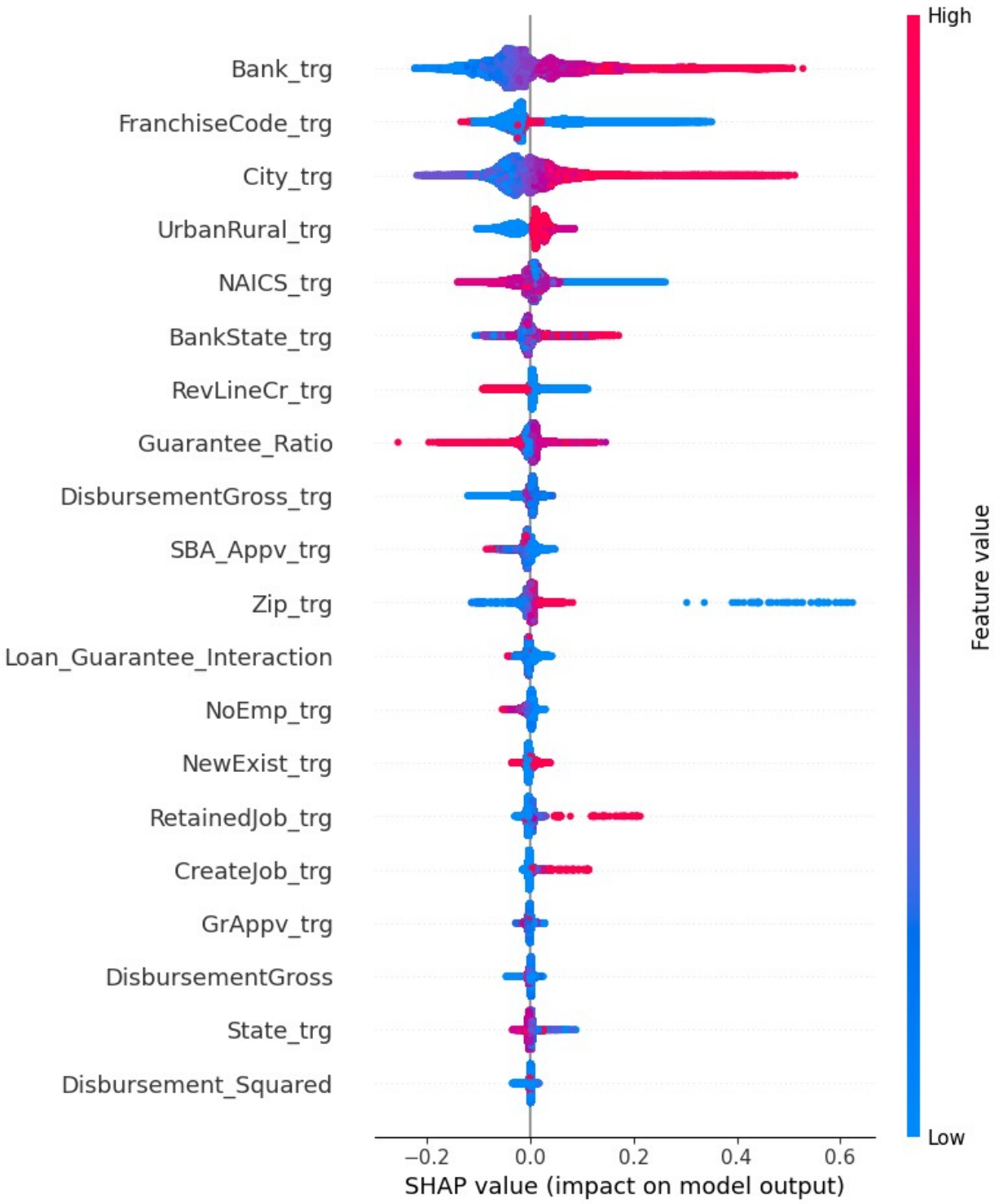
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0.0
0.2
0.4
0.6
SHAP value (impact on model output)
High
Feature value
Low

SHAP summary plot shows the contribution of the features for each instance (row of data). The sum of the feature contributions and the bias term is equal to the raw prediction of the model, i.e., prediction before applying inverse link function.

Its a beeswarm plot, for each variable, every instance (i.e. row) of the dataset appears as its own point. The points are distributed along the x-axis according to their SHAP values. In places of high density of SHAP values, they are stacked vertically

Knowing how a variable may influence the model predictions, it can be seen by how the SHAP values are distributed. The features are ranked from top to bottom by their mean absolute SHAP values for the entire dataset. As we can see the TERM feature is the most important feature according to the SHAP values

Examining the color distribution horizontally along the x-axis for each feature provides insights into general relationship between a variables raw values and its SHAP values

As we can see, Bank Shap value for most instances are on the positive side with color red, which means the instances of Bank variable pushes the variable in predicting if a customer will default in a higher degree.

Next, Most important variable seems to be City, with its most average instances pushing the prediction to higher side, that is helping in detecting the city to be a good factor along with other contributions from other feature in detecting whether the customer will default or not

```
import pickle

# Assuming you have a variable named 'best_params' containing the best hyperparameters
best_params = study.best_params

with open('best_params.pkl', 'wb') as f:
    pickle.dump(best_params, f)

best_params
```

```
{'learning_rate': 0.13238993755297335,
 'num_leaves': 700,
 'max_depth': 10,
 'min_data_in_leaf': 900,
```

```
 'lambda_l1': 0.16858915562508314,
 'lambda_l2': 1.773650587284315,
 'bagging_fraction': 1.0,
 'bagging_freq': 5,
 'feature_fraction': 1.0,
 'is_unbalance': False}
```

```
print(f"\tBest value (AUC): {study.best_value:.5f}")
print(f"\tBest params:")

for key, value in study.best_params.items():
    print(f"\t\t{key}: {value}")

print("Best model best_iteration:",
study_model_iteractions[study.best_trial.number])
```

```
     Best value (AUC): 0.86003
     Best params:
          learning_rate: 0.13238993755297335
          num_leaves: 700
          max_depth: 10
          min_data_in_leaf: 900
          lambda_l1: 0.16858915562508314
          lambda_l2: 1.773650587284315
          bagging_fraction: 1.0
          bagging_freq: 5
          feature_fraction: 1.0
          is_unbalance: False
Best model best_iteration: 250.6
```

```
best_params = {"verbose": -1,
               "objective":"binary",
               "metric":"auc"
            }
for key,val in study.best_params.items():
    best_params[key] = val

best_params["num_iterations"] =
int(study_model_iteractions[study.best_trial.number])
print(best_params)
```

```
{'verbose': -1, 'objective': 'binary', 'metric': 'auc',
'learning_rate': 0.13238993755297335, 'num_leaves': 700, 'max_depth':
10, 'min_data_in_leaf': 900, 'lambda_l1': 0.16858915562508314,
'lambda_l2': 1.773650587284315, 'bagging_fraction': 1.0,
'bagging_freq': 5, 'feature_fraction': 1.0, 'is_unbalance': False,
'num_iterations': 250}
```

AUCPR Score

```
print("AUCPR score on Test dataset:", roc_auc_score(y_test,
lgb_clf.predict(X_test)))
print("AUCPR score on Train dataset:", roc_auc_score(y_train,
lgb_clf.predict(X_train)))
```

```
AUCPR score on Test dataset: 0.8225855591034863
AUCPR score on Train dataset: 0.8473599291272692
```

```
from sklearn.metrics import f1_score

# Assuming best_lgb is the trained LightGBM model and X_test, y_test
are defined

# Get the predicted probabilities for the positive class (class 1)
y_pred_proba = lgb_clf.predict(X_test)

# Set a range of thresholds to test
thresholds = [0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9]

best_f1 = 0
best_threshold = 0

# Find the threshold that maximizes the F1 score
for threshold in thresholds:
    y_pred = (y_pred_proba > threshold).astype(int)
    f1 = f1_score(y_test, y_pred, average='macro')

    if f1 > best_f1:
        best_f1 = f1
        best_threshold = threshold

print("Best F1 score:", best_f1)
print("Best threshold:", best_threshold)
```

```
Best F1 score: 0.7082954969946077
Best threshold: 0.3
```

Confusion matrix

As we can see the data distrubution is imbalanced

As such, when we calculate f1 and threshold, we use average = "macro"

Also, we can see TN = 117125, TP = 15180, FP = 15077, FN = 12669

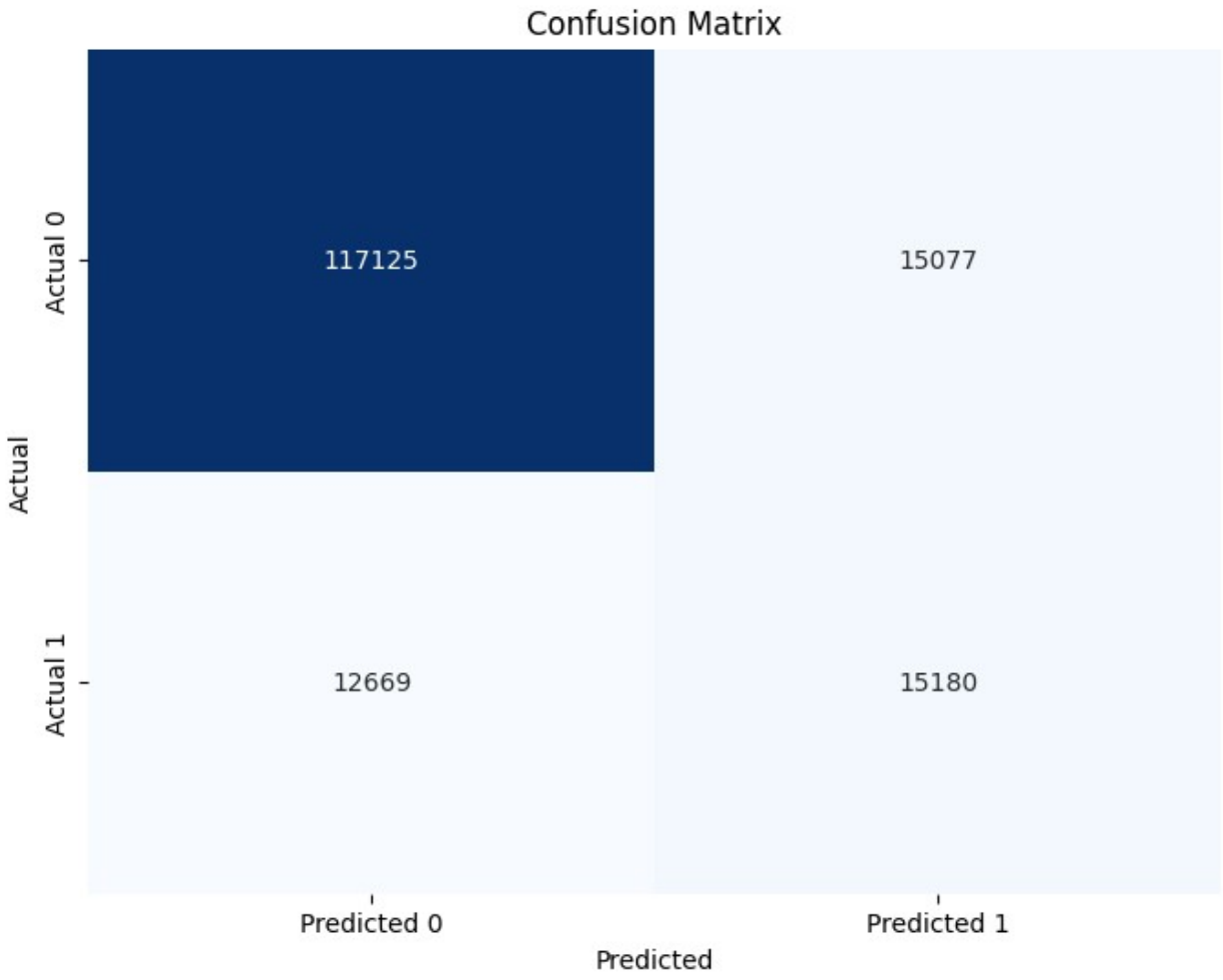
```
import seaborn as sns
from sklearn.metrics import confusion_matrix
```

```
# Get the predicted probabilities for the positive class (class 1)
from the test set
y_pred_proba = lgb_clf.predict(X_test)

# Use the threshold obtained earlier to predict binary labels
threshold = best_threshold
y_pred = (y_pred_proba > threshold).astype(int)

# Construct the confusion matrix
conf_matrix = confusion_matrix(y_test, y_pred)

# Plot confusion matrix using seaborn heatmap
plt.figure(figsize=(8, 6))
sns.heatmap(conf_matrix, annot=True, fmt='d', cmap='Blues',
cbar=False,
            xticklabels=['Predicted 0', 'Predicted 1'],
            yticklabels=['Actual 0', 'Actual 1'])
plt.title('Confusion Matrix')
plt.xlabel('Predicted')
plt.ylabel('Actual')
plt.show()
```




```
import pickle

# Assuming you have a variable named 'best_params' containing the best
hyperparameters
best_params = best_params

with open('best_params.pkl', 'wb') as f:
    pickle.dump(best_params, f)

from sklearn.metrics import f1_score
def calculate_optimal_threshold(classifier, X, y):
    y_prob = classifier.predict_proba(X)[:, 1]
    thresholds = np.linspace(0, 1, 100)
    f1_scores = []

    for threshold in thresholds:
        y_pred = (y_prob > threshold).astype(int)
        score = f1_score(y, y_pred, average='macro')
        f1_scores.append(score)
```

```
    optimal_threshold = thresholds[np.argmax(f1_scores)]
    return optimal_threshold

import pandas as pd
import numpy as np
import lightgbm as lgb
from sklearn.metrics import roc_auc_score
import category_encoders as ce
from sklearn.preprocessing import StandardScaler
import optuna
from sklearn.model_selection import StratifiedKFold
from optuna.integration import LightGBMPruningCallback
import warnings
import pickle
warnings.filterwarnings("ignore", category=UserWarning)

def train_model(data):

    data.drop(columns="index",inplace=True)
    for i in data['RevLineCr']:
        if i not in ['Y','N']:
            data['RevLineCr'].replace(i,'N',inplace=True)
    for i in data['LowDoc']:
        if i not in ['Y','N']:
            data['LowDoc'].replace(i,'N',inplace=True)
    for i in data['NewExist']:
        if i not in [1,2]:
            data['NewExist'].replace(i,None,inplace=True)

    cat_cols=['City', 'State', 'Bank', 'BankState', 'RevLineCr',
'LowDoc','NewExist']
    for column in cat_cols:
        data[column]=data[column].fillna(data[column].mode()[0])

    for column in cat_cols:
        data[column]=data[column].fillna(data[column].mode()[0])
    encoder = ce.TargetEncoder(cols=cat_cols)
    encoder.fit(data, data['MIS_Status'])
    data_encoded = encoder.transform(data)
    data_encoded = data_encoded.add_suffix('_trg')
    data_encoded = pd.concat([data_encoded, data], axis=1)
    for column in cat_cols:
        data_encoded[column + "_trg"].fillna(data_encoded[column +
"_trg"].mean(), inplace=True)
    data_encoded.drop(columns=cat_cols, inplace=True)
    data_encoded.drop(columns='MIS_Status_trg', inplace=True)


    #Feature Engineering
    data_encoded['Log_DisbursementGross'] =
```

```
np.log1p(data_encoded['DisbursementGross'])
    data_encoded['Log_NoEmp'] = np.log1p(data_encoded['NoEmp'])
    data_encoded['Log_GrAppv'] = np.log1p(data_encoded['GrAppv'])
    data_encoded['Log_SBA_Appv'] = np.log1p(data_encoded['SBA_Appv'])
    data_encoded['Log_BalanceGross'] =
np.log1p(data_encoded['BalanceGross'])

    data_encoded['Disbursement_Bins'] =
pd.cut(data_encoded['DisbursementGross'],
                                           bins=[-np.inf, 50000,
150000, np.inf],
                                           labels=['Low',
'Medium', 'High'])

    data_encoded['Loan_Efficiency'] =
data_encoded['DisbursementGross'] / (data_encoded['CreateJob'] +
data_encoded['RetainedJob'] + 1)  # Adding 1 to avoid division by zero

    data_encoded['Guarantee_Ratio'] = data_encoded['SBA_Appv'] /
data_encoded['GrAppv']

    data_encoded['Loan_Guarantee_Interaction'] =
data_encoded['SBA_Appv'] * data_encoded['GrAppv']

    data_encoded['Disbursement_Squared'] =
data_encoded['DisbursementGross'] ** 2

    numerical_columns = [ 'NoEmp', 'CreateJob', 'RetainedJob',
'GrAppv', 'SBA_Appv', 'DisbursementGross', 'BalanceGross',
'Log_DisbursementGross', 'Log_NoEmp', 'Log_GrAppv', 'Log_SBA_Appv',
'Log_BalanceGross', 'Loan_Efficiency', 'Guarantee_Ratio',
'Loan_Guarantee_Interaction', 'Disbursement_Squared']
    scaler = StandardScaler()
    data_encoded[numerical_columns] =
scaler.fit_transform(data_encoded[numerical_columns])
    for col in data_encoded.columns:
        print(col,":",data_encoded[col].dtype)

    X_train = data_encoded.copy()
    y_train = X_train['MIS_Status']
    X_train.drop(columns=['MIS_Status'], inplace=True)
    study_model_iteractions = {}
    def objective(trial, X, y):
        param_grid = {
            "num_iterations": 10000,
            "learning_rate": trial.suggest_float("learning_rate",
0.01, 0.3, step=0.05),
            "num_leaves": trial.suggest_int("num_leaves", 50, 150,
step=5),
            "max_depth": trial.suggest_int("max_depth", 5, 20,
```

```
step=2),
            "min_data_in_leaf": trial.suggest_int("min_data_in_leaf",
100, 1000, step=100),
            'lambda_l1': trial.suggest_float('lambda_l1', 1e-8, 10.0,
log=True),
            'lambda_l2': trial.suggest_float('lambda_l2', 1e-8, 10.0,
log=True),
            "bagging_fraction":
trial.suggest_float("bagging_fraction", 0.8, 1.0, step=0.1),
            "bagging_freq": trial.suggest_categorical("bagging_freq",
[5]),
            "feature_fraction":
trial.suggest_float("feature_fraction", 0.8, 1.0, step=0.1),
            "is_unbalance": trial.suggest_categorical("is_unbalance",
[True, False]),
            "objective": "binary",
            "metric": "auc",
            "verbose": -1
        }

        cv = StratifiedKFold(n_splits=5, shuffle=True,
random_state=1121218)

        cv_scores = np.empty(5)
        cv_iteractions = np.empty(5)
        for idx, (train_idx, test_idx) in enumerate(cv.split(X, y)):
            X_train, X_valid = X.iloc[train_idx], X.iloc[test_idx]
            y_train, y_valid = y.iloc[train_idx], y.iloc[test_idx]

            train_data = lgb.Dataset(data=X_train, label=y_train,
params={"verbose":-1})
            valid_data = lgb.Dataset(data=X_valid, label=y_valid,
params={"verbose":-1})
            lgb_clf = lgb.train(params=param_grid,
                                train_set=train_data,
                                valid_sets=[valid_data],

#categorical_feature=categorical_columns,

callbacks=[LightGBMPruningCallback(trial, "auc"),

lgb.early_stopping(stopping_rounds=5)]
                                )
            preds = lgb_clf.predict(X_valid)
            cv_scores[idx] = roc_auc_score(y_valid, preds)
            cv_iteractions[idx] = lgb_clf.best_iteration

        study_model_iteractions[trial.number] =
np.mean(cv_iteractions)
```

```
        return np.mean(cv_scores)

    study = optuna.create_study(direction="maximize", study_name="LGBM
Classifier")
    func = lambda trial: objective(trial, X_train, y_train)
    study.optimize(func, n_trials=200)
    best_params = study.best_params
    print("Best Parameters:", best_params)

    best_params = study.best_params
    print("Best Parameters:", best_params)

    # Create and train the classifier with the best parameters
    best_classifier = lgb.LGBMClassifier(**best_params)
    best_classifier.fit(X_train, y_train)

    # Now pass this classifier to your function
    optimal_threshold = calculate_optimal_threshold(best_classifier,
X_train, y_train)
    print("Optimal Threshold:", optimal_threshold)
    print("Best AUC:", study.best_value)


    artifacts_dict ={
        "best_classifier":best_classifier,
        "encoder":encoder,
        "scaler":scaler,
        "optimal_threshold":optimal_threshold,
        "numerical_columns":numerical_columns,
        "cat_cols":cat_cols,
        "columns_to_score":X_train.columns
    }

    artifacts_dict_file =
open("D:/Work/Gre/UTD/Courses/Fall/MIS6341/Softwares/Python/ml-fall-
2023/Project2/N/Artifacts/artifacts_dict_file.pkl", "wb")
    #artifacts_dict_file =
open("D:/Work/rtifacts/artifacts_dict_file.pkl", "wb")
    pickle.dump(artifacts_dict, artifacts_dict_file)
    artifacts_dict_file.close()

    return best_classifier

from sklearn.model_selection import train_test_split

df =
pd.read_csv('D:/Work/Gre/UTD/Courses/Fall/MIS6341/Softwares/Python/ml-
fall-2023/Project2/N/SBA_loans_project_2.csv')
```

```
X_train, X_test = train_test_split(df, test_size=0.2, random_state=42)
train_model(X_train)
```

```
[I 2023-12-10 17:40:31,359] A new study created in memory with name: LGBM Classifier

City_trg : float64
State_trg : float64
Zip_trg : int64
Bank_trg : float64
BankState_trg : float64
NAICS_trg : int64
NoEmp_trg : int64
NewExist_trg : float64
CreateJob_trg : int64
RetainedJob_trg : int64
FranchiseCode_trg : int64
UrbanRural_trg : int64
RevLineCr_trg : float64
LowDoc_trg : float64
DisbursementGross_trg : float64
BalanceGross_trg : float64
GrAppv_trg : float64
SBA_Appv_trg : float64
Zip : int64
NAICS : int64
NoEmp : float64
CreateJob : float64
RetainedJob : float64
FranchiseCode : int64
UrbanRural : int64
DisbursementGross : float64
BalanceGross : float64
GrAppv : float64
SBA_Appv : float64
MIS_Status : int64
Log_DisbursementGross : float64
Log_NoEmp : float64
Log_GrAppv : float64
Log_SBA_Appv : float64
Log_BalanceGross : float64
Disbursement_Bins : category
Loan_Efficiency : float64
Guarantee_Ratio : float64
Loan_Guarantee_Interaction : float64
Disbursement_Squared : float64
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[291]	valid_0's auc: 0.858072
Training until validation scores don't improve for 5 rounds
```

```
Early stopping, best iteration is:
[368] valid_0's auc: 0.860734
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[361] valid_0's auc: 0.861681
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[421] valid_0's auc: 0.857693
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[396] valid_0's auc: 0.858617

[I 2023-12-10 17:42:07,934] Trial 0 finished with value:
0.8593593156075828 and parameters: {'learning_rate':
0.060000000000000005, 'num_leaves': 105, 'max_depth': 13,
'min_data_in_leaf': 800, 'lambda_l1': 0.0007294828396849513,
'lambda_l2': 5.108521430431259e-06, 'bagging_fraction': 0.8,
'bagging_freq': 5, 'feature_fraction': 0.8, 'is_unbalance': True}.
Best is trial 0 with value: 0.8593593156075828.

Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[84]  valid_0's auc: 0.856037
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[70]  valid_0's auc: 0.857428
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[79]  valid_0's auc: 0.858647
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[81]  valid_0's auc: 0.854754
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[58]  valid_0's auc: 0.854709

[I 2023-12-10 17:42:27,599] Trial 1 finished with value:
0.8563152058745531 and parameters: {'learning_rate': 0.26,
'num_leaves': 110, 'max_depth': 19, 'min_data_in_leaf': 1000,
'lambda_l1': 0.00020767319353613123, 'lambda_l2': 3.506479946794111e-
08, 'bagging_fraction': 0.8, 'bagging_freq': 5, 'feature_fraction':
0.8, 'is_unbalance': True}. Best is trial 0 with value:
0.8593593156075828.

Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[115] valid_0's auc: 0.856251
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[118] valid_0's auc: 0.858761
```

```
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[103] valid_0's auc: 0.85866
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[119] valid_0's auc: 0.855495
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[88]  valid_0's auc: 0.855453

[I 2023-12-10 17:42:50,717] Trial 2 finished with value:
0.8569240535312534 and parameters: {'learning_rate': 0.26,
'num_leaves': 115, 'max_depth': 11, 'min_data_in_leaf': 900,
'lambda_l1': 0.0012650869657303628, 'lambda_l2': 0.012743405139318804,
'bagging_fraction': 0.8, 'bagging_freq': 5, 'feature_fraction': 0.8,
'is_unbalance': True}. Best is trial 0 with value: 0.8593593156075828.

Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[175] valid_0's auc: 0.858308
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[163] valid_0's auc: 0.859376
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[156] valid_0's auc: 0.860168
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[214] valid_0's auc: 0.857027
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[152] valid_0's auc: 0.857791

[I 2023-12-10 17:43:16,042] Trial 3 finished with value:
0.8585339979814254 and parameters: {'learning_rate':
0.21000000000000002, 'num_leaves': 145, 'max_depth': 7,
'min_data_in_leaf': 500, 'lambda_l1': 3.434452351183798e-08,
'lambda_l2': 1.2982877727223658e-07, 'bagging_fraction': 1.0,
'bagging_freq': 5, 'feature_fraction': 0.9, 'is_unbalance': True}.
Best is trial 0 with value: 0.8593593156075828.

Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[116] valid_0's auc: 0.856008
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[116] valid_0's auc: 0.858573
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[78]  valid_0's auc: 0.85838
```

```
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[108] valid_0's auc: 0.854772
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[103] valid_0's auc: 0.856718

[I 2023-12-10 17:43:35,782] Trial 4 finished with value:
0.8568901737323303 and parameters: {'learning_rate':
0.21000000000000002, 'num_leaves': 65, 'max_depth': 19,
'min_data_in_leaf': 100, 'lambda_l1': 0.05999174365063189,
'lambda_l2': 0.0003925644844827173, 'bagging_fraction': 0.8,
'bagging_freq': 5, 'feature_fraction': 0.9, 'is_unbalance': True}.
Best is trial 0 with value: 0.8593593156075828.
[I 2023-12-10 17:43:36,607] Trial 5 pruned. Trial was pruned at
iteration 1.

Training until validation scores don't improve for 5 rounds
Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:43:37,740] Trial 6 pruned. Trial was pruned at
iteration 5.
[I 2023-12-10 17:43:38,605] Trial 7 pruned. Trial was pruned at
iteration 2.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:43:39,428] Trial 8 pruned. Trial was pruned at
iteration 1.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:43:40,262] Trial 9 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:43:41,126] Trial 10 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:43:41,889] Trial 11 pruned. Trial was pruned at
iteration 0.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:43:43,230] Trial 12 pruned. Trial was pruned at
iteration 12.
[I 2023-12-10 17:43:44,065] Trial 13 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:43:44,848] Trial 14 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:43:45,742] Trial 15 pruned. Trial was pruned at
iteration 0.

Training until validation scores don't improve for 5 rounds
```

```
[I 2023-12-10 17:43:46,755] Trial 16 pruned. Trial was pruned at
iteration 4.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:43:48,138] Trial 17 pruned. Trial was pruned at
iteration 12.
[I 2023-12-10 17:43:49,003] Trial 18 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:43:49,908] Trial 19 pruned. Trial was pruned at
iteration 2.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:43:50,698] Trial 20 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:43:51,556] Trial 21 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:43:52,350] Trial 22 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:43:53,172] Trial 23 pruned. Trial was pruned at
iteration 0.

Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[69]  valid_0's auc: 0.856497
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[87]  valid_0's auc: 0.858386
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[79]  valid_0's auc: 0.859018
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[104] valid_0's auc: 0.855878
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[121] valid_0's auc: 0.858122

[I 2023-12-10 17:44:15,472] Trial 24 finished with value:
0.8575802742034476 and parameters: {'learning_rate':
0.21000000000000002, 'num_leaves': 125, 'max_depth': 11,
'min_data_in_leaf': 400, 'lambda_l1': 5.41397438200559e-05,
'lambda_l2': 0.03642798716791687, 'bagging_fraction': 0.8,
'bagging_freq': 5, 'feature_fraction': 0.8, 'is_unbalance': True}.
Best is trial 0 with value: 0.8593593156075828.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:44:17,138] Trial 25 pruned. Trial was pruned at
iteration 20.
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Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:44:18,170] Trial 26 pruned. Trial was pruned at
iteration 5.
[I 2023-12-10 17:44:18,951] Trial 27 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:44:19,808] Trial 28 pruned. Trial was pruned at
iteration 0.

Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[97]  valid_0's auc: 0.858074
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[88]  valid_0's auc: 0.859385
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[62]  valid_0's auc: 0.85955
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[75]  valid_0's auc: 0.855792
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[62]  valid_0's auc: 0.856149

[I 2023-12-10 17:44:38,617] Trial 29 finished with value:
0.8577899033967459 and parameters: {'learning_rate':
0.21000000000000002, 'num_leaves': 120, 'max_depth': 17,
'min_data_in_leaf': 200, 'lambda_l1': 0.00019911511110333972,
'lambda_l2': 1.5813713570672085e-07, 'bagging_fraction': 0.8,
'bagging_freq': 5, 'feature_fraction': 0.8, 'is_unbalance': True}.
Best is trial 0 with value: 0.8593593156075828.

Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[90]  valid_0's auc: 0.858231
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[85]  valid_0's auc: 0.859585
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[108] valid_0's auc: 0.861808
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[80]  valid_0's auc: 0.856392
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[97]  valid_0's auc: 0.858113
```

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[I 2023-12-10 17:44:56,442] Trial 30 finished with value:
0.8588256917449023 and parameters: {'learning_rate': 0.26,
'num_leaves': 105, 'max_depth': 19, 'min_data_in_leaf': 200,
'lambda_l1': 0.00023986212760882902, 'lambda_l2': 6.768350003830076e-
08, 'bagging_fraction': 1.0, 'bagging_freq': 5, 'feature_fraction':
0.8, 'is_unbalance': True}. Best is trial 0 with value:
0.8593593156075828.

Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[79]  valid_0's auc: 0.858073
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[88]  valid_0's auc: 0.85945
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[60]  valid_0's auc: 0.860599
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[52]  valid_0's auc: 0.854305
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[85]  valid_0's auc: 0.858422

[I 2023-12-10 17:45:12,364] Trial 31 finished with value:
0.8581697696592523 and parameters: {'learning_rate': 0.26,
'num_leaves': 110, 'max_depth': 19, 'min_data_in_leaf': 200,
'lambda_l1': 0.00025415993703682883, 'lambda_l2': 1.1109942622327962e-
07, 'bagging_fraction': 1.0, 'bagging_freq': 5, 'feature_fraction':
0.8, 'is_unbalance': True}. Best is trial 0 with value:
0.8593593156075828.

Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[73]  valid_0's auc: 0.858113
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[88]  valid_0's auc: 0.85945
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[60]  valid_0's auc: 0.860599
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[52]  valid_0's auc: 0.854305
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[85]  valid_0's auc: 0.858421

[I 2023-12-10 17:45:28,380] Trial 32 finished with value:
0.8581774392881247 and parameters: {'learning_rate': 0.26,
```

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'num_leaves': 110, 'max_depth': 19, 'min_data_in_leaf': 200,
'lambda_l1': 0.000301563476347318, 'lambda_l2': 5.633548686680852e-08,
'bagging_fraction': 1.0, 'bagging_freq': 5, 'feature_fraction': 0.8,
'is_unbalance': True}. Best is trial 0 with value: 0.8593593156075828.

Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[60]  valid_0's auc: 0.856913
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[80]  valid_0's auc: 0.859041
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[73]  valid_0's auc: 0.860962
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[84]  valid_0's auc: 0.856374
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[52]  valid_0's auc: 0.857359

[I 2023-12-10 17:45:43,757] Trial 33 finished with value:
0.858129744503508 and parameters: {'learning_rate': 0.26,
'num_leaves': 105, 'max_depth': 19, 'min_data_in_leaf': 200,
'lambda_l1': 0.008282084265738301, 'lambda_l2': 3.941182372565828e-08,
'bagging_fraction': 1.0, 'bagging_freq': 5, 'feature_fraction': 0.8,
'is_unbalance': True}. Best is trial 0 with value: 0.8593593156075828.
[I 2023-12-10 17:45:44,508] Trial 34 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:45:45,303] Trial 35 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:45:46,149] Trial 36 pruned. Trial was pruned at
iteration 2.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:45:46,940] Trial 37 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:45:47,759] Trial 38 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:45:48,627] Trial 39 pruned. Trial was pruned at
iteration 2.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:45:49,429] Trial 40 pruned. Trial was pruned at
iteration 0.

Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[79]  valid_0's auc: 0.858072
```

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Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[88]  valid_0's auc: 0.85945
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[60]  valid_0's auc: 0.860599
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[52]  valid_0's auc: 0.854305
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[85]  valid_0's auc: 0.858421

[I 2023-12-10 17:46:05,411] Trial 41 finished with value:
0.8581692615557197 and parameters: {'learning_rate': 0.26,
'num_leaves': 110, 'max_depth': 19, 'min_data_in_leaf': 200,
'lambda_l1': 0.00020812647692055951, 'lambda_l2': 1.1947431445708323e-
07, 'bagging_fraction': 1.0, 'bagging_freq': 5, 'feature_fraction':
0.8, 'is_unbalance': True}. Best is trial 0 with value:
0.8593593156075828.
[I 2023-12-10 17:46:06,205] Trial 42 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:46:06,959] Trial 43 pruned. Trial was pruned at
iteration 0.

Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[45]  valid_0's auc: 0.855779
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[52]  valid_0's auc: 0.857884
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[72]  valid_0's auc: 0.86074
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[73]  valid_0's auc: 0.856211
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[75]  valid_0's auc: 0.856636

[I 2023-12-10 17:46:21,323] Trial 44 finished with value:
0.8574499181751891 and parameters: {'learning_rate': 0.26,
'num_leaves': 110, 'max_depth': 19, 'min_data_in_leaf': 100,
'lambda_l1': 9.058964072301895e-05, 'lambda_l2': 1.962377877992129e-
08, 'bagging_fraction': 1.0, 'bagging_freq': 5, 'feature_fraction':
0.8, 'is_unbalance': True}. Best is trial 0 with value:
0.8593593156075828.
[I 2023-12-10 17:46:22,136] Trial 45 pruned. Trial was pruned at
iteration 0.
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[I 2023-12-10 17:46:23,025] Trial 46 pruned. Trial was pruned at
iteration 2.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:46:23,825] Trial 47 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:46:24,707] Trial 48 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:46:25,590] Trial 49 pruned. Trial was pruned at
iteration 1.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:46:26,494] Trial 50 pruned. Trial was pruned at
iteration 2.

Training until validation scores don't improve for 5 rounds
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[79]  valid_0's auc: 0.858073
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[88]  valid_0's auc: 0.859449
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[60]  valid_0's auc: 0.860599
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[52]  valid_0's auc: 0.854305
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[85]  valid_0's auc: 0.858421

[I 2023-12-10 17:46:42,122] Trial 51 finished with value:
0.8581693034757668 and parameters: {'learning_rate': 0.26,
'num_leaves': 110, 'max_depth': 19, 'min_data_in_leaf': 200,
'lambda_l1': 0.00023708418299524776, 'lambda_l2': 9.301666749304991e-
08, 'bagging_fraction': 1.0, 'bagging_freq': 5, 'feature_fraction':
0.8, 'is_unbalance': True}. Best is trial 0 with value:
0.8593593156075828.
[I 2023-12-10 17:46:42,887] Trial 52 pruned. Trial was pruned at
iteration 0.

Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[45]  valid_0's auc: 0.855778
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[86]  valid_0's auc: 0.858576
Training until validation scores don't improve for 5 rounds
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Early stopping, best iteration is:
[72]  valid_0's auc: 0.86074
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[73]  valid_0's auc: 0.856211
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[75]  valid_0's auc: 0.856636

[I 2023-12-10 17:46:59,525] Trial 53 finished with value:
0.8575884610451567 and parameters: {'learning_rate': 0.26,
'num_leaves': 110, 'max_depth': 19, 'min_data_in_leaf': 100,
'lambda_l1': 0.00021603546652211255, 'lambda_l2': 6.78717145298089e-
08, 'bagging_fraction': 1.0, 'bagging_freq': 5, 'feature_fraction':
0.8, 'is_unbalance': True}. Best is trial 0 with value:
0.8593593156075828.
[I 2023-12-10 17:47:00,313] Trial 54 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:47:01,154] Trial 55 pruned. Trial was pruned at
iteration 0.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:47:02,881] Trial 56 pruned. Trial was pruned at
iteration 20.
[I 2023-12-10 17:47:03,756] Trial 57 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:47:04,669] Trial 58 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:47:05,482] Trial 59 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:47:06,309] Trial 60 pruned. Trial was pruned at
iteration 0.

Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[79]  valid_0's auc: 0.858072
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[88]  valid_0's auc: 0.859449
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[60]  valid_0's auc: 0.860599
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[52]  valid_0's auc: 0.854305
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[85]  valid_0's auc: 0.858421
```

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[I 2023-12-10 17:47:22,645] Trial 61 finished with value:
0.8581691595813377 and parameters: {'learning_rate': 0.26,
'num_leaves': 110, 'max_depth': 19, 'min_data_in_leaf': 200,
'lambda_l1': 0.00026601976257152723, 'lambda_l2': 1.3738545315784982e-
07, 'bagging_fraction': 1.0, 'bagging_freq': 5, 'feature_fraction':
0.8, 'is_unbalance': True}. Best is trial 0 with value:
0.8593593156075828.
[I 2023-12-10 17:47:23,428] Trial 62 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:47:24,213] Trial 63 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:47:25,152] Trial 64 pruned. Trial was pruned at
iteration 4.

Training until validation scores don't improve for 5 rounds
Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:47:28,044] Trial 65 pruned. Trial was pruned at
iteration 44.
[I 2023-12-10 17:47:28,917] Trial 66 pruned. Trial was pruned at
iteration 2.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:47:29,721] Trial 67 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:47:30,545] Trial 68 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:47:31,365] Trial 69 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:47:32,163] Trial 70 pruned. Trial was pruned at
iteration 0.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:47:34,967] Trial 71 pruned. Trial was pruned at
iteration 59.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:47:36,326] Trial 72 pruned. Trial was pruned at
iteration 14.
[I 2023-12-10 17:47:37,128] Trial 73 pruned. Trial was pruned at
iteration 0.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:47:38,730] Trial 74 pruned. Trial was pruned at
iteration 21.

Training until validation scores don't improve for 5 rounds
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[I 2023-12-10 17:47:41,314] Trial 75 pruned. Trial was pruned at
iteration 44.
[I 2023-12-10 17:47:42,145] Trial 76 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:47:42,928] Trial 77 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:47:43,804] Trial 78 pruned. Trial was pruned at
iteration 0.

Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[51]  valid_0's auc: 0.857365
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[60]  valid_0's auc: 0.859514
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[80]  valid_0's auc: 0.861006
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[70]  valid_0's auc: 0.856183
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[63]  valid_0's auc: 0.85772

[I 2023-12-10 17:48:00,240] Trial 79 finished with value:
0.8583579049964092 and parameters: {'learning_rate': 0.26,
'num_leaves': 150, 'max_depth': 17, 'min_data_in_leaf': 300,
'lambda_l1': 0.00035399875137996287, 'lambda_l2': 1.5649397722683178e-
08, 'bagging_fraction': 1.0, 'bagging_freq': 5, 'feature_fraction':
0.8, 'is_unbalance': True}. Best is trial 0 with value:
0.8593593156075828.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:48:03,358] Trial 80 pruned. Trial was pruned at
iteration 65.

Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[51]  valid_0's auc: 0.857462
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[53]  valid_0's auc: 0.859372
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[62]  valid_0's auc: 0.860089
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[82]  valid_0's auc: 0.857171
```

```
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[62]  valid_0's auc: 0.857673

[I 2023-12-10 17:48:19,690] Trial 81 finished with value:
0.8583536413305616 and parameters: {'learning_rate': 0.26,
'num_leaves': 150, 'max_depth': 19, 'min_data_in_leaf': 200,
'lambda_l1': 0.00032215957201415526, 'lambda_l2': 8.372366155639107e-
08, 'bagging_fraction': 1.0, 'bagging_freq': 5, 'feature_fraction':
0.8, 'is_unbalance': True}. Best is trial 0 with value:
0.8593593156075828.

Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[51]  valid_0's auc: 0.857462
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[55]  valid_0's auc: 0.859496
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[71]  valid_0's auc: 0.861451
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[41]  valid_0's auc: 0.854938
Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:48:34,186] Trial 82 finished with value:
0.8581809124850672 and parameters: {'learning_rate': 0.26,
'num_leaves': 150, 'max_depth': 19, 'min_data_in_leaf': 200,
'lambda_l1': 0.0006777050613986626, 'lambda_l2': 3.00934489356491e-08,
'bagging_fraction': 1.0, 'bagging_freq': 5, 'feature_fraction': 0.8,
'is_unbalance': True}. Best is trial 0 with value: 0.8593593156075828.

Early stopping, best iteration is:
[58]  valid_0's auc: 0.857557
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[51]  valid_0's auc: 0.857365
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[60]  valid_0's auc: 0.859513
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[82]  valid_0's auc: 0.861032
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[70]  valid_0's auc: 0.856183
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[69]  valid_0's auc: 0.857758
```

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[I 2023-12-10 17:48:51,389] Trial 83 finished with value:
0.8583703276007008 and parameters: {'learning_rate': 0.26,
'num_leaves': 150, 'max_depth': 17, 'min_data_in_leaf': 300,
'lambda_l1': 0.0009200743844244359, 'lambda_l2': 3.01018638121821e-08,
'bagging_fraction': 1.0, 'bagging_freq': 5, 'feature_fraction': 0.8,
'is_unbalance': True}. Best is trial 0 with value: 0.8593593156075828.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:48:53,321] Trial 84 pruned. Trial was pruned at
iteration 30.
[I 2023-12-10 17:48:54,110] Trial 85 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:48:54,958] Trial 86 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:48:55,791] Trial 87 pruned. Trial was pruned at
iteration 0.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:48:57,751] Trial 88 pruned. Trial was pruned at
iteration 25.
[I 2023-12-10 17:48:58,733] Trial 89 pruned. Trial was pruned at
iteration 2.

Training until validation scores don't improve for 5 rounds
Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:49:00,904] Trial 90 pruned. Trial was pruned at
iteration 29.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:49:03,904] Trial 91 pruned. Trial was pruned at
iteration 60.

Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[51]  valid_0's auc: 0.857462
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[53]  valid_0's auc: 0.859372
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[62]  valid_0's auc: 0.860089
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[82]  valid_0's auc: 0.857171
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[62]  valid_0's auc: 0.857673
```

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[I 2023-12-10 17:49:19,393] Trial 92 finished with value:
0.8583536576931486 and parameters: {'learning_rate': 0.26,
'num_leaves': 150, 'max_depth': 19, 'min_data_in_leaf': 200,
'lambda_l1': 0.00034587343339359566, 'lambda_l2': 8.990795322509813e-
08, 'bagging_fraction': 1.0, 'bagging_freq': 5, 'feature_fraction':
0.8, 'is_unbalance': True}. Best is trial 0 with value:
0.8593593156075828.

Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[51]  valid_0's auc: 0.857462
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[53]  valid_0's auc: 0.859372
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[62]  valid_0's auc: 0.860089
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[82]  valid_0's auc: 0.857171
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[62]  valid_0's auc: 0.857673

[I 2023-12-10 17:49:34,522] Trial 93 finished with value:
0.8583536433548151 and parameters: {'learning_rate': 0.26,
'num_leaves': 150, 'max_depth': 19, 'min_data_in_leaf': 200,
'lambda_l1': 0.00034335303819519697, 'lambda_l2': 4.43122335557561e-
08, 'bagging_fraction': 1.0, 'bagging_freq': 5, 'feature_fraction':
0.8, 'is_unbalance': True}. Best is trial 0 with value:
0.8593593156075828.

Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[51]  valid_0's auc: 0.857462
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[53]  valid_0's auc: 0.859372
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[62]  valid_0's auc: 0.860089
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[41]  valid_0's auc: 0.854937
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[62]  valid_0's auc: 0.857673

[I 2023-12-10 17:49:48,623] Trial 94 finished with value:
0.8579069100746128 and parameters: {'learning_rate': 0.26,
```

```
'num_leaves': 150, 'max_depth': 19, 'min_data_in_leaf': 200,
'lambda_l1': 0.00038334558282613517, 'lambda_l2': 4.2822378076287936e-
08, 'bagging_fraction': 1.0, 'bagging_freq': 5, 'feature_fraction':
0.8, 'is_unbalance': True}. Best is trial 0 with value:
0.8593593156075828.
[I 2023-12-10 17:49:49,370] Trial 95 pruned. Trial was pruned at
iteration 0.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:49:51,790] Trial 96 pruned. Trial was pruned at
iteration 48.
[I 2023-12-10 17:49:52,665] Trial 97 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:49:53,745] Trial 98 pruned. Trial was pruned at
iteration 4.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:49:54,544] Trial 99 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:49:55,346] Trial 100 pruned. Trial was pruned at
iteration 0.

Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[51]  valid_0's auc: 0.857462
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[55]  valid_0's auc: 0.859496
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[63]  valid_0's auc: 0.860804
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[41]  valid_0's auc: 0.854938
Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:50:09,780] Trial 101 finished with value:
0.8580514985181871 and parameters: {'learning_rate': 0.26,
'num_leaves': 150, 'max_depth': 19, 'min_data_in_leaf': 200,
'lambda_l1': 0.0005379484960110202, 'lambda_l2': 1.803714698485151e-
07, 'bagging_fraction': 1.0, 'bagging_freq': 5, 'feature_fraction':
0.8, 'is_unbalance': True}. Best is trial 0 with value:
0.8593593156075828.

Early stopping, best iteration is:
[58]  valid_0's auc: 0.857557
Training until validation scores don't improve for 5 rounds
```

```
[I 2023-12-10 17:50:12,601] Trial 102 pruned. Trial was pruned at
iteration 60.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:50:15,190] Trial 103 pruned. Trial was pruned at
iteration 51.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:50:17,787] Trial 104 pruned. Trial was pruned at
iteration 51.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:50:19,647] Trial 105 pruned. Trial was pruned at
iteration 28.
[I 2023-12-10 17:50:20,510] Trial 106 pruned. Trial was pruned at
iteration 2.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:50:21,376] Trial 107 pruned. Trial was pruned at
iteration 2.

Training until validation scores don't improve for 5 rounds
Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:50:23,350] Trial 108 pruned. Trial was pruned at
iteration 29.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:50:24,629] Trial 109 pruned. Trial was pruned at
iteration 11.
[I 2023-12-10 17:50:25,486] Trial 110 pruned. Trial was pruned at
iteration 1.

Training until validation scores don't improve for 5 rounds
Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:50:28,057] Trial 111 pruned. Trial was pruned at
iteration 51.
[I 2023-12-10 17:50:28,832] Trial 112 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:50:29,635] Trial 113 pruned. Trial was pruned at
iteration 0.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:50:32,344] Trial 114 pruned. Trial was pruned at
iteration 60.
```

```
Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:50:35,104] Trial 115 pruned. Trial was pruned at
iteration 51.
[I 2023-12-10 17:50:35,878] Trial 116 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:50:36,654] Trial 117 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:50:37,475] Trial 118 pruned. Trial was pruned at
iteration 0.

Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[55]  valid_0's auc: 0.857971
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[75]  valid_0's auc: 0.860334
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[74]  valid_0's auc: 0.860617
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[95]  valid_0's auc: 0.857411
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[70]  valid_0's auc: 0.857828

[I 2023-12-10 17:50:54,915] Trial 119 finished with value:
0.8588321170123605 and parameters: {'learning_rate': 0.26,
'num_leaves': 145, 'max_depth': 19, 'min_data_in_leaf': 300,
'lambda_l1': 1.0296947261146976e-05, 'lambda_l2': 1.843243281473822e-
08, 'bagging_fraction': 1.0, 'bagging_freq': 5, 'feature_fraction':
0.8, 'is_unbalance': True}. Best is trial 0 with value:
0.8593593156075828.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:50:57,135] Trial 120 pruned. Trial was pruned at
iteration 30.

Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[55]  valid_0's auc: 0.857971
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[51]  valid_0's auc: 0.859496
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[74]  valid_0's auc: 0.860617
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
```

```
[83]  valid_0's auc: 0.856397
Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:51:13,114] Trial 121 finished with value:
0.8582386375342198 and parameters: {'learning_rate': 0.26,
'num_leaves': 145, 'max_depth': 19, 'min_data_in_leaf': 300,
'lambda_l1': 0.0005542795997062075, 'lambda_l2': 1.0462346131552537e-
08, 'bagging_fraction': 1.0, 'bagging_freq': 5, 'feature_fraction':
0.8, 'is_unbalance': True}. Best is trial 0 with value:
0.8593593156075828.

Early stopping, best iteration is:
[44]  valid_0's auc: 0.856712

[I 2023-12-10 17:51:13,884] Trial 122 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:51:14,675] Trial 123 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:51:15,597] Trial 124 pruned. Trial was pruned at
iteration 0.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:51:17,156] Trial 125 pruned. Trial was pruned at
iteration 16.
[I 2023-12-10 17:51:17,944] Trial 126 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:51:18,905] Trial 127 pruned. Trial was pruned at
iteration 2.

Training until validation scores don't improve for 5 rounds
Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:51:20,156] Trial 128 pruned. Trial was pruned at
iteration 10.
[I 2023-12-10 17:51:20,979] Trial 129 pruned. Trial was pruned at
iteration 0.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:51:23,563] Trial 130 pruned. Trial was pruned at
iteration 51.
[I 2023-12-10 17:51:24,338] Trial 131 pruned. Trial was pruned at
iteration 0.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:51:27,092] Trial 132 pruned. Trial was pruned at
iteration 60.
[I 2023-12-10 17:51:27,877] Trial 133 pruned. Trial was pruned at
iteration 0.
```

```
Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:51:30,519] Trial 134 pruned. Trial was pruned at
iteration 51.
[I 2023-12-10 17:51:31,356] Trial 135 pruned. Trial was pruned at
iteration 0.

Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[55]  valid_0's auc: 0.857971
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[51]  valid_0's auc: 0.859496
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[74]  valid_0's auc: 0.860617
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[70]  valid_0's auc: 0.856352
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[81]  valid_0's auc: 0.858358

[I 2023-12-10 17:51:47,619] Trial 136 finished with value:
0.8585587032296338 and parameters: {'learning_rate': 0.26,
'num_leaves': 145, 'max_depth': 19, 'min_data_in_leaf': 300,
'lambda_l1': 0.0006764163020627052, 'lambda_l2': 4.6918977262527884e-
08, 'bagging_fraction': 1.0, 'bagging_freq': 5, 'feature_fraction':
0.8, 'is_unbalance': True}. Best is trial 0 with value:
0.8593593156075828.
[I 2023-12-10 17:51:48,398] Trial 137 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:51:49,263] Trial 138 pruned. Trial was pruned at
iteration 2.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:51:50,058] Trial 139 pruned. Trial was pruned at
iteration 0.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:51:51,737] Trial 140 pruned. Trial was pruned at
iteration 21.
[I 2023-12-10 17:51:52,517] Trial 141 pruned. Trial was pruned at
iteration 0.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:51:55,174] Trial 142 pruned. Trial was pruned at
iteration 51.
```

```
[I 2023-12-10 17:51:56,064] Trial 143 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:51:56,837] Trial 144 pruned. Trial was pruned at
iteration 0.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:51:59,393] Trial 145 pruned. Trial was pruned at
iteration 51.
[I 2023-12-10 17:52:00,255] Trial 146 pruned. Trial was pruned at
iteration 1.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:52:01,047] Trial 147 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:52:01,907] Trial 148 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:52:02,683] Trial 149 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:52:03,495] Trial 150 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:52:04,276] Trial 151 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:52:05,046] Trial 152 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:52:05,866] Trial 153 pruned. Trial was pruned at
iteration 0.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:52:07,029] Trial 154 pruned. Trial was pruned at
iteration 8.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:52:09,808] Trial 155 pruned. Trial was pruned at
iteration 60.
[I 2023-12-10 17:52:10,599] Trial 156 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:52:11,330] Trial 157 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:52:12,253] Trial 158 pruned. Trial was pruned at
iteration 2.

Training until validation scores don't improve for 5 rounds
Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:52:15,361] Trial 159 pruned. Trial was pruned at
iteration 60.
[I 2023-12-10 17:52:16,154] Trial 160 pruned. Trial was pruned at
```

```
iteration 0.
[I 2023-12-10 17:52:17,092] Trial 161 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:52:17,881] Trial 162 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:52:18,706] Trial 163 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:52:19,487] Trial 164 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:52:20,255] Trial 165 pruned. Trial was pruned at
iteration 0.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:52:21,636] Trial 166 pruned. Trial was pruned at
iteration 13.
[I 2023-12-10 17:52:22,483] Trial 167 pruned. Trial was pruned at
iteration 2.

Training until validation scores don't improve for 5 rounds
Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:52:24,676] Trial 168 pruned. Trial was pruned at
iteration 34.
[I 2023-12-10 17:52:25,456] Trial 169 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:52:26,214] Trial 170 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:52:26,999] Trial 171 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:52:27,758] Trial 172 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:52:28,521] Trial 173 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:52:29,325] Trial 174 pruned. Trial was pruned at
iteration 0.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:52:31,908] Trial 175 pruned. Trial was pruned at
iteration 51.
[I 2023-12-10 17:52:32,728] Trial 176 pruned. Trial was pruned at
iteration 1.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:52:33,595] Trial 177 pruned. Trial was pruned at
iteration 0.

Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
```

```
[51]  valid_0's auc: 0.857365
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[60]  valid_0's auc: 0.859515
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[82]  valid_0's auc: 0.861033
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[70]  valid_0's auc: 0.856183
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[83]  valid_0's auc: 0.85795

[I 2023-12-10 17:52:50,064] Trial 178 finished with value:
0.8584091758723 and parameters: {'learning_rate': 0.26, 'num_leaves':
150, 'max_depth': 17, 'min_data_in_leaf': 300, 'lambda_l1':
0.0006304358828227806, 'lambda_l2': 2.306174954096987e-08,
'bagging_fraction': 1.0, 'bagging_freq': 5, 'feature_fraction': 0.8,
'is_unbalance': True}. Best is trial 0 with value: 0.8593593156075828.

Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[51]  valid_0's auc: 0.857365
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[60]  valid_0's auc: 0.859513
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[82]  valid_0's auc: 0.861031
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[70]  valid_0's auc: 0.856183
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[83]  valid_0's auc: 0.857953

[I 2023-12-10 17:53:06,651] Trial 179 finished with value:
0.8584092551629986 and parameters: {'learning_rate': 0.26,
'num_leaves': 150, 'max_depth': 17, 'min_data_in_leaf': 300,
'lambda_l1': 0.0006121444959858329, 'lambda_l2': 2.0603028341705394e-
08, 'bagging_fraction': 1.0, 'bagging_freq': 5, 'feature_fraction':
0.8, 'is_unbalance': True}. Best is trial 0 with value:
0.8593593156075828.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:53:09,549] Trial 180 pruned. Trial was pruned at
iteration 49.

Training until validation scores don't improve for 5 rounds
```

```
[I 2023-12-10 17:53:12,179] Trial 181 pruned. Trial was pruned at
iteration 50.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:53:14,070] Trial 182 pruned. Trial was pruned at
iteration 28.
[I 2023-12-10 17:53:15,029] Trial 183 pruned. Trial was pruned at
iteration 4.

Training until validation scores don't improve for 5 rounds
Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:53:17,624] Trial 184 pruned. Trial was pruned at
iteration 50.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:53:20,248] Trial 185 pruned. Trial was pruned at
iteration 50.
[I 2023-12-10 17:53:21,029] Trial 186 pruned. Trial was pruned at
iteration 0.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:53:23,632] Trial 187 pruned. Trial was pruned at
iteration 50.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:53:25,377] Trial 188 pruned. Trial was pruned at
iteration 25.
[I 2023-12-10 17:53:26,163] Trial 189 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:53:26,905] Trial 190 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:53:27,724] Trial 191 pruned. Trial was pruned at
iteration 0.
[I 2023-12-10 17:53:28,497] Trial 192 pruned. Trial was pruned at
iteration 0.

Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[51]  valid_0's auc: 0.857462
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[55]  valid_0's auc: 0.859496
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[47]  valid_0's auc: 0.860026
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
```

```
[51]  valid_0's auc: 0.855438
Training until validation scores don't improve for 5 rounds
Early stopping, best iteration is:
[58]  valid_0's auc: 0.857557

[I 2023-12-10 17:53:42,096] Trial 193 finished with value:
0.8579959604978974 and parameters: {'learning_rate': 0.26,
'num_leaves': 150, 'max_depth': 19, 'min_data_in_leaf': 200,
'lambda_l1': 0.0009660725843792929, 'lambda_l2': 3.6912285848172e-08,
'bagging_fraction': 1.0, 'bagging_freq': 5, 'feature_fraction': 0.8,
'is_unbalance': True}. Best is trial 0 with value: 0.8593593156075828.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:53:44,598] Trial 194 pruned. Trial was pruned at
iteration 50.
[I 2023-12-10 17:53:45,379] Trial 195 pruned. Trial was pruned at
iteration 0.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:53:47,785] Trial 196 pruned. Trial was pruned at
iteration 50.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:53:50,723] Trial 197 pruned. Trial was pruned at
iteration 65.
[I 2023-12-10 17:53:51,571] Trial 198 pruned. Trial was pruned at
iteration 2.

Training until validation scores don't improve for 5 rounds

[I 2023-12-10 17:53:52,381] Trial 199 pruned. Trial was pruned at
iteration 0.

Best Parameters: {'learning_rate': 0.060000000000000005, 'num_leaves':
105, 'max_depth': 13, 'min_data_in_leaf': 800, 'lambda_l1':
0.0007294828396849513, 'lambda_l2': 5.108521430431259e-06,
'bagging_fraction': 0.8, 'bagging_freq': 5, 'feature_fraction': 0.8,
'is_unbalance': True}
Best Parameters: {'learning_rate': 0.060000000000000005, 'num_leaves':
105, 'max_depth': 13, 'min_data_in_leaf': 800, 'lambda_l1':
0.0007294828396849513, 'lambda_l2': 5.108521430431259e-06,
'bagging_fraction': 0.8, 'bagging_freq': 5, 'feature_fraction': 0.8,
'is_unbalance': True}
[LightGBM] [Warning] min_data_in_leaf is set=800, min_child_samples=20
will be ignored. Current value: min_data_in_leaf=800
[LightGBM] [Warning] feature_fraction is set=0.8, colsample_bytree=1.0
will be ignored. Current value: feature_fraction=0.8
[LightGBM] [Warning] lambda_l1 is set=0.0007294828396849513,
```

```
reg_alpha=0.0 will be ignored. Current value:
lambda_l1=0.0007294828396849513
[LightGBM] [Warning] lambda_l2 is set=5.108521430431259e-06,
reg_lambda=0.0 will be ignored. Current value:
lambda_l2=5.108521430431259e-06
[LightGBM] [Warning] bagging_fraction is set=0.8, subsample=1.0 will
be ignored. Current value: bagging_fraction=0.8
[LightGBM] [Warning] bagging_freq is set=5, subsample_freq=0 will be
ignored. Current value: bagging_freq=5
[LightGBM] [Warning] min_data_in_leaf is set=800, min_child_samples=20
will be ignored. Current value: min_data_in_leaf=800
[LightGBM] [Warning] feature_fraction is set=0.8, colsample_bytree=1.0
will be ignored. Current value: feature_fraction=0.8
[LightGBM] [Warning] lambda_l1 is set=0.0007294828396849513,
reg_alpha=0.0 will be ignored. Current value:
lambda_l1=0.0007294828396849513
[LightGBM] [Warning] lambda_l2 is set=5.108521430431259e-06,
reg_lambda=0.0 will be ignored. Current value:
lambda_l2=5.108521430431259e-06
[LightGBM] [Warning] bagging_fraction is set=0.8, subsample=1.0 will
be ignored. Current value: bagging_fraction=0.8
[LightGBM] [Warning] bagging_freq is set=5, subsample_freq=0 will be
ignored. Current value: bagging_freq=5
[LightGBM] [Info] Number of positive: 112291, number of negative:
527913
[LightGBM] [Warning] Auto-choosing col-wise multi-threading, the
overhead of testing was 0.040718 seconds.
You can set `force_col_wise=true` to remove the overhead.
[LightGBM] [Info] Total Bins 6795
[LightGBM] [Info] Number of data points in the train set: 640204,
number of used features: 36
[LightGBM] [Info] [binary:BoostFromScore]: pavg=0.175399 ->
initscore=-1.547838
[LightGBM] [Info] Start training from score -1.547838
[LightGBM] [Warning] min_data_in_leaf is set=800, min_child_samples=20
will be ignored. Current value: min_data_in_leaf=800
[LightGBM] [Warning] feature_fraction is set=0.8, colsample_bytree=1.0
will be ignored. Current value: feature_fraction=0.8
[LightGBM] [Warning] lambda_l1 is set=0.0007294828396849513,
reg_alpha=0.0 will be ignored. Current value:
lambda_l1=0.0007294828396849513
[LightGBM] [Warning] lambda_l2 is set=5.108521430431259e-06,
reg_lambda=0.0 will be ignored. Current value:
lambda_l2=5.108521430431259e-06
[LightGBM] [Warning] bagging_fraction is set=0.8, subsample=1.0 will
be ignored. Current value: bagging_fraction=0.8
[LightGBM] [Warning] bagging_freq is set=5, subsample_freq=0 will be
ignored. Current value: bagging_freq=5
```

```
Optimal Threshold: 0.6767676767676768
Best AUC: 0.8593593156075828

LGBMClassifier(bagging_fraction=0.8, bagging_freq=5,
feature_fraction=0.8,
               is_unbalance=True, lambda_l1=0.0007294828396849513,
               lambda_l2=5.108521430431259e-06,
               learning_rate=0.060000000000000005, max_depth=13,
               min_data_in_leaf=800, num_leaves=105)
```

```
import shap
import matplotlib
matplotlib.use('TkAgg')
import matplotlib.pyplot as plt
%matplotlib inline
def examine_indiv_reason_codes(df_vals_and_cotribs,
                               rec_num,
                               include_columns,
                               contrib_columns,
                               use_matplotlib=False):

    shap_columns = contrib_columns.copy()
    shap_columns.remove("BiasTerm")
    ftr_columns = include_columns.copy()
    bias = df_vals_and_cotribs['BiasTerm'].iloc[rec_num]
    shap_contribs =
df_vals_and_cotribs[shap_columns].iloc[rec_num,:].values
    ftr_values =
df_vals_and_cotribs[ftr_columns].iloc[rec_num,:].values

    shap_plot= shap.force_plot(bias,
                           shap_contribs,
                           ftr_values,
                           shap_columns,
                           link="identity",
                           matplotlib=use_matplotlib)
    plt.show()

    # return shap.force_plot(bias,
    #                      shap_contribs,
    #                      ftr_values,
    #                      shap_columns,
    #                      link="logit",
    #                      matplotlib=use_matplotlib)

from matplotlib import pyplot as plt
import shap
from sklearn.inspection import permutation_importance
from sklearn.metrics import confusion_matrix
from sklearn.metrics import roc_auc_score
```

```
import lightgbm as lgb
import warnings
warnings.filterwarnings("ignore", category=Warning)

def scoring(data):
    """
    Function to score input dataset.

    Input: dataset in Pandas DataFrame format
    Output: Python list of labels in the same order as input records

    Flow:
        - Load artifacts
        - Transform dataset
        - Score dataset
        - Return labels

    """
    artifacts_dict_file =
open("D:/Work/Gre/UTD/Courses/Fall/MIS6341/Softwares/Python/ml-fall-
2023/Project2/artifacts/artifacts_dict_file.pkl", "rb")
    artifacts_dict = pickle.load(file=artifacts_dict_file)
    artifacts_dict_file.close()
    best_classifier = artifacts_dict["best_classifier"]
    encoder = artifacts_dict["encoder"]
    scaler = artifacts_dict["scaler"]
    threshold = artifacts_dict["optimal_threshold"]
    numerical_columns = artifacts_dict["numerical_columns"]
    cat_cols = artifacts_dict["cat_cols"]
    columns_to_score = artifacts_dict["columns_to_score"]

    for i in data['RevLineCr']:
        if i not in ['Y','N']:
            data['RevLineCr'].replace(i,'N',inplace=True)
    for i in data['LowDoc']:
        if i not in ['Y','N']:
            data['LowDoc'].replace(i,'N',inplace=True)
    for i in data['NewExist']:
        if i not in [1,2]:
            data['NewExist'].replace(i,None,inplace=True)

    for column in cat_cols:
        data[column]=data[column].fillna(data[column].mode()[0])

    data_encoded =
encoder.transform(data.drop(columns=['MIS_Status']))
    data_encoded = data_encoded.add_suffix('_trg')
    data_encoded = pd.concat([data_encoded, data], axis=1)
    for column in cat_cols:
```

```
        data_encoded[column + "_trg"].fillna(data_encoded[column +
"_trg"].mean(), inplace=True)
    data_encoded.drop(columns=cat_cols, inplace=True)

    data_encoded['Log_DisbursementGross'] =
np.log1p(data_encoded['DisbursementGross'])
    data_encoded['Log_NoEmp'] = np.log1p(data_encoded['NoEmp'])
    data_encoded['Log_GrAppv'] = np.log1p(data_encoded['GrAppv'])
    data_encoded['Log_SBA_Appv'] = np.log1p(data_encoded['SBA_Appv'])
    data_encoded['Log_BalanceGross'] =
np.log1p(data_encoded['BalanceGross'])

    data_encoded['Disbursement_Bins'] =
pd.cut(data_encoded['DisbursementGross'],
                                           bins=[-np.inf, 50000,
150000, np.inf],
                                           labels=['Low',
'Medium', 'High'])

    data_encoded['Loan_Efficiency'] =
data_encoded['DisbursementGross'] / (data_encoded['CreateJob'] +
data_encoded['RetainedJob'] + 1)  # Adding 1 to avoid division by zero

    data_encoded['Guarantee_Ratio'] = data_encoded['SBA_Appv'] /
data_encoded['GrAppv']

    data_encoded['Loan_Guarantee_Interaction'] =
data_encoded['SBA_Appv'] * data_encoded['GrAppv']

    data_encoded['Disbursement_Squared'] =
data_encoded['DisbursementGross'] ** 2

    data_encoded[numerical_columns] =
scaler.transform(data_encoded[numerical_columns])

    y_prob =
best_classifier.predict_proba(data_encoded[columns_to_score])
    y_pred = (y_prob[:,0] < threshold).astype(int)
    d = {
        "index" : data_encoded.index,
        "label" : y_pred,
        "probability_0": y_prob[:,0],
        "probability_1": y_prob[:,1]
    }
    #metric to report and optimize for AUC
    print("\n\nAUC score on Test dataset:",
roc_auc_score(data['MIS_Status'], y_prob[:,1]))
    print("\nConfusion Matrix:\n",
confusion_matrix(data['MIS_Status'], y_pred))
```

```
    # #plotting global feature importance
    # fig, ax = plt.subplots(figsize=(10, 10))
    # lgb.plot_importance(best_classifier, ax=ax, max_num_features=30)
    # plt.show()


    # #shap plots
    # explainer = shap.TreeExplainer(best_classifier)
    # shap_values =
explainer.shap_values(data_encoded[columns_to_score])
    # shap.summary_plot(shap_values, data_encoded[columns_to_score])
    # plt.show()

    # #plotting permutation feature importance
    # result = permutation_importance(best_classifier,
data_encoded[columns_to_score], data['MIS_Status'], n_repeats=10,
random_state=42, n_jobs=2)
    # sorted_idx = result.importances_mean.argsort()
    # fig, ax = plt.subplots()
    # ax.boxplot(result.importances[sorted_idx].T, vert=False,
labels=data_encoded[columns_to_score].columns[sorted_idx])
    # ax.set_title("Permutation Importances (test set)")
    # fig.tight_layout()
    # plt.show()


    #add columns to data_encoded
    data_encoded['label'] = y_pred
    data_encoded['probability_0'] = y_prob[:,0]
    data_encoded['probability_1'] = y_prob[:,1]

    #residual analysis
    data_encoded['residual'] = data_encoded['label'] -
data['MIS_Status']
    misclassified = data_encoded[data_encoded['residual'] != 0]


    #get 2 records where
    #Label `0` is correctly identified significantly high probability
    correctly_identified_0 = data_encoded[(data_encoded['residual'] ==
0) & (data_encoded['label'] == 0)].sort_values(by='probability_0',
ascending=False).head(2)
    #Label `1` is correctly identified significantly high probability
    correctly_identified_1 = data_encoded[(data_encoded['residual'] ==
0) & (data_encoded['label'] == 1)].sort_values(by='probability_1',
ascending=False).head(2)
    #Label `0` is incorrectly identified significantly high
probability
    incorrectly_identified_0 = data_encoded[(data_encoded['residual']
!= 0) & (data_encoded['label'] == 0)].sort_values(by='probability_0',
```

```
ascending=False).head(2)
    #Label `1` is incorrectly identified significantly high
probability
    incorrectly_identified_1 = data_encoded[(data_encoded['residual']
!= 0) & (data_encoded['label'] == 1)].sort_values(by='probability_1',
ascending=False).head(2)



    pred_contributions_orig_table =
best_classifier.predict(data_encoded[columns_to_score],
pred_contrib=True)
    pred_contributions_orig_table =
pd.DataFrame(pred_contributions_orig_table)

    contrib_columns =[]
    for col in columns_to_score:
        contrib_columns.append("contrib_"+col)

    contrib_columns.append("BiasTerm")
    pred_contributions_orig_table.columns = contrib_columns
    print(pred_contributions_orig_table.shape)
    print(data_encoded.shape)
    include_cols = columns_to_score
    pred_contributions_orig_table.index = data_encoded.index

    #concatenate data_encoded and pred_contributions_orig_table
    test_yhat = pd.concat([data_encoded,
pred_contributions_orig_table],axis=1)
    print(test_yhat)

    correctly_identified_0 = test_yhat[(test_yhat['residual'] == 0) &
(test_yhat['label'] == 0)].sort_values(by='probability_0',
ascending=False).head(2)
    correctly_identified_1 = test_yhat[(test_yhat['residual'] == 0) &
(test_yhat['label'] == 1)].sort_values(by='probability_1',
ascending=False).head(2)
    incorrectly_identified_0 = test_yhat[(test_yhat['residual'] != 0)
& (test_yhat['label'] == 0)].sort_values(by='probability_0',
ascending=False).head(2)
    incorrectly_identified_1 = test_yhat[(test_yhat['residual'] != 0)
& (test_yhat['label'] == 1)].sort_values(by='probability_1',
ascending=False).head(2)
    print(correctly_identified_0)
    examine_indiv_reason_codes(correctly_identified_0, 0,
include_cols, contrib_columns, use_matplotlib=True)
    examine_indiv_reason_codes(correctly_identified_0, 1,
include_cols, contrib_columns, use_matplotlib=True)
    examine_indiv_reason_codes(correctly_identified_1, 0,
include_cols, contrib_columns, use_matplotlib=True)
```

```
    examine_indiv_reason_codes(correctly_identified_1, 1,
include_cols, contrib_columns, use_matplotlib=True)
    examine_indiv_reason_codes(incorrectly_identified_0, 0,
include_cols, contrib_columns, use_matplotlib=True)
    examine_indiv_reason_codes(incorrectly_identified_0, 1,
include_cols, contrib_columns, use_matplotlib=True)
    examine_indiv_reason_codes(incorrectly_identified_1, 0,
include_cols, contrib_columns, use_matplotlib=True)
    examine_indiv_reason_codes(incorrectly_identified_1, 1,
include_cols, contrib_columns, use_matplotlib=True)




    return pd.DataFrame(d)

print(scoring(X_test))
```

```
[LightGBM] [Warning] min_data_in_leaf is set=300, min_child_samples=20
will be ignored. Current value: min_data_in_leaf=300
[LightGBM] [Warning] feature_fraction is set=0.9, colsample_bytree=1.0
will be ignored. Current value: feature_fraction=0.9
[LightGBM] [Warning] lambda_l1 is set=9.408025110972025, reg_alpha=0.0
will be ignored. Current value: lambda_l1=9.408025110972025
[LightGBM] [Warning] lambda_l2 is set=3.9690665922792114e-08,
reg_lambda=0.0 will be ignored. Current value:
lambda_l2=3.9690665922792114e-08
[LightGBM] [Warning] bagging_fraction is set=1.0, subsample=1.0 will
be ignored. Current value: bagging_fraction=1.0
[LightGBM] [Warning] bagging_freq is set=5, subsample_freq=0 will be
ignored. Current value: bagging_freq=5


AUC score on Test dataset: 0.833374867073196

Confusion Matrix:
 [[78223 53979]
 [ 3553 24296]]
[LightGBM] [Warning] min_data_in_leaf is set=300, min_child_samples=20
will be ignored. Current value: min_data_in_leaf=300
[LightGBM] [Warning] feature_fraction is set=0.9, colsample_bytree=1.0
will be ignored. Current value: feature_fraction=0.9
[LightGBM] [Warning] lambda_l1 is set=9.408025110972025, reg_alpha=0.0
will be ignored. Current value: lambda_l1=9.408025110972025
[LightGBM] [Warning] lambda_l2 is set=3.9690665922792114e-08,
reg_lambda=0.0 will be ignored. Current value:
lambda_l2=3.9690665922792114e-08
[LightGBM] [Warning] bagging_fraction is set=1.0, subsample=1.0 will
be ignored. Current value: bagging_fraction=1.0
[LightGBM] [Warning] bagging_freq is set=5, subsample_freq=0 will be
```

```
ignored. Current value: bagging_freq=5
(160051, 40)
(160051, 46)
        index_trg  City_trg  State_trg  Zip_trg  Bank_trg
BankState_trg  \
384386     384386  0.140612   0.197919    12953  0.367531
0.168015
662652     662652  0.136187   0.197919    14850  0.094340
0.168015
269020     269020  0.149920   0.138693    98004  0.175041
0.159471
752306     752306  0.224138   0.275144    33905  0.112576
0.293824
675193     675193  0.335998   0.275144    33172  0.000000
0.160260
...           ...       ...        ...      ...       ...
..
82879       82879  0.103234   0.177082    84741  0.271345
0.219710
649244     649244  0.184514   0.197919    11704  0.271345
0.198438
454383     454383  0.135417   0.138693    98502  0.000000
0.074400
679182     679182  0.195900   0.225274    61920  0.146400
0.223360
355393     355393  0.247039   0.187682    41046  0.175041
0.159471

        NAICS_trg  NoEmp_trg  NewExist_trg  CreateJob_trg
RetainedJob_trg  \
384386          0          5      0.170871              0
0
662652     235920          7      0.170871              0
0
269020          0         17      0.170871              0
0
752306     541940         15      0.186933             15
0
675193     811111          4      0.170871              7
0
...           ...        ...           ...            ...
...
82879           0          1      0.186933              0
0
649244     441110          1      0.170871              0
1
454383     451110          3      0.170871             16
0
679182          0          4      0.170871              0
```

```
0
355393     238990          1      0.170871              0
1

        FranchiseCode_trg  UrbanRural_trg  RevLineCr_trg
LowDoc_trg  \
384386                  1               0       0.152838    0.187475

662652                  0               0       0.152838    0.187475

269020                  1               0       0.152838    0.187475

752306                  1               1       0.152838    0.187475

675193                  1               0       0.152838    0.187475

...                   ...             ...            ...         ...

82879                   1               0       0.152838    0.187475

649244                  1               1       0.253428    0.187475

454383                  1               1       0.152838    0.187475

679182                  1               0       0.152838    0.089033

355393                  0               1       0.253428    0.187475


        DisbursementGross_trg  BalanceGross_trg  GrAppv_trg
SBA_Appv_trg  \
384386               420000.0               0.0    420000.0
315000.0
662652               165000.0               0.0    165000.0
140250.0
269020                65000.0               0.0     65000.0
52000.0
752306              1125000.0               0.0   1125000.0
843750.0
675193               240000.0               0.0    240000.0
240000.0
...                       ...               ...         ...
...
82879                380000.0               0.0    380000.0
285000.0
649244                24000.0               0.0     24000.0
12000.0
454383               411000.0               0.0    423000.0
423000.0
679182                48750.0               0.0     48750.0
```

```
39000.0
355393                20000.0               0.0     20000.0
10000.0

         index    Zip   NAICS     NoEmp  CreateJob  RetainedJob  \
384386  384386  12953       0 -0.086398  -0.035203    -0.045349
662652  662652  14850  235920 -0.059623  -0.035203    -0.045349
269020  269020  98004       0  0.074252  -0.035203    -0.045349
752306  752306  33905  541940  0.047477   0.029733    -0.045349
675193  675193  33172  811111 -0.099785  -0.004899    -0.045349
...        ...    ...     ...       ...        ...          ...
82879    82879  84741       0 -0.139948  -0.035203    -0.045349
649244  649244  11704  441110 -0.139948  -0.035203    -0.041029
454383  454383  98502  451110 -0.113173   0.034062    -0.045349
679182  679182  61920       0 -0.099785  -0.035203    -0.045349
355393  355393  41046  238990 -0.139948  -0.035203    -0.041029

        FranchiseCode  UrbanRural  DisbursementGross  BalanceGross
GrAppv  \
384386              1           0           0.761437     -0.002347
0.802282
662652              0           0          -0.125062     -0.002347 -
0.097242
269020              1           0          -0.472708     -0.002347 -
0.449997
752306              1           1           3.212347     -0.002347
3.289204
675193              1           0           0.135673     -0.002347
0.167324
...               ...         ...                ...           ...
...
82879               1           0           0.622379     -0.002347
0.661180
649244              1           1          -0.615243     -0.002347 -
0.594627
454383              1           1           0.730149     -0.002347
0.812865
679182              1           0          -0.529201     -0.002347 -
0.507320
355393              0           1          -0.629149     -0.002347 -
0.608737

        SBA_Appv  MIS_Status  Log_DisbursementGross  Log_NoEmp
Log_GrAppv  \
384386  0.725015           0               1.157104  -0.048393
1.205831
662652 -0.039847           0               0.423160   0.246620
0.488425
269020 -0.426107           0              -0.308620   1.078217   -
0.226864
```

```
752306  3.039296           1               1.931094   0.957432
1.962379
675193  0.396748           0               0.717499  -0.235361
0.776132
...          ...         ...                    ...        ...
...
82879   0.593708           0               1.078484  -1.175003
1.128982
649244 -0.601183           0              -1.091270  -1.175003   -
0.991878
454383  1.197719           0               1.140088  -0.464192
1.211296
679182 -0.483007           0              -0.534605  -0.235361   -
0.447757
355393 -0.609937           0              -1.234487  -1.175003   -
1.131867

        Log_SBA_Appv  Log_BalanceGross Disbursement_Bins
Loan_Efficiency  \
384386      1.159638         -0.004091              High
1.648470
662652      0.593798         -0.004091              High
0.324071
269020     -0.100035         -0.004091            Medium         -
0.195301
752306      1.848654         -0.004091              High         -
0.167710
675193      0.969473         -0.004091              High         -
0.377082
...              ...               ...               ...
...
82879       1.089649         -0.004091              High
1.440721
649244     -1.125412         -0.004091               Low         -
0.470569
454383      1.365793         -0.004091              High         -
0.407327
679182     -0.301209         -0.004091               Low         -
0.279699
355393     -1.252899         -0.004091               Low         -
0.480956

        Guarantee_Ratio  Loan_Guarantee_Interaction
Disbursement_Squared  \
384386         0.234647                    0.106400
0.090669
662652         0.810093                   -0.180743             -
0.163246
269020         0.522370                   -0.232725             -
```

```
0.202395
752306         0.234647                    2.255308
1.944665
675193         1.673261                   -0.090099              -
0.111544
...                 ...                         ...
...
82879          0.234647                    0.043268
0.036201
649244        -1.203966                   -0.240858              -
0.208606
454383         1.673261                    0.229058
0.077938
679182         0.522370                   -0.236615              -
0.205541
355393        -1.203966                   -0.241090              -
0.208905

        label  probability_0  probability_1  residual
contrib_City_trg  \
384386      0       0.943830       0.056170         0          -
0.934532
662652      1       0.542527       0.457473         1          -
0.105747
269020      0       0.846271       0.153729         0
0.042933
752306      0       0.745137       0.254863        -1
0.454252
675193      0       0.999835       0.000165         0
0.554612
...       ...            ...            ...       ...                ..
.
82879       0       0.840566       0.159434         0          -
0.372871
649244      1       0.610946       0.389054         1
0.184832
454383      0       0.999605       0.000395         0
0.046261
679182      1       0.681184       0.318816         1
0.289187
355393      1       0.587844       0.412156         1
0.506721

        contrib_State_trg  contrib_Zip_trg  contrib_Bank_trg  \
384386          -0.093977        -0.163654          0.797845
662652           0.054234         0.118141          0.033474
269020           0.105042        -0.110902          0.287373
752306          -0.035211         0.035707          0.170405
675193          -0.024294        -0.050025         -4.555447
```

```
...                    ...             ...              ...
82879           -0.027083         0.022158         0.480644
649244          -0.086382        -0.177557         0.495285
454383           0.059378         0.131292        -4.406189
679182           0.003434         0.190960         0.164955
355393          -0.054707        -0.039058         0.496466

        contrib_BankState_trg  contrib_NAICS_trg  contrib_NoEmp_trg  \
384386              -0.180398           0.013258           0.037824
662652              -0.042528          -0.122208           0.066717
269020              -0.079472           0.192177          -0.096102
752306              -0.059847          -0.692703          -0.016002
675193               0.012035          -0.078391          -0.017965
...                       ...                ...                ...
82879               -0.113945           0.073846           0.084438
649244              -0.094537           0.265089           0.068435
454383              -0.069914           0.126589           0.035071
679182              -0.071640           0.017075           0.039923
355393              -0.202338           0.092097           0.069528

        contrib_NewExist_trg  contrib_CreateJob_trg
contrib_RetainedJob_trg  \
384386              -0.038126              -0.037566                -
0.036683
662652              -0.049804              -0.047931                -
0.049519
269020              -0.119024              -0.042712                -
0.059163
752306               0.143502               0.054557                -
0.063381
675193              -0.028090               0.101265                -
0.038396
...                       ...                    ...
...
82879                0.167312              -0.027472                -
0.023855
649244               0.020075              -0.022972
0.062656
454383              -0.032881               0.117990                -
0.035814
679182              -0.059613              -0.032215                -
0.053374
355393              -0.002982              -0.041762
0.050848

        contrib_FranchiseCode_trg  contrib_UrbanRural_trg  \
384386                  -0.406968               -0.612943
662652                   1.056014               -0.035410
269020                  -0.371995               -0.602798
752306                  -0.155099                0.193968
```

```
675193                   -0.209829               -0.341918
...                            ...                     ...
82879                    -0.441587               -0.591827
649244                   -0.217901                0.257231
454383                   -0.092967                0.170124
679182                   -0.239224               -0.363180
355393                    0.354558                0.115063

        contrib_RevLineCr_trg  contrib_LowDoc_trg  \
384386               0.035589            0.003007
662652               0.070158           -0.011788
269020              -0.014453           -0.007704
752306               0.190771            0.000412
675193               0.020445            0.005092
...                       ...                 ...
82879                0.057730            0.006778
649244              -0.270487            0.014294
454383               0.080766           -0.003325
679182               0.056459            0.001364
355393              -0.114565            0.002845

        contrib_DisbursementGross_trg  contrib_BalanceGross_trg  \
384386                       0.104887                       0.0
662652                       0.102348                       0.0
269020                      -0.009316                       0.0
752306                       0.065205                       0.0
675193                      -0.081258                       0.0
...                               ...                       ...
82879                        0.153950                       0.0
649244                       0.017453                       0.0
454383                      -0.019491                       0.0
679182                       0.053316                       0.0
355393                      -0.130364                       0.0

        contrib_GrAppv_trg  contrib_SBA_Appv_trg  contrib_Zip
contrib_NAICS  \
384386           -0.118379             -0.019138    -0.055540
0.001878
662652           -0.043829             -0.045103     0.010904
0.017584
269020           -0.002948             -0.025928    -0.003249
0.002728
752306           -0.134172             -0.065651    -0.005182      -
0.185662
675193           -0.098061             -0.128892    -0.000602
0.036292
...                    ...                   ...          ...
...
82879            -0.054800             -0.083458     0.003042      -
0.010972
```

```
649244             0.033724              0.037394    -0.023027
0.078830
454383            -0.133725             -0.031935    -0.008163
0.053150
679182             0.024816             -0.037052     0.028039      -
0.010710
355393             0.043839             -0.020262    -0.003979
0.007919

        contrib_NoEmp  contrib_CreateJob  contrib_RetainedJob  \
384386       0.004899          -0.003840            -0.005447
662652      -0.014431           0.000004            -0.004623
269020      -0.015288           0.000227            -0.003030
752306      -0.010989          -0.000200             0.001330
675193      -0.026937           0.002162             0.006826
...               ...                ...                  ...
82879       -0.033689          -0.001171            -0.006951
649244       0.005585          -0.002344             0.004977
454383       0.037518          -0.026706             0.000327
679182       0.008752          -0.001347            -0.001767
355393       0.003142          -0.000879             0.009003

        contrib_FranchiseCode  contrib_UrbanRural
contrib_DisbursementGross  \
384386               0.002202            0.018332                    -
0.006166
662652               0.007885            0.007614
0.012673
269020              -0.004865           -0.005155
0.034502
752306              -0.012671            0.013339
0.014534
675193              -0.002525            0.005100                    -
0.015281
...                       ...                 ...
...
82879               -0.001920           -0.037160
0.025122
649244              -0.001369           -0.017380                    -
0.013811
454383              -0.000399            0.001673                    -
0.006801
679182              -0.002487            0.001815
0.023518
355393              -0.006899           -0.022667
0.003538

        contrib_BalanceGross  contrib_GrAppv  contrib_SBA_Appv  \
384386                   0.0       -0.097893         -0.026553
662652                   0.0       -0.090422         -0.091710
```

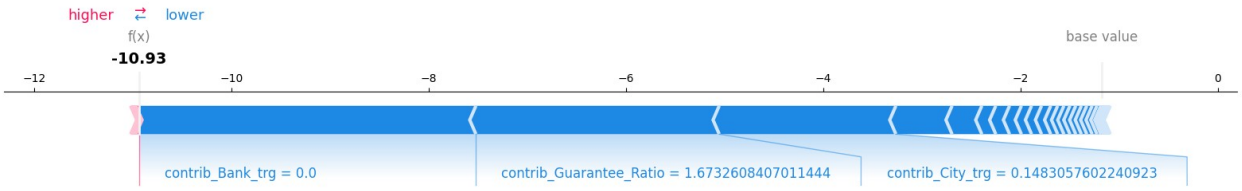
```
269020                    0.0        0.036604          0.038577
752306                    0.0       -0.008100         -0.006509
675193                    0.0       -0.101935         -0.037919
...                       ...             ...               ...
82879                     0.0       -0.048980         -0.028733
649244                    0.0       -0.006971          0.003221
454383                    0.0       -0.078278         -0.026623
679182                    0.0        0.019777         -0.003591
355393                    0.0       -0.014497          0.015784

        contrib_Log_DisbursementGross  contrib_Log_NoEmp
contrib_Log_GrAppv  \
384386                        0.003130           0.000260            -
0.010586
662652                        0.030123           0.000274            -
0.016909
269020                       -0.022502           0.000334
0.007268
752306                       -0.046088           0.000106            -
0.007804
675193                       -0.008417           0.000178            -
0.026906
...                                ...                ...
...
82879                         0.033005          -0.000247            -
0.017163
649244                       -0.039599          -0.009157            -
0.002230
454383                       -0.003628           0.000359            -
0.021271
679182                       -0.087055           0.000344
0.013456
355393                       -0.089822          -0.003049
0.003549

        contrib_Log_SBA_Appv  contrib_Log_BalanceGross  \
384386             -0.024835                       0.0
662652             -0.009523                       0.0
269020             -0.006551                       0.0
752306             -0.004631                       0.0
675193             -0.058045                       0.0
...                      ...                       ...
82879              -0.015962                       0.0
649244              0.022038                       0.0
454383             -0.077039                       0.0
679182             -0.013551                       0.0
355393             -0.075486                       0.0

        contrib_Disbursement_Bins  contrib_Loan_Efficiency  \
384386                        0.0                -0.048834
```

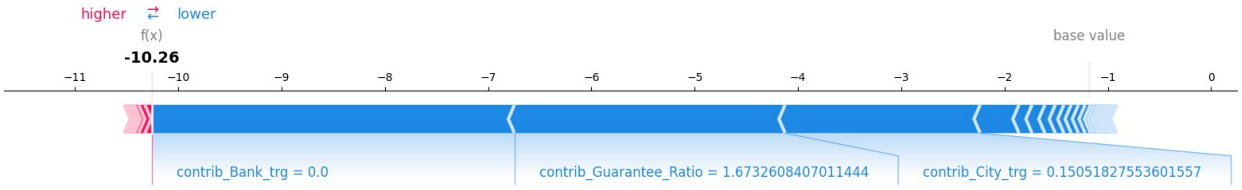
```
662652                          0.0                  0.067451
269020                          0.0                  0.044274
752306                          0.0                 -0.026701
675193                          0.0                  0.033181
...                             ...                       ...
82879                           0.0                  0.027790
649244                          0.0                  0.046999
454383                          0.0                 -0.001760
679182                          0.0                  0.091584
355393                          0.0                 -0.022920

        contrib_Guarantee_Ratio  contrib_Loan_Guarantee_Interaction  \
384386                 0.338273                           -0.088660
662652                 0.195145                           -0.055975
269020                 0.291259                           -0.023199
752306                 0.338373                           -0.030128
675193                -2.302087                           -0.068785
...                         ...                                 ...
82879                  0.409184                           -0.107193
649244                 0.068673                            0.032241
454383                -2.362056                           -0.073143
679182                 0.370638                           -0.023699
355393                 0.004129                            0.022350

        contrib_Disbursement_Squared  BiasTerm
384386                      0.006146 -1.178383
662652                     -0.005423 -1.178383
269020                      0.015793 -1.178383
752306                     -0.004193 -1.178383
675193                     -0.006210 -1.178383
...                              ...       ...
82879                       0.017979 -1.178383
649244                     -0.006215 -1.178383
454383                     -0.007162 -1.178383
679182                      0.020261 -1.178383
355393                     -0.131818 -1.178383

[160051 rows x 86 columns]
        index_trg  City_trg  State_trg  Zip_trg  Bank_trg
BankState_trg  \
262672     262672  0.148306   0.186605    22624       0.0
0.381893
335545     335545  0.150518   0.118097    55150       0.0
0.076794

        NAICS_trg  NoEmp_trg  NewExist_trg  CreateJob_trg
RetainedJob_trg  \
262672     541940          7      0.170871              2
0
335545     445310          3      0.170871              3
```

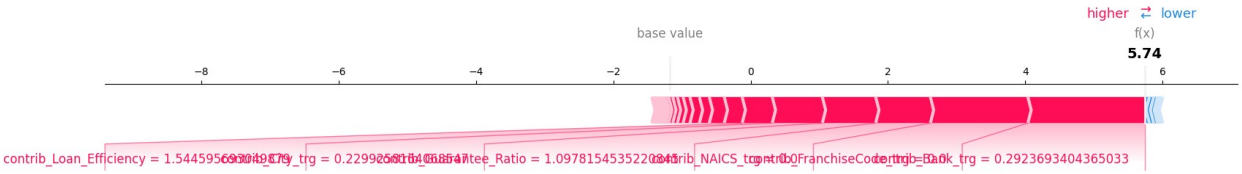
```
        FranchiseCode_trg  UrbanRural_trg  RevLineCr_trg
LowDoc_trg  \
262672                  1               0       0.152838    0.187475

335545                  1               0       0.152838    0.187475


        DisbursementGross_trg  BalanceGross_trg  GrAppv_trg
SBA_Appv_trg  \
262672              270000.0               0.0    270000.0
270000.0
335545              297000.0               0.0    297000.0
297000.0

         index    Zip   NAICS     NoEmp  CreateJob  RetainedJob  \
262672  262672  22624  541940 -0.059623  -0.026545    -0.045349
335545  335545  55150  445310 -0.113173  -0.022216    -0.045349

        FranchiseCode  UrbanRural  DisbursementGross  BalanceGross
GrAppv  \
262672             1           0           0.239967     -0.002347
0.273150
335545             1           0           0.333832     -0.002347
0.368394

        SBA_Appv  MIS_Status  Log_DisbursementGross  Log_NoEmp
Log_GrAppv  \
262672  0.528055           0               0.810023   0.246620
0.866571
335545  0.646231           0               0.884894  -0.464192
0.939754

        Log_SBA_Appv  Log_BalanceGross Disbursement_Bins
Loan_Efficiency  \
262672      1.051840         -0.004091              High        -
0.065458
335545      1.118491         -0.004091              High        -
0.147259

        Guarantee_Ratio  Loan_Guarantee_Interaction
Disbursement_Squared  \
262672         1.673261                   -0.049852             -
0.085501
335545         1.673261                   -0.009582             -
0.059443

        label  probability_0  probability_1  residual
contrib_City_trg  \
```

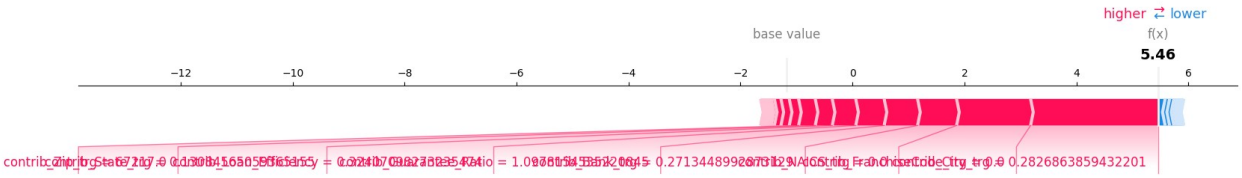
```
262672      0       0.999982       0.000018         0          -
1.790595
335545      0       0.999965       0.000035         0          -
1.888794

        contrib_State_trg  contrib_Zip_trg  contrib_Bank_trg  \
262672          -0.011402        -0.039790         -3.411782
335545           0.059716         0.041313         -3.513081

        contrib_BankState_trg  contrib_NAICS_trg  contrib_NoEmp_trg  \
262672              -0.120120          -0.569701          -0.101256
335545              -0.124431          -0.029214          -0.031089

        contrib_NewExist_trg  contrib_CreateJob_trg
contrib_RetainedJob_trg  \
262672             -0.028231               0.034699                -
0.060988
335545             -0.029959               0.065138                -
0.035656

        contrib_FranchiseCode_trg  contrib_UrbanRural_trg  \
262672                  -0.141370               -0.301535
335545                  -0.126214               -0.376065

        contrib_RevLineCr_trg  contrib_LowDoc_trg  \
262672               0.023194            0.002386
335545               0.019308            0.004800

        contrib_DisbursementGross_trg  contrib_BalanceGross_trg  \
262672                      -0.093149                       0.0
335545                      -0.071012                       0.0

        contrib_GrAppv_trg  contrib_SBA_Appv_trg  contrib_Zip
contrib_NAICS  \
262672           -0.059155             -0.070337    -0.018556      -
0.139586
335545           -0.069656             -0.035407     0.011798
0.011562

        contrib_NoEmp  contrib_CreateJob  contrib_RetainedJob  \
262672       0.000467          -0.006739             0.014002
335545       0.028760          -0.031876             0.002681

        contrib_FranchiseCode  contrib_UrbanRural
contrib_DisbursementGross  \
262672              -0.001596            0.011369                -
0.054538
335545              -0.000481            0.014242                -
0.051468
```

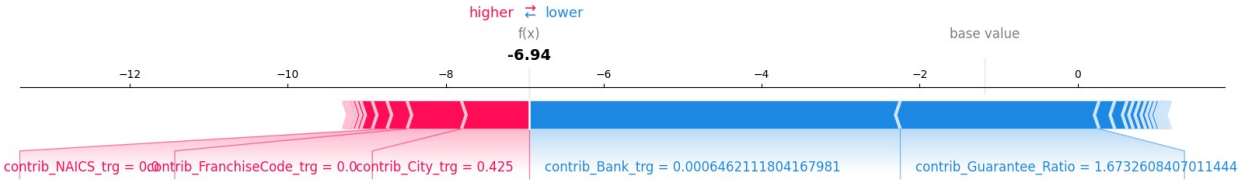
```
        contrib_BalanceGross  contrib_GrAppv  contrib_SBA_Appv  \
262672                   0.0       -0.103012         -0.057136
335545                   0.0       -0.100983         -0.021318

        contrib_Log_DisbursementGross  contrib_Log_NoEmp
contrib_Log_GrAppv  \
262672                      -0.054571           0.000124            -
0.011563
335545                      -0.012545           0.000359            -
0.013423

        contrib_Log_SBA_Appv  contrib_Log_BalanceGross  \
262672             -0.063135                       0.0
335545             -0.065177                       0.0

        contrib_Disbursement_Bins  contrib_Loan_Efficiency  \
262672                        0.0                -0.004000
335545                        0.0                 0.003897

        contrib_Guarantee_Ratio  contrib_Loan_Guarantee_Interaction  \
262672                -2.466320                           -0.048376
335545                -2.620345                           -0.082973

        contrib_Disbursement_Squared  BiasTerm
262672                     -0.012504 -1.178383
335545                     -0.012185 -1.178383
```

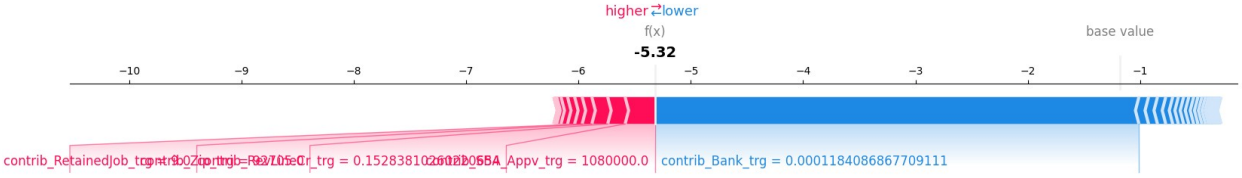


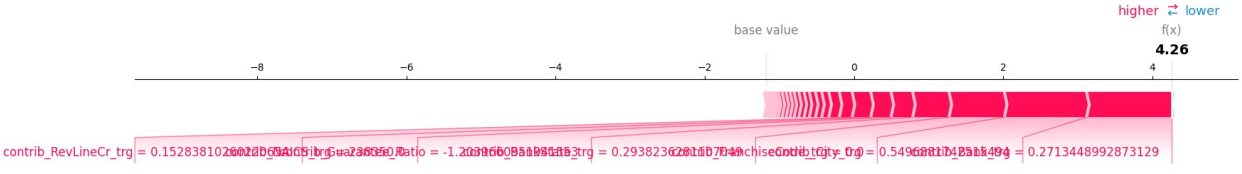


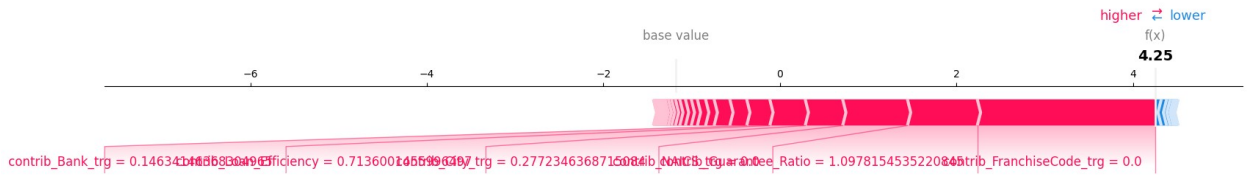

higher ⇄ lower
base value
f(x)
5.74
−8
−6
−4
−2
0
2
4
6
contrib_Loan_Efficiency = 1.5445956
contrib_Bank_trg = 0.2923693404365033


higher ⇄ lower
base value
f(x)
5.46
−12
−10
−8
−6
−4
−2
0
2
4
6
contrib_Bank_trg = 0.2826863859432201


higher ⇄ lower
f(x)
-6.94
base value
−12
−10
−8
−6
−4
−2
0
contrib_NAICS_trg = 0.0
contrib_FranchiseCode_trg = 0.0
contrib_City_trg = 0.425
contrib_Bank_trg = 0.0006462111804167981
contrib_Guarantee_Ratio = 1.6732608407011444


higher ⇄ lower
f(x)
-5.32
base value
−10
−9
−8
−7
−6
−5
−4
−3
−2
−1
contrib_Appv_trg = 1080000.0
contrib_Bank_trg = 0.0001184086867709111


higher ⇄ lower
base value
f(x)
4.26
−8
−6
−4
−2
0
2
4
contrib_RevLineCr_trg = 0.1528381
contrib_Bank_trg = 0.2938236
contrib_City_trg = 0.5496
contrib_Appv_trg = 0.2713448992873129



	index	label	probability_0	probability_1
0	384386	0	0.943830	0.056170
1	662652	1	0.542527	0.457473
2	269020	0	0.846271	0.153729
3	752306	0	0.745137	0.254863
4	675193	0	0.999835	0.000165
...	...	...	...	...
160046	82879	0	0.840566	0.159434
160047	649244	1	0.610946	0.389054
160048	454383	0	0.999605	0.000395
160049	679182	1	0.681184	0.318816
160050	355393	1	0.587844	0.412156

[160051 rows x 4 columns]

Residual Analysis

As we can see, Plot records with largest negative residuals when not defaulted, will push the model predictability to high. Similarly, Plot records with largest positive residuals when defaulted and model predicts low probability of default.

Conclusion

In summary, the developed LightGBM model showcased promising performance and contributed meaningful insights into the customer defaulting on loan or not. Despite certain limitations, the project lays a foundation for future improvements and applications in Default detection

We used in SBA Dataset, with MIS_Status being our predictor variable and other explanatory variables like NoEmp', 'CreateJob', 'RetainedJob', 'GrAppv', 'SBA_Appv', 'DisbursementGross', 'BalanceGross', 'Log_DisbursementGross', 'Log_NoEmp', 'Log_GrAppv', 'Log_SBA_Appv', 'Log_BalanceGross', 'Loan_Efficiency', 'Guarantee_Ratio', 'Loan_Guarantee_Interaction', 'Disbursement_Squared.

We used Target encoding as an encoder for converting categorical variables to numerical variables, followed by Standard scaling to transform features to have a mean of 0 and a standard deviation of 1.

We then committed 10 feature exatraction -> Log_DisbursementGross, Log_NoEmp, Log_GrAppv, Log_SBA_Appv', Log_BalanceGross,Disbursement_Bins, Loan_Efficiency, Guarantee_Ratio', Loan_Guarantee_Interaction, and Disbursement_Square.

Then we used LightGBM Classifier: To use Optuna you first need to create an objective function. This includes a dictionary of the model's hyperparameters you want to test, as well as the ranges of values you want to cover during testing. Optuna will do a series of runs and test different combinations of hyperparameters by fitting them to your model and then measuring the accuracy (or whatever objective you set) before finally returning the best parameters.

o run the Optuna study and identify the best hyperparameters for our LightGBMClassifier model we need to create a sampler. We're using TPESampler, which uses the Tree-Structured Parzen Estimator algorithm. We want to maximise the accuracy of our model during tuning, so we'll pass in the maximize argument to create_study() along with our sampler. We'll then use optimize() to run 100 trials against our objective function.

To examine the results of our Optuna study we can print some values returned in the study variable. We can see that we ran 200 trials and that trial number 14 generated the best results, with an AUCPR score of approx 84%. By looping over the trial.params.items() we can see what the winning hyperparameters were and use them in our final tuned model.

Following observations on hyperparameters were made during training the model:

``` A common strategy for achieving higher accuracy is to use many decision trees and decrease the learning rate. In other words, find the best combination of n_estimators and learning_rate in LGBM.

n_estimators controls the number of decision trees while learning_rate is the step size parameter of the gradient descent.

Ensembles like LGBM build trees in iterations, and each new tree is used to correct the "errors" of the previous trees. This approach is fast and powerful, and prone to overfitting.

That's why gradient boosted ensembles have a learning_rate parameter that controls the learning speed. Typical values lie within 0.01 and 0.3, but it is possible to go beyond these, especially towards 0.```

```

LGBM also has important regularization parameters.

lambda_l1 and lambda_l2 specifies L1 or L2 regularization, like XGBoost's reg_lambda and reg_alpha. The optimal value for these parameters is harder to tune because their magnitude is not directly correlated with overfitting. However, a good search range is (0, 100) for both.

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** Constructed Shapley Values : hows features each contributing to push the model output from the base value (the average model output over the training dataset we passed) to the model output. Features pushing the prediction higher are shown in red, those pushing the prediction lower are in blue. BANK Encoded had the highest shapley value contributions**

** Permutation Importance shows Bank encoded has the highest importance in predicting the target variable **

We calculated the AUC score of 0.8593593156075828, F1 score with average = macro for imbalanced dataset and obtained optimal threshold: 0.6767676767676768

Constructed confusion matrix

Created a Training function and stored the parameters in artifacts

Using the SBA training data set, Splitted the dataset and trained it