Project-Pdfoutput-Team4

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1 Machine Learning I Final Project

Team 4

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[ ]:
```
# import packages
import pandas as pd
from datetime import datetime
import numpy as np
from keras.models import Model, Sequential
from keras.layers import Dense, Activation, Dropout, BatchNormalization,␣
↪Embedding, Flatten, Input, concatenate
from keras_tuner import BayesianOptimization, RandomSearch
from sklearn.preprocessing import MinMaxScaler, StandardScaler, LabelEncoder
import matplotlib.pyplot as plt
from sklearn.metrics import mean_absolute_error
import keras.backend as K
import sklearn
import category_encoders as ce
from keras.optimizers import SGD, Adam, RMSprop
from keras.callbacks import EarlyStopping
from sklearn.metrics import log_loss
from keras import regularizers
from sklearn.model_selection import train_test_split
from keras import initializers
from datatable import dt, f, by, g, join, sort, update, ifelse
from sklearn.model_selection import GridSearchCV
from lightgbm import LGBMClassifier
import seaborn as sns
```

2 Data Exploration

2.1 Data Import

[ ]:
```
# Import the training data
train = pd.read_csv('Project Data/ProjectTrainingData.csv')
```

[ ]:
```
# Import the test data
test = pd.read_csv('Project Data/ProjectTestData.csv')
```

[ ]:
```
train.shape
# there are 31991090 rows and 24 columns
```

```
(31991090, 24)
```

[ ]:
```
# shuffle the train dataset into 10 parts
shuffled = train.sample(frac=1,random_state=42)
result = np.array_split(shuffled, 10)
```

[ ]:
```
# name those parts with number
for i in range(len(result)):
    exec(f'train_{i} = result[i]')
```

[ ]:
```
print(train_3.shape)
```

```
(3199109, 24)
```

2.2 Data Overview

[ ]:
```
# Explore the training data
train_3.head()
```

[ ]:
```
                    id  click      hour    C1  banner_pos   site_id  \
5616589   1.211469e+19      0  14102210  1005           1  5114c672
31825749  1.028758e+19      0  14102922  1005           0  85f751fd
13548281  1.757268e+19      1  14102413  1005           0  2b1ddb24
11682204  7.256027e+18      0  14102322  1005           0  85f751fd
29186795  1.731978e+18      0  14102904  1005           0  8d7e1373

          site_domain site_category    app_id app_domain  … device_type  \
5616589     3f2f3819      3e814130  ecad2386   7801e8d9  …           1
31825749    c4e18dd6      50e219e0  e2fcccd2   5c5a694b  …           1
13548281    98acf46c      3e814130  ecad2386   7801e8d9  …           1
11682204    c4e18dd6      50e219e0  8bcb1385   2347f47a  …           1
29186795    3b953bf0      75fa27f6  ecad2386   7801e8d9  …           1

          device_conn_type    C14  C15  C16   C17  C18  C19     C20  C21
5616589                  0  21764  216   36  2506    0   35  100076  157
```

```
31825749                0   4687  320   50   423    2   39  100148   32
13548281                0  20128  320   50  2303    2   39  100148   23
11682204                0  15708  320   50  1722    0   35      -1   79
29186795                0  22951  320   50  2654    3   38      -1   23

[5 rows x 24 columns]
```

[ ]:
```
# set test set naive prediction value as 0.5
test['click'] = 0.5
# set test set column names
test = test[['id', 'click', 'hour', 'C1', 'banner_pos', 'site_id',␣
 ↪'site_domain', 'site_category', 'app_id', 'app_domain', 'app_category',␣
 ↪'device_id', 'device_ip', 'device_model',
                   'device_type', 'device_conn_type', 'C14', 'C15', 'C16',␣
 ↪'C17', 'C18', 'C19', 'C20', 'C21']]
```

[ ]:
```
test.shape
```

[ ]:
```
(13015341, 24)
```

[ ]:
```
train_3.describe(include='all')
```

[ ]:
```
                  id         click          hour            C1    banner_pos  \
count   3.199109e+06  3.199109e+06  3.199109e+06  3.199109e+06  3.199109e+06
unique           NaN           NaN           NaN           NaN           NaN
top              NaN           NaN           NaN           NaN           NaN
freq             NaN           NaN           NaN           NaN           NaN
mean    9.221241e+18  1.697601e-01  1.410251e+07  1.004971e+03  2.939415e-01
std     5.325019e+18  3.754219e-01  2.675345e+02  1.116570e+00  5.107964e-01
min     6.644102e+12  0.000000e+00  1.410210e+07  1.001000e+03  0.000000e+00
25%     4.609702e+18  0.000000e+00  1.410222e+07  1.005000e+03  0.000000e+00
50%     9.218715e+18  0.000000e+00  1.410251e+07  1.005000e+03  0.000000e+00
75%     1.383416e+19  0.000000e+00  1.410280e+07  1.005000e+03  1.000000e+00
max     1.844674e+19  1.000000e+00  1.410292e+07  1.012000e+03  7.000000e+00

         site_id site_domain site_category    app_id app_domain  …  \
count    3199109     3199109       3199109   3199109    3199109  …
unique      3278        4010            23      4586        294  …
top     85f751fd    c4e18dd6      50e219e0  ecad2386   7801e8d9  …
freq     1117161     1160312       1273551   2081948    2199153  …
mean         NaN         NaN           NaN       NaN        NaN  …
std          NaN         NaN           NaN       NaN        NaN  …
min          NaN         NaN           NaN       NaN        NaN  …
25%          NaN         NaN           NaN       NaN        NaN  …
50%          NaN         NaN           NaN       NaN        NaN  …
75%          NaN         NaN           NaN       NaN        NaN  …
max          NaN         NaN           NaN       NaN        NaN  …
```

```
         device_type device_conn_type           C14           C15  \
count   3.199109e+06     3.199109e+06  3.199109e+06  3.199109e+06
unique           NaN              NaN           NaN           NaN
top              NaN              NaN           NaN           NaN
freq             NaN              NaN           NaN           NaN
mean    1.018046e+00     3.294061e-01  1.858709e+04  3.188324e+02
std     5.407373e-01     8.574898e-01  4.972518e+03  2.145895e+01
min     0.000000e+00     0.000000e+00  3.750000e+02  1.200000e+02
25%     1.000000e+00     0.000000e+00  1.661500e+04  3.200000e+02
50%     1.000000e+00     0.000000e+00  2.015300e+04  3.200000e+02
75%     1.000000e+00     0.000000e+00  2.177000e+04  3.200000e+02
max     5.000000e+00     5.000000e+00  2.383600e+04  1.024000e+03

                C16           C17           C18           C19           C20  \
count   3.199109e+06  3.199109e+06  3.199109e+06  3.199109e+06  3.199109e+06
unique           NaN           NaN           NaN           NaN           NaN
top              NaN           NaN           NaN           NaN           NaN
freq             NaN           NaN           NaN           NaN           NaN
mean    6.017037e+01  2.081027e+03  1.432369e+00  2.217995e+02  5.364687e+04
std     4.760673e+01  6.093760e+02  1.323083e+00  3.495668e+02  4.992757e+04
min     2.000000e+01  1.120000e+02  0.000000e+00  3.300000e+01 -1.000000e+00
25%     5.000000e+01  1.800000e+03  0.000000e+00  3.500000e+01 -1.000000e+00
50%     5.000000e+01  2.299000e+03  2.000000e+00  3.900000e+01  1.000550e+05
75%     5.000000e+01  2.506000e+03  3.000000e+00  1.690000e+02  1.000940e+05
max     1.024000e+03  2.729000e+03  3.000000e+00  1.959000e+03  1.002480e+05

                C21
count   3.199109e+06
unique           NaN
top              NaN
freq             NaN
mean    8.052746e+01
std     6.698060e+01
min     1.000000e+00
25%     2.300000e+01
50%     6.100000e+01
75%     9.100000e+01
max     2.530000e+02

[11 rows x 24 columns]
```

[ ]:
```
# # concat all data to explore
# df = pd.concat([train, test])
# # transform into a datatable just in case of speed limit
# all_dt = dt.Frame(df)
```

2.3 Categorical Data Encoding

Category with names: * id: drop * site categories: * site_id: base 5 encoding * site_domain: base 5 encoding * site_category: base 10 encoding * app cats: * app_id: base 5 encoding * app_domain: one-hot encoding * app_category: base 10 encoding * device cats: * device_id: one-hot encoding * device_ip: drop * device_model: base 10 encoding

Category without names: * C1: stay same * C14: base 5 encoding * C15: stay same * C16: stay same * C17: base 5 encoding * C18: stay same * C19: base 5 encoding * C20: base 5 encoding * C21: base 5 encoding

[ ]:
```
# drop id in column
del train_3['id']
del test['id']
```

[ ]:
```
# define a function to transform skewed categorical value based on frequency
def categorical_replace(train_data, test_data, column, pct = 0.01):
    """
    train_data: train dataset to input
    test_data: test to input
    column: column name string to input
    pct: transform frequency treshold, default 0.01
    """
    cond = train_data[column].value_counts(normalize = True) > pct
    non_others = cond[cond].index  # define a list to save main category

    train_data['temp'] = 'other'
    train_data.loc[train_data[column].isin(non_others),'temp'] =␣
 ↪train_data[column]
    train_data[column] = train_data['temp'].values
    del train_data['temp']
    print("Train Test Replace Finished!")

    test_data['temp'] = 'other'
    test_data.loc[test_data[column].isin(non_others),'temp'] = test_data[column]
    test_data[column] = test_data['temp'].values
    del test_data['temp']
    print("Test data replace finished!")
```

[ ]:
```
# define function to draw category distribution
def hist_bar_cat(data, column):
    categories = data[column].value_counts().index.astype('str')
    counts = data[column].value_counts().values
    plt.bar(categories, counts, width=0.5)
    plt.title('Distribution for column {}'.format(column))
```

2.3.1 Site Categories

site_id

[ ]:
```
# check the number of unique values for each column
train_3['site_id'].nunique()
```

[ ]: 3278

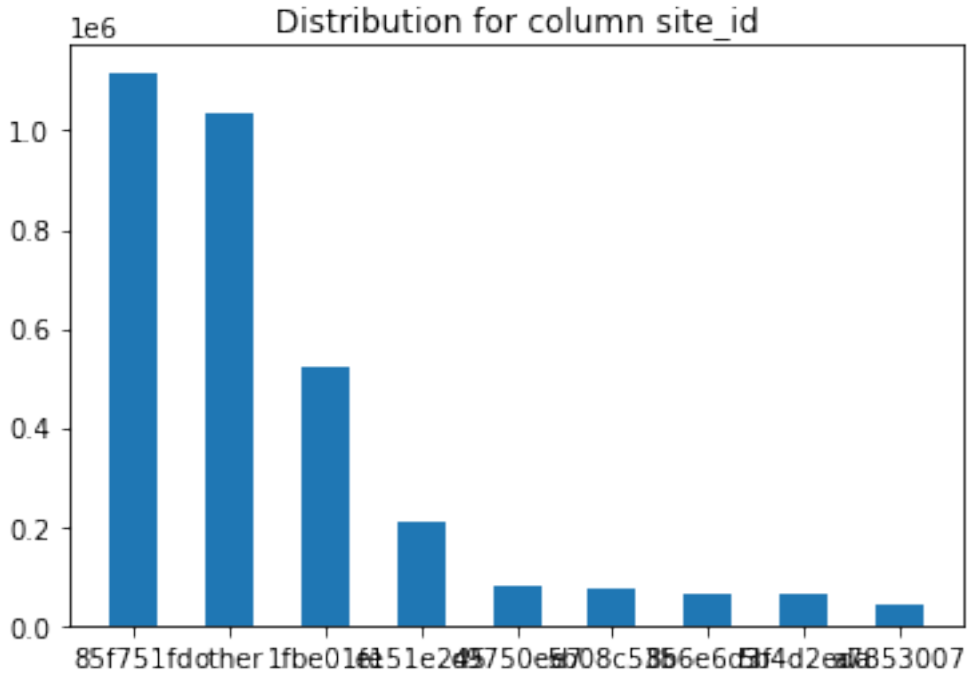
[ ]:
```
train_3['site_id'].value_counts(normalize = True).skew()
# as shown below, the skewness it is quite high
```

[ ]: 43.94039373056989

[ ]:
```
categorical_replace(train_3, test, 'site_id')
```

```
Train Test Replace Finished!
Test data replace finished!
```

[ ]:
```
hist_bar_cat(train_3, "site_id")
# much better
```



site_domain

[ ]:
```
train_3['site_domain'].nunique()
# check non-dup value
```

[ ]: 4010

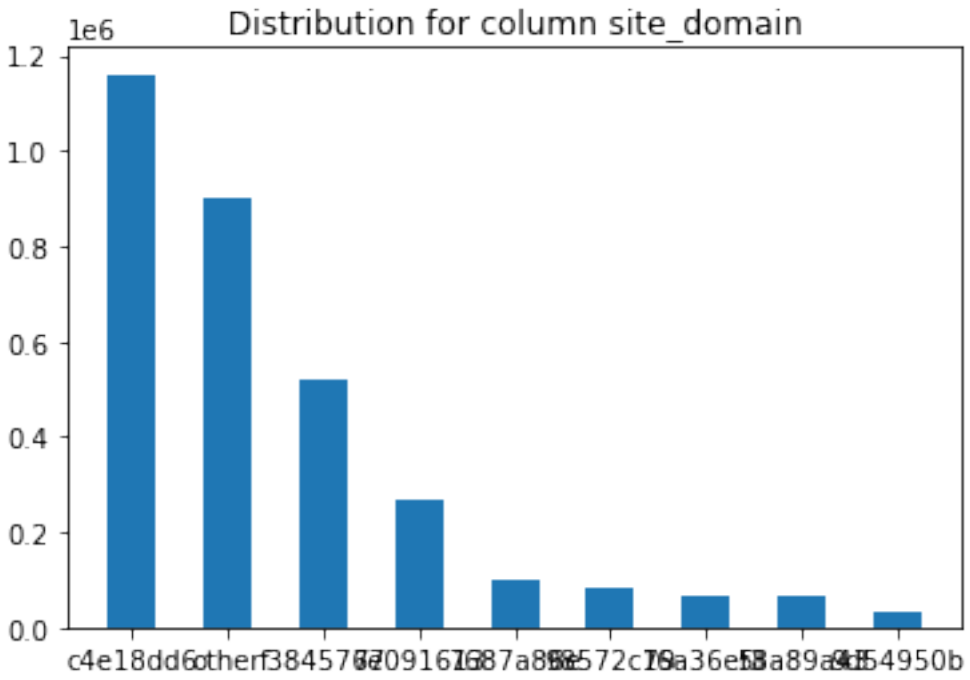
[ ]:
```
train_3['site_domain'].value_counts(normalize = True).skew()
# as shown below, the skewness it is quite high
```

[ ]: 48.12296789950277

[ ]:
```
categorical_replace(train_3, test, 'site_domain')
```

```
Train Test Replace Finished!
Test data replace finished!
```

[ ]:
```
hist_bar_cat(train_3, "site_domain")
# much better
```



site_category Use Label Encoder Later

[ ]:
```
train_3['site_category'].nunique()
```

[ ]: 23

2.3.2 App Categories

app_id

[ ]:
```
train_3['app_id'].nunique()
```

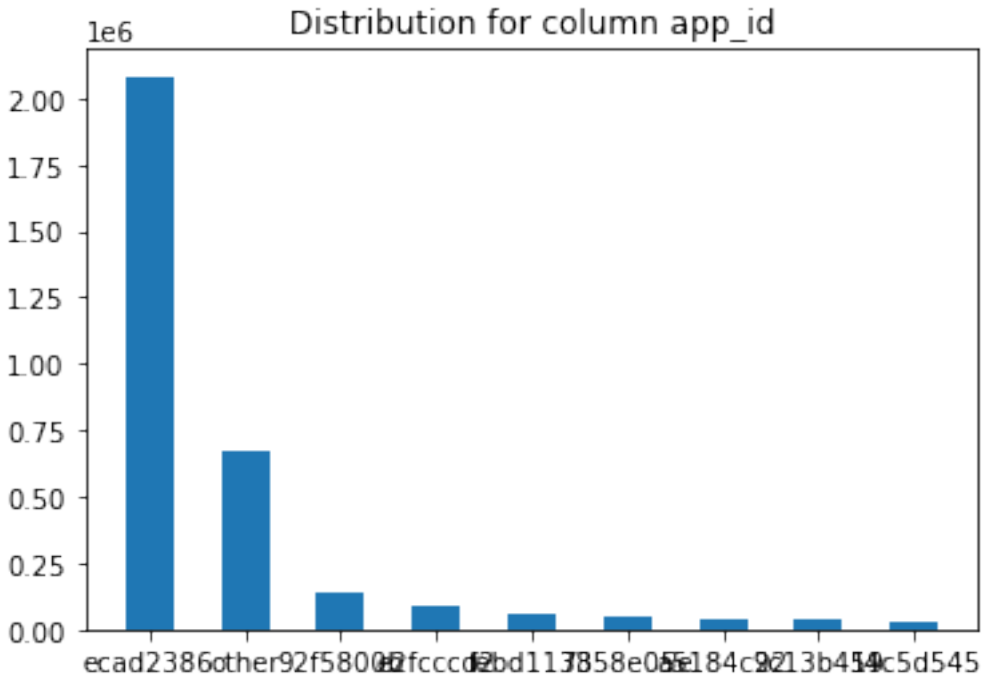
[ ]: 4586

[ ]:
```
train_3['app_id'].value_counts(normalize = True).skew()
# as shown below, the skewness it is quite high
```

[ ]: 66.7564684913619

[ ]:
```
categorical_replace(train_3, test, 'app_id')
hist_bar_cat(train_3, "app_id")
```

```
Train Test Replace Finished!
Test data replace finished!
```



app_domain

[ ]:
```
train_3['app_domain'].nunique()
```

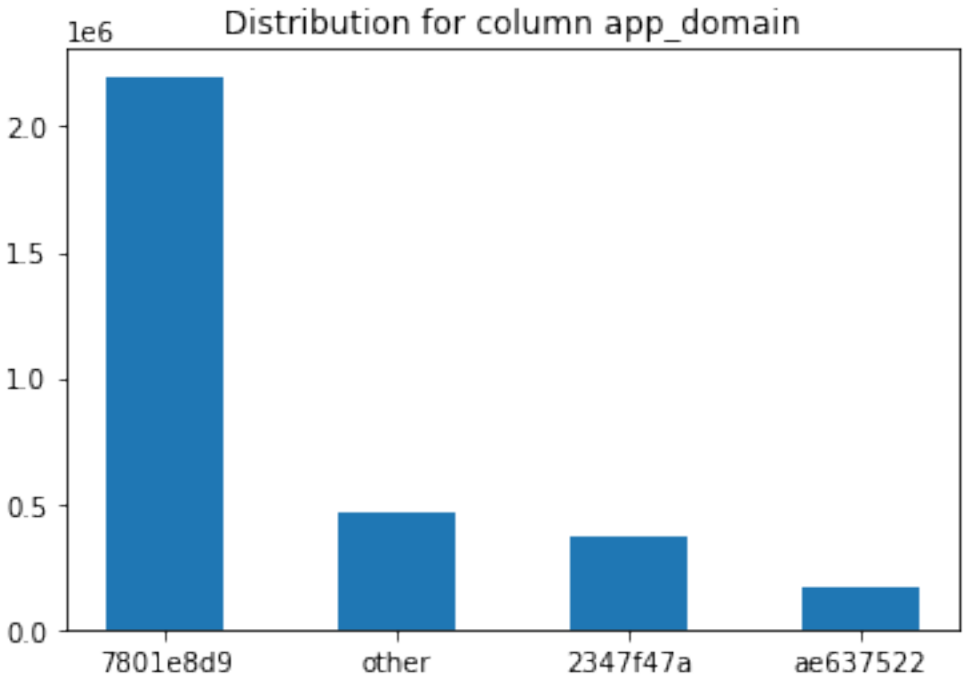
[ ]: 294

[ ]:
```
train_3['app_domain'].value_counts(normalize = True).skew()
# as shown below, the skewness it is quite high
```

[ ]: 16.285788826071837

[ ]:
```
categorical_replace(train_3, test, 'app_domain', pct = 0.05)
hist_bar_cat(train_3, "app_domain")
```

```
Train Test Replace Finished!
Test data replace finished!
```



app_category Label Encode Later

[ ]:
```
train_3['app_category'].nunique()
```

[ ]: 27

2.3.3 Device Categoris

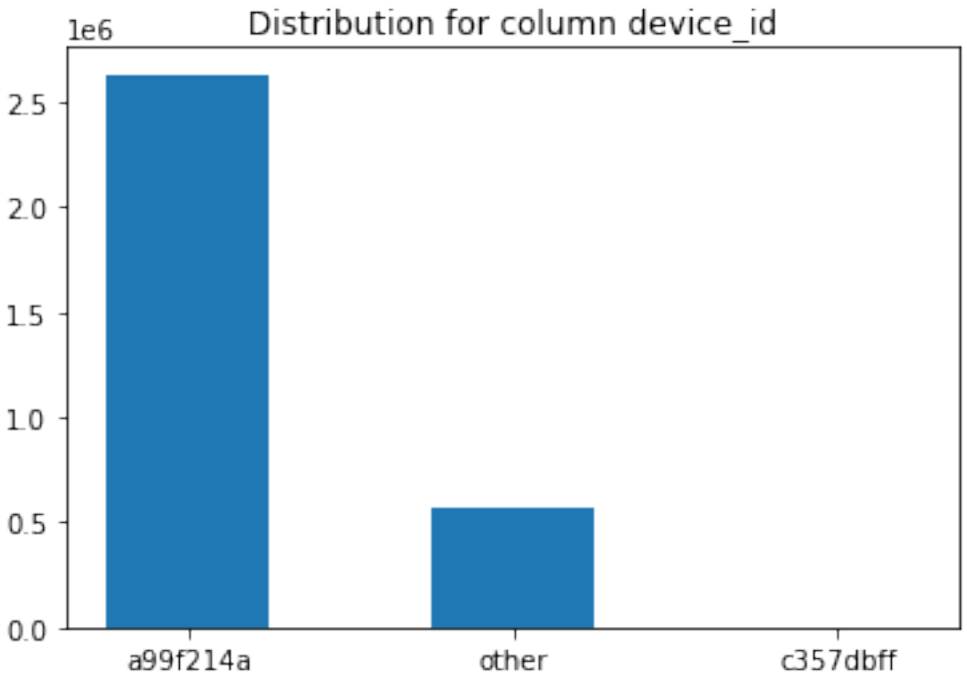
device_id

[ ]:
```
train_3['device_id'].value_counts(normalize = True).skew()
# as shown below, the skewness it is quite high
```

[ ]: 646.6309681657631

[ ]:
```
categorical_replace(train_3, test, 'device_id', pct = 0.0005)
hist_bar_cat(train_3, "device_id")
```

```
Train Test Replace Finished!
Test data replace finished!
```



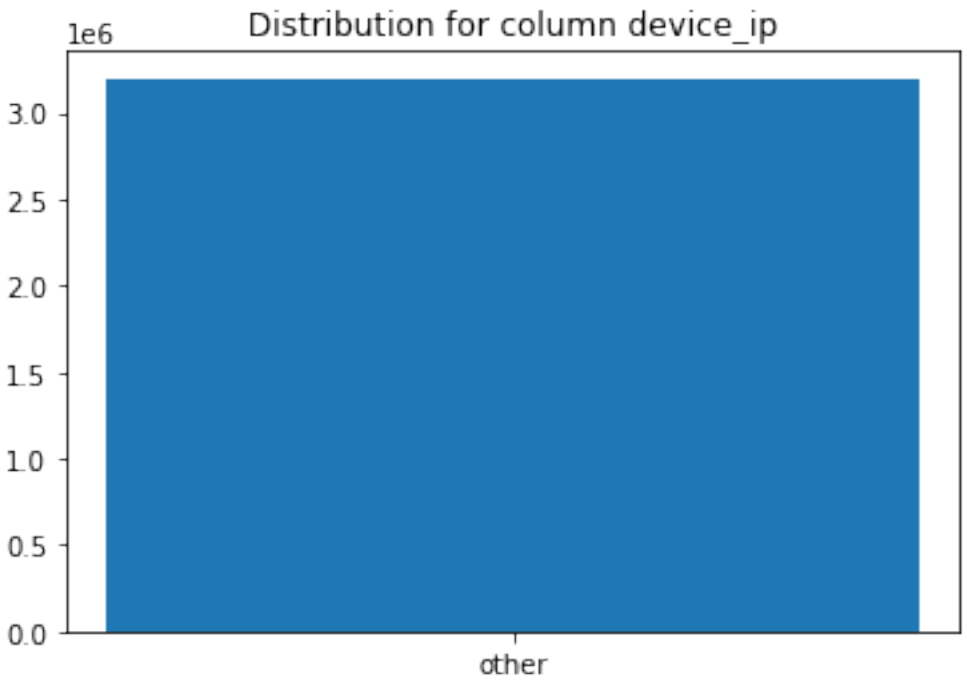
device_ip

[ ]:
```
train_3['device_ip'].value_counts(normalize = True).skew()
# as shown below, the skewness it is quite high
```

[ ]:
```
252.18416764934165
```

[ ]:
```
categorical_replace(train_3, test, 'device_ip')
hist_bar_cat(train_3, "device_ip")
```

```
Train Test Replace Finished!
Test data replace finished!
```



This variable is too skew that we decide to drop it.

[ ]:
```
del train_3['device_ip']
del test['device_ip']
```

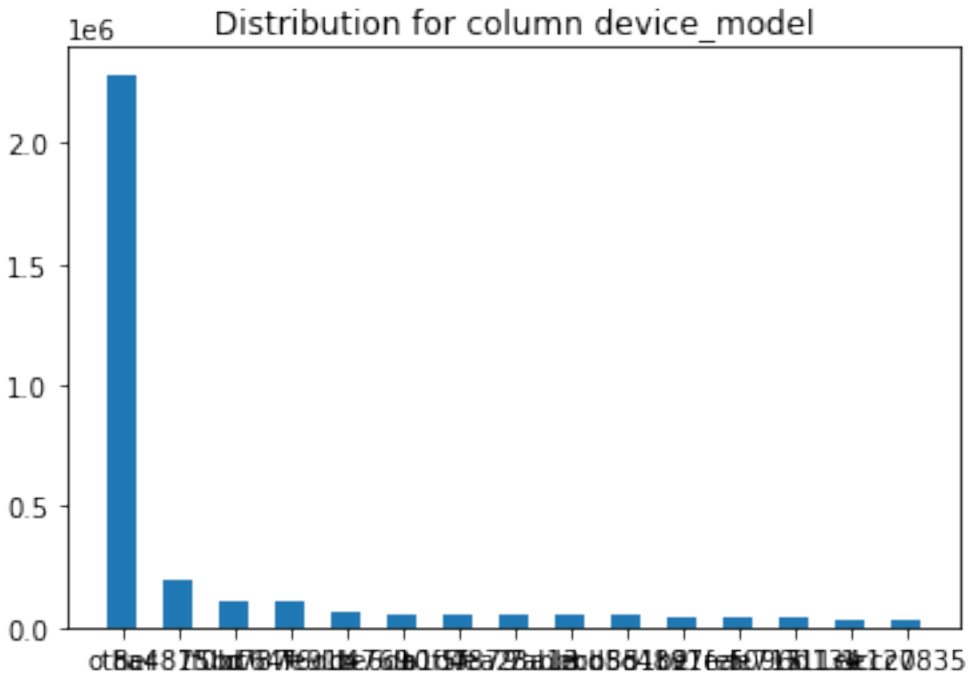
device_model

[ ]:
```
train_3['device_model'].value_counts(normalize = True).skew()
# as shown below, the skewness it is quite high
```

[ ]:
```
25.976421186589164
```

[ ]:
```
categorical_replace(train_3, test, 'device_model')
hist_bar_cat(train_3, "device_model")
```

```
Train Test Replace Finished!
Test data replace finished!
```



2.3.4 Anonymized Categorical Variables

C14

[ ]:
```
train_3['C14'].nunique()
```

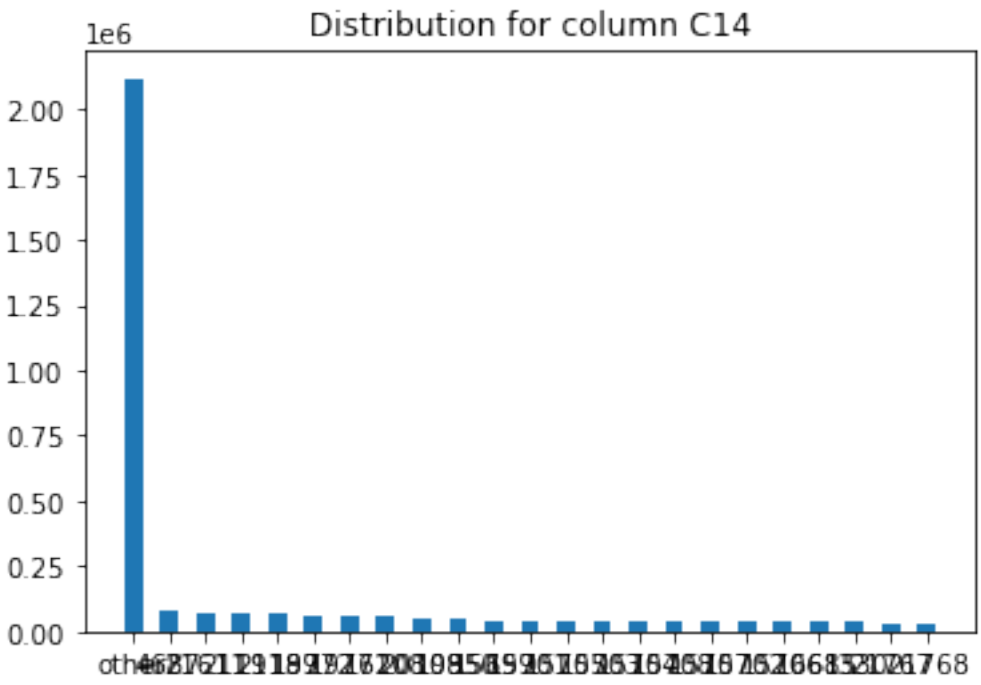
[ ]: 2284

[ ]:
```
train_3['C14'].value_counts(normalize = True).skew()
# as shown below, the skewness it is quite high
```

[ ]: 7.99323307497523

[ ]:
```
categorical_replace(train_3, test, 'C14', pct = 0.01)
hist_bar_cat(train_3, "C14")
```

```
Train Test Replace Finished!
Test data replace finished!
```



C17

[ ]:
```
train_3['C17'].nunique()
```

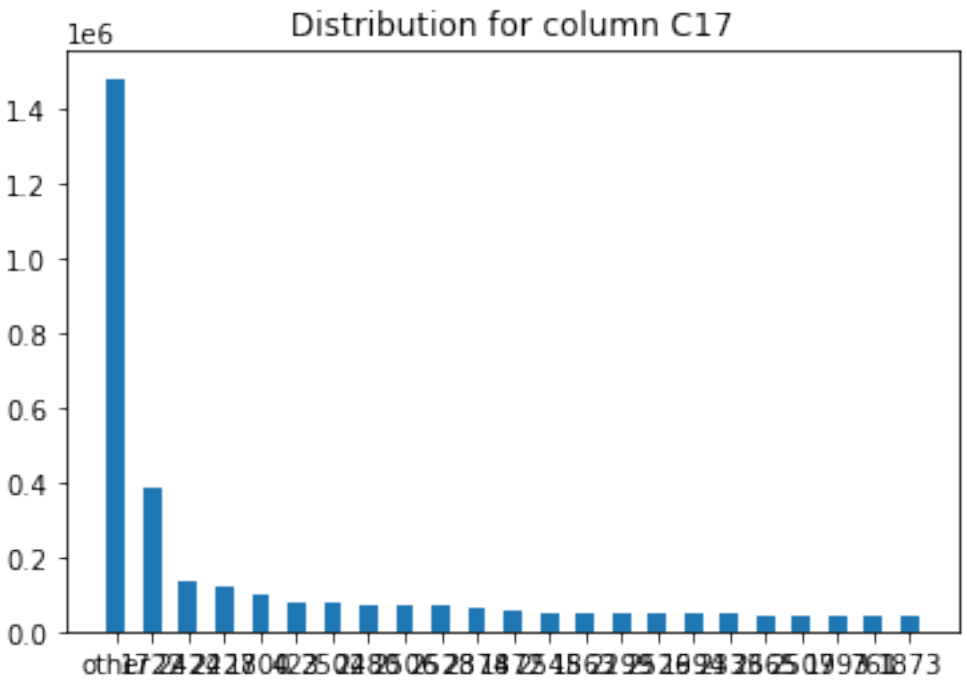
[ ]: 405

[ ]:
```
train_3['C17'].value_counts(normalize = True).skew()
# as shown below, the skewness it is quite high
```

[ ]: 10.171913349163981

[ ]:
```
categorical_replace(train_3, test, 'C17')
hist_bar_cat(train_3, "C17")
```

```
Train Test Replace Finished!
Test data replace finished!
```



C19

[ ]:
```
train_3['C19'].nunique()
```

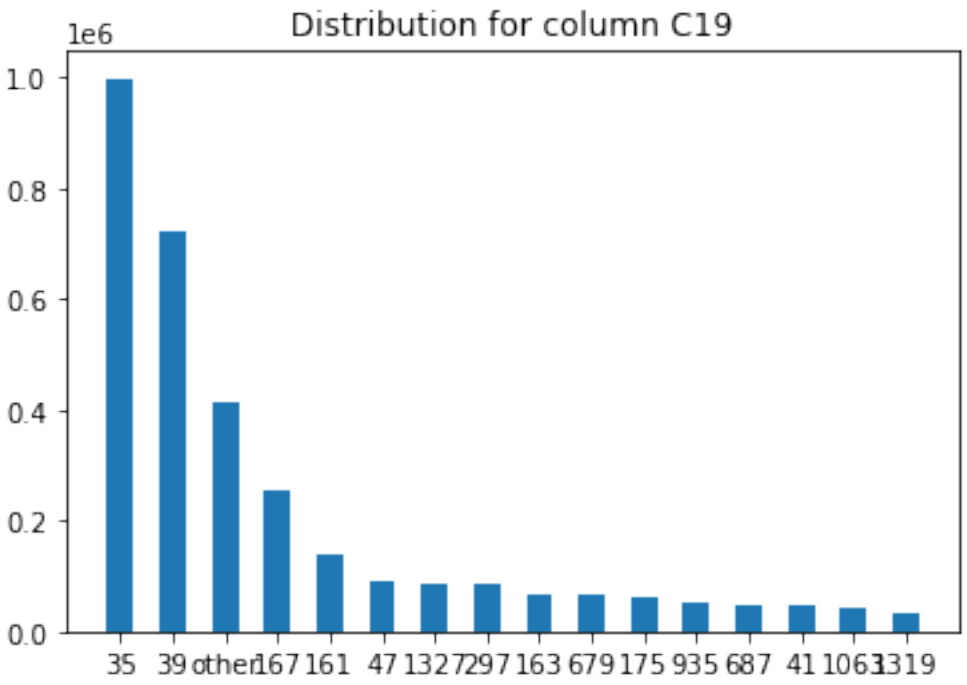
[ ]:
```
65
```

[ ]:
```
train_3['C19'].value_counts(normalize = True).skew()
# as shown below, the skewness it is quite high
```

[ ]:
```
5.252812769397987
```

[ ]:
```
categorical_replace(train_3, test, 'C19')
hist_bar_cat(train_3, "C19")
```

```
Train Test Replace Finished!
Test data replace finished!
```



C20

[ ]:
```
train_3['C20'].nunique()
```

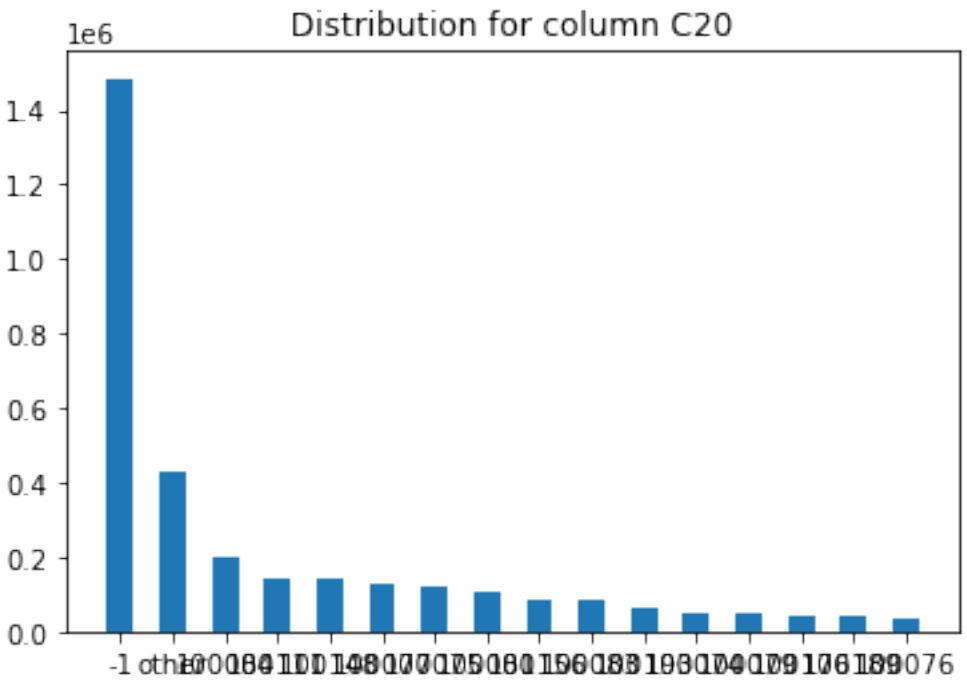
[ ]:
```
168
```

[ ]:
```
train_3['C20'].value_counts(normalize = True).skew()
# as shown below, the skewness it is quite high
```

[ ]:
```
11.87592669177848
```

[ ]:
```
categorical_replace(train_3, test, 'C20')
hist_bar_cat(train_3, "C20")
```

```
Train Test Replace Finished!
Test data replace finished!
```



C21

[ ]:
```
train_3['C21'].nunique()
```

[ ]:
```
55
```

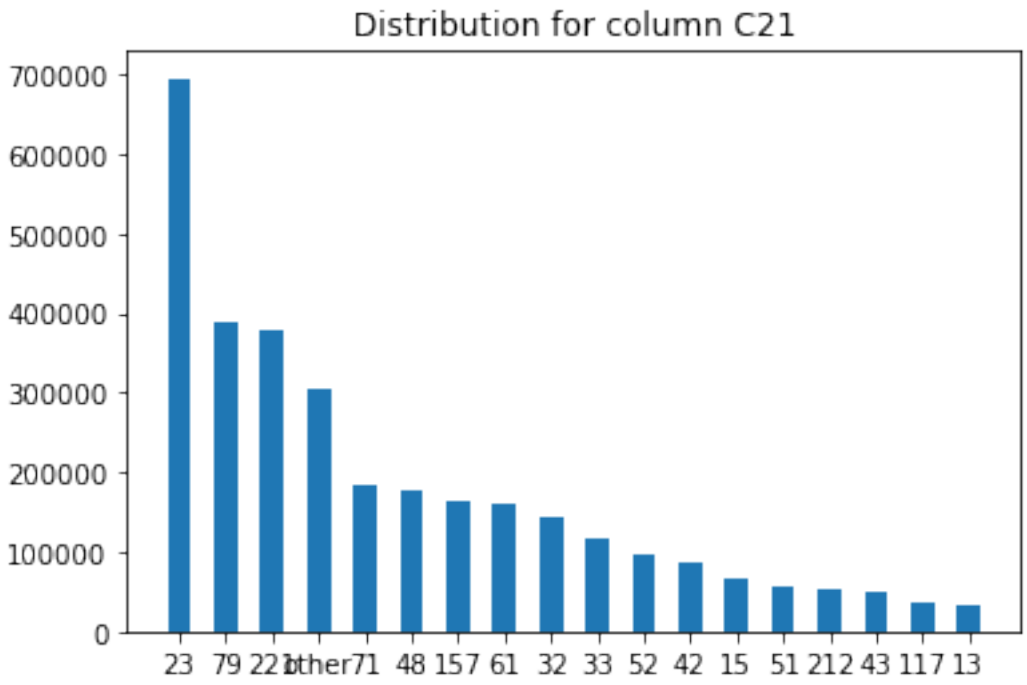
[ ]:
```
train_3['C21'].value_counts(normalize = True).skew()
# as shown below, the skewness it is not quite high
```

[ ]:
```
3.6204617840011357
```

[ ]:
```
categorical_replace(train_3, test, 'C21')
```

```
Train Test Replace Finished!
Test data replace finished!
```

[ ]:
```
hist_bar_cat(train_3, "C21")
```



2.3.5 Encoding

One-hot

```
[ ]: # one-hot encoding: app_domain, device_id
encoder=ce.
  ↪OneHotEncoder(cols=['app_domain','device_id'],handle_unknown='return_nan',return_df=True,us
one_hot_encoder = encoder.fit(train_3)
```

```
[ ]: train_3 = one_hot_encoder.transform(train_3)
```

```
[ ]: test = one_hot_encoder.transform(test)
```

Base 5

```
[ ]: # base 5 encoding: site_id, site_domain, app_id, C14, C17, C19, C20, C21
encoder1 = ce.
  ↪BaseNEncoder(cols=['site_id','site_domain','app_id','C14','C17','C19','C20','C21'],␣
  ↪return_df=True, base=5)
base_5_encoder = encoder1.fit(train_3)
```

```
[ ]: train_3 = base_5_encoder.transform(train_3)
```

```
[ ]: test = base_5_encoder.transform(test)
```

Base 10

```
[ ]: # base 10 encoding: site_category, app_category, device_model
encoder2 = ce.
  ↪BaseNEncoder(cols=['site_category','app_category','device_model'],␣
  ↪return_df=True, base=10)
base_10_encoder = encoder2.fit(train_3)
```

```
[ ]: train_3 = base_10_encoder.transform(train_3)
```

```
[ ]: test = base_10_encoder.transform(test)
```

2.4 Numerical Variables

- hour: detail shown below
- banner_pos: encoded by professor
- device_type: encoded by professor
- device_conn_type: encoded by professor

2.4.1 Hour

- Day: week number
- Hour:
  - 1: 00-06
  - 2: 07-12
  - 3: 13-18
  - 4: 19-24

```
[ ]: splitat = 6
train_3['day'], train_3['time'] = train_3['hour'].astype('str').str[:splitat],␣
  ↪train_3['hour'].astype('str').str[splitat:].astype('int')
```

```
[ ]: # time of day
def add_time_of_day(data):
    data['day'], data['time'] = data['hour'].astype('str').str[:splitat],␣
  ↪data['hour'].astype('str').str[splitat:].astype('int')
    conditions = [(data.time <=6),
                  (data.time > 6) & (data.time <= 12),
                  (data.time > 12) & (data.time <= 18),
                  (data.time >18)
                  ]
    values = [1, 2, 3, 4]
    data['time_of_day'] = np.select(conditions, values, 0)
```

```
[ ]: add_time_of_day(train_3)
add_time_of_day(test)
```

```
[ ]: train_3[['day','time','hour','time_of_day']].head(5)
```

[ ]:

	day	time	hour	time_of_day
5616589	141022	10	14102210	2
31825749	141029	22	14102922	4
13548281	141024	13	14102413	3
11682204	141023	22	14102322	4
29186795	141029	4	14102904	1

[ ]:
```
def add_day_of_week(data):
    data['day']= pd.to_datetime(data['day'],format="%y%m%d")
    data['day_of_week'] = data['day'].dt.dayofweek
```

[ ]:
```
add_day_of_week(train_3)
add_day_of_week(test)
```

2.5 Finalize the data

[ ]:
```
train_3.head()
```

[ ]:

	click	hour	C1	banner_pos	site_id_0	site_id_1	\
5616589	0	14102210	1005	1	0	1	
31825749	0	14102922	1005	0	0	2	
13548281	1	14102413	1005	0	0	1	
11682204	0	14102322	1005	0	0	2	
29186795	0	14102904	1005	0	0	1	

	site_domain_0	site_domain_1	site_category_0	site_category_1	…	\
5616589	0	1	0	1	…	
31825749	0	2	0	2	…	
13548281	0	1	0	1	…	
11682204	0	2	0	2	…	
29186795	0	1	0	3	…	

	C19_0	C19_1	C20_0	C20_1	C21_0	C21_1	day	time	\
5616589	0	1	0	1	0	1	2014-10-22	10	
31825749	0	2	0	2	0	2	2014-10-29	22	
13548281	0	2	0	2	0	3	2014-10-24	13	
11682204	0	1	0	3	0	4	2014-10-23	22	
29186795	0	3	0	3	0	3	2014-10-29	4	

	time_of_day	day_of_week
5616589	2	2
31825749	4	2
13548281	3	4
11682204	4	3
29186795	1	2

[5 rows x 42 columns]

[ ]:

[ ]:
```
x_col = ['C1', 'banner_pos', 'site_id_0', 'site_id_1',
       'site_domain_0', 'site_domain_1', 'site_category_0', 'site_category_1',
       'app_id_0', 'app_id_1', 'app_domain_7801e8d9', 'app_domain_ae637522',
       'app_domain_2347f47a', 'app_domain_other', 'app_category_0',
       'app_category_1', 'device_id_other', 'device_id_a99f214a',
       'device_id_c357dbff', 'device_model_0', 'device_model_1', 'device_type',␣
 ↪'device_conn_type',
       'C14_0', 'C14_1', 'C15', 'C16', 'C17_0', 'C17_1', 'C18', 'C19_0',
       'C19_1', 'C20_0', 'C20_1', 'C21_0', 'C21_1',
       'time_of_day', 'day_of_week']
y_col = 'click'
```

[ ]:
```
X_train3 = train_3[x_col]
y_train3 = train_3[y_col]
X_test = test[x_col]
y_pred_naive = test[y_col]
```

3 Model Training

[ ]:
```
# Split to Sub-train & Validation dataset
X_train, X_val, y_train, y_val = train_test_split(X_train3, y_train3,␣
 ↪test_size=0.2, random_state=42)
```

3.1 Logistic Regression

[ ]:
```
from sklearn.linear_model import LogisticRegression
```

[ ]:
```
lr = LogisticRegression(random_state=42, n_jobs=-1, penalty="l2").fit(X_train,␣
 ↪y_train)
```

```
/Users/rebecca/opt/anaconda3/lib/python3.9/site-
packages/sklearn/linear_model/_logistic.py:444: ConvergenceWarning: lbfgs failed
to converge (status=1):
STOP: TOTAL NO. of ITERATIONS REACHED LIMIT.

Increase the number of iterations (max_iter) or scale the data as shown in:
    https://scikit-learn.org/stable/modules/preprocessing.html
Please also refer to the documentation for alternative solver options:
    https://scikit-learn.org/stable/modules/linear_model.html#logistic-
regression
  n_iter_i = _check_optimize_result(
```

[ ]:
```
y_pred = lr.predict_proba(X_val)
```

[ ]:
```
# print log loss of the validation data
log_loss(y_val, y_pred)
```

[ ]:
```
0.4360344851617682
```

Since the log-loss is quite high, LR is not a great model to be chosen as a final step.

3.2 Random Forest

3.2.1 TuneGridsearchCV

[ ]:
```
from sklearn.ensemble import RandomForestClassifier
```

[ ]:
```
rfc=RandomForestClassifier(random_state=42)
```

Random Serach using random forest

[ ]:
```
rs_space={'max_depth':[20,30],
              'max_features':['sqrt', 'log2'],
              'min_samples_split':[50, 100]
         }
```

[ ]:
```
# param_grid = {
#     'n_estimators': [100, 200, 300, 400],
#     'max_features': ['sqrt', 'log2'],
#     'min_samples_split': [2, 10, 100],
#     'max_depth' : [10,20,30],
# }
# gs_rfc = GridSearchCV(estimator=rfc,
#     param_grid=param_grid,
#     cv=3,
#     scoring='neg_log_loss',
#     n_jobs=-1,
#     verbose = 3)
# gs_rfc.fit(X_train, y_train)
```

[ ]:
```
from tune_sklearn import TuneGridSearchCV
from sklearn.model_selection import RandomizedSearchCV
```

[ ]:
```
gs_rfc = TuneGridSearchCV(rfc, rs_space,
                                scoring='neg_log_loss',
                                n_jobs=-1,
                                cv=3,
                                max_iters=10,
                                early_stopping = True,
                                verbose=2)
```

[ ]:
```
gs_rfc.fit(X_train, y_train)
```

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

(raylet) Spilled 2460 MiB, 10 objects, write throughput 129 MiB/s.
Set RAY_verbose_spill_logs=0 to disable this message.

<IPython.core.display.HTML object>

2022-12-05 20:28:43,216 INFO tune.py:777 -- Total run time: 2454.85 seconds
(2454.71 seconds for the tuning loop).
```

```
[ ]: TuneGridSearchCV(cv=3, early_stopping=True,
                      estimator=RandomForestClassifier(random_state=42),
                      max_iters=10, mode='max', n_jobs=-1,
                      param_grid={'max_depth': [20, 30],
                                  'max_features': ['sqrt', 'log2'],
                                  'min_samples_split': [50, 100]},
                      scoring='neg_log_loss', sk_n_jobs=1, verbose=2)
```

```
[ ]: # rfc_random = RandomizedSearchCV(rfc, rs_space,
     #                                scoring='neg_log_loss',
     #                                n_jobs=-1,
     #                                cv=2,
     #                                n_iter=10,
     #                                verbose=30)
     # rfc_random.fit(X_train,y_train)
```

```
[ ]: print("Parameter: ", gs_rfc.best_params_)
     print("Non-nested LogLoss: ", gs_rfc.best_score_)
     print("Best Estimator: ", gs_rfc.best_estimator_)
```

```
Parameter:  {'max_depth': 20, 'max_features': 'sqrt', 'min_samples_split': 100,
'n_estimators': 10}
Non-nested LogLoss:  -0.40525057984573404
Best Estimator:  RandomForestClassifier(max_depth=20, min_samples_split=100,
n_estimators=10,
                       random_state=42)
```

```
[ ]: rf = RandomForestClassifier(n_estimators = 10,
                                random_state = 42,
                                min_samples_split=100,
                                max_depth=20,
                                n_jobs=-1)
```

```
[ ]: rf.fit(X_train, y_train)
```

```
[ ]: RandomForestClassifier(max_depth=20, min_samples_split=100, n_estimators=10,
                          n_jobs=-1, random_state=42)
```

[ ]:
```
y_pred_rf = rf.predict_proba(X_val)
log_loss(y_val, y_pred_rf)
```

[ ]:
```
0.4047542503530167
```

3.3 Neural Net

[ ]:
```
# initialize nn
nnc = Sequential()
# add input layer
nnc.add(Dense(10, kernel_regularizer = regularizers.l2(0.003),␣
 ↪kernel_initializer=initializers.RandomNormal(stddev=0.01),␣
 ↪activation='relu', input_shape = (X_train.shape[1],), use_bias=True))
nnc.add(Dropout(0.4))
# add hidden layer
nnc.add(Dense(10, kernel_regularizer = regularizers.l2(0.003),␣
 ↪kernel_initializer=initializers.RandomNormal(stddev=0.01),␣
 ↪activation='relu'))
nnc.add(Dropout(0.3))
nnc.add(Dense(units = 6, activation = 'sigmoid', use_bias = True))
# add output layer
nnc.add(Dense(1, activation = 'sigmoid', use_bias = True))
nnc.compile(optimizer = Adam(learning_rate=1e-3), loss = 'binary_crossentropy',␣
 ↪metrics = ['accuracy'])
```

```
2022-12-05 17:21:14.358862: I tensorflow/core/platform/cpu_feature_guard.cc:193]
This TensorFlow binary is optimized with oneAPI Deep Neural Network Library
(oneDNN) to use the following CPU instructions in performance-critical
operations:  SSE4.1 SSE4.2 AVX AVX2 FMA
To enable them in other operations, rebuild TensorFlow with the appropriate
compiler flags.
```

[ ]:
```
nnc.fit(X_train, y_train, epochs=10, batch_size = 512, validation_data =␣
 ↪(X_val, y_val))
```

```
Epoch 1/10
4374/4374 [==============================] - 8s 2ms/step - loss: 0.4494 -
accuracy: 0.8302 - val_loss: 0.4479 - val_accuracy: 0.8303
Epoch 2/10
4374/4374 [==============================] - 6s 1ms/step - loss: 0.4493 -
accuracy: 0.8302 - val_loss: 0.4478 - val_accuracy: 0.8303
Epoch 3/10
4374/4374 [==============================] - 6s 1ms/step - loss: 0.4493 -
accuracy: 0.8302 - val_loss: 0.4485 - val_accuracy: 0.8303
Epoch 4/10
4374/4374 [==============================] - 6s 1ms/step - loss: 0.4504 -
accuracy: 0.8302 - val_loss: 0.4483 - val_accuracy: 0.8303
```

```
Epoch 5/10
4374/4374 [==============================] - 6s 1ms/step - loss: 0.4516 -
accuracy: 0.8302 - val_loss: 0.4501 - val_accuracy: 0.8303
Epoch 6/10
4374/4374 [==============================] - 6s 1ms/step - loss: 0.4520 -
accuracy: 0.8302 - val_loss: 0.4498 - val_accuracy: 0.8303
Epoch 7/10
4374/4374 [==============================] - 6s 1ms/step - loss: 0.4532 -
accuracy: 0.8302 - val_loss: 0.4534 - val_accuracy: 0.8303
Epoch 8/10
4374/4374 [==============================] - 6s 1ms/step - loss: 0.4552 -
accuracy: 0.8302 - val_loss: 0.4555 - val_accuracy: 0.8303
Epoch 9/10
4374/4374 [==============================] - 6s 1ms/step - loss: 0.4555 -
accuracy: 0.8302 - val_loss: 0.4555 - val_accuracy: 0.8303
Epoch 10/10
4374/4374 [==============================] - 6s 1ms/step - loss: 0.4555 -
accuracy: 0.8302 - val_loss: 0.4555 - val_accuracy: 0.8303
```

[ ]:
```
<keras.callbacks.History at 0x7fc0a83c37c0>
```

[ ]:
```
y_pred_nn = nnc.predict(X_val)
log_loss(y_val, y_pred_nn)
```

```
29992/29992 [==============================] - 17s 570us/step
```

[ ]:
```
0.4554982736349612
```

3.4 LightGBM

[ ]:
```
lgb = LGBMClassifier(random_state=42)
```

[ ]:
```
lgb.fit(X_train,y_train,verbose=3,eval_metric='logloss')
```

[ ]:
```
LGBMClassifier(random_state=42)
```

[ ]:
```
parameters = {
    'learning_rate': [0.01,0.05,0.09,0.1],
    'num_leaves': [31,250,300],
}

gbm = LGBMClassifier(objective='binary',
                         n_jobs=-1,
                         metric = 'binary_logloss',
                         boosting_type='gbdt',
                         cat_smooth= 35)
```

```
gs_lgb = GridSearchCV(gbm, param_grid=parameters, scoring='neg_log_loss', cv=3,␣
 ↪verbose = 1)
```

[ ]:
```
gs_lgb.fit(X_train, y_train)
```

```
Fitting 3 folds for each of 12 candidates, totalling 36 fits
```

[ ]:
```
GridSearchCV(cv=3,
             estimator=LGBMClassifier(cat_smooth=35, metric='binary_logloss',
                                      objective='binary'),
             param_grid={'learning_rate': [0.01, 0.05, 0.09, 0.1],
                         'num_leaves': [31, 250, 300]},
             scoring='neg_log_loss', verbose=1)
```

[ ]:
```
print('best parameter:{0}'.format(gs_lgb.best_params_))
```

```
best parameter:{'learning_rate': 0.1, 'num_leaves': 300}
```

[ ]:
```
lgb = LGBMClassifier(learning_rate=0.1,num_leaves = 300,random_state=42, metric␣
 ↪= 'binary_logloss',cat_smooth= 35).\
   fit(X_train, y_train,eval_metric='logloss')
```

[ ]:
```
y_pred_lgb=lgb.predict_proba(X_val)[:, 1]
```

[ ]:
```
log_loss(y_val, y_pred_lgb)
```

[ ]:
```
0.40189174104048725
```

3.5 CatBoost

[ ]:
```
from catboost import CatBoostClassifier, Pool
```

[ ]:
```
ctb = CatBoostClassifier(random_seed=42)
```

[ ]:
```
ctb.fit(X_train, y_train)
```

```
Learning rate set to 0.277612
0:      learn: 0.5546360        total: 286ms    remaining: 4m 46s
1:      learn: 0.4901436        total: 466ms    remaining: 3m 52s
2:      learn: 0.4580588        total: 677ms    remaining: 3m 45s
3:      learn: 0.4419956        total: 875ms    remaining: 3m 37s
4:      learn: 0.4337565        total: 1.09s    remaining: 3m 37s
5:      learn: 0.4287606        total: 1.29s    remaining: 3m 34s
6:      learn: 0.4262102        total: 1.58s    remaining: 3m 44s
7:      learn: 0.4243884        total: 1.75s    remaining: 3m 37s
8:      learn: 0.4233272        total: 1.94s    remaining: 3m 33s
9:      learn: 0.4221519        total: 2.12s    remaining: 3m 30s
```

```
10:     learn: 0.4211780        total: 2.31s    remaining: 3m 28s
11:     learn: 0.4200521        total: 2.5s     remaining: 3m 25s
12:     learn: 0.4192943        total: 2.71s    remaining: 3m 25s
13:     learn: 0.4189905        total: 2.9s     remaining: 3m 24s
14:     learn: 0.4184677        total: 3.09s    remaining: 3m 23s
15:     learn: 0.4181608        total: 3.27s    remaining: 3m 20s
16:     learn: 0.4178235        total: 3.46s    remaining: 3m 20s
17:     learn: 0.4173590        total: 3.65s    remaining: 3m 19s
18:     learn: 0.4171426        total: 3.84s    remaining: 3m 18s
19:     learn: 0.4167615        total: 4.05s    remaining: 3m 18s
20:     learn: 0.4164154        total: 4.28s    remaining: 3m 19s
21:     learn: 0.4161804        total: 4.51s    remaining: 3m 20s
22:     learn: 0.4159316        total: 4.74s    remaining: 3m 21s
23:     learn: 0.4157913        total: 4.94s    remaining: 3m 21s
24:     learn: 0.4156897        total: 5.16s    remaining: 3m 21s
25:     learn: 0.4155136        total: 5.36s    remaining: 3m 20s
26:     learn: 0.4153259        total: 5.6s     remaining: 3m 21s
27:     learn: 0.4150533        total: 5.84s    remaining: 3m 22s
28:     learn: 0.4148490        total: 6.08s    remaining: 3m 23s
29:     learn: 0.4146303        total: 6.3s     remaining: 3m 23s
30:     learn: 0.4145423        total: 6.52s    remaining: 3m 23s
31:     learn: 0.4143679        total: 6.77s    remaining: 3m 24s
32:     learn: 0.4141760        total: 7.02s    remaining: 3m 25s
33:     learn: 0.4139500        total: 7.25s    remaining: 3m 26s
34:     learn: 0.4138078        total: 7.48s    remaining: 3m 26s
35:     learn: 0.4137127        total: 7.71s    remaining: 3m 26s
36:     learn: 0.4135380        total: 7.98s    remaining: 3m 27s
37:     learn: 0.4133628        total: 8.31s    remaining: 3m 30s
38:     learn: 0.4132991        total: 8.51s    remaining: 3m 29s
39:     learn: 0.4132065        total: 8.72s    remaining: 3m 29s
40:     learn: 0.4130997        total: 8.93s    remaining: 3m 28s
41:     learn: 0.4129088        total: 9.16s    remaining: 3m 28s
42:     learn: 0.4127877        total: 9.38s    remaining: 3m 28s
43:     learn: 0.4127018        total: 9.65s    remaining: 3m 29s
44:     learn: 0.4126035        total: 9.86s    remaining: 3m 29s
45:     learn: 0.4124666        total: 10.1s    remaining: 3m 28s
46:     learn: 0.4124038        total: 10.3s    remaining: 3m 28s
47:     learn: 0.4122297        total: 10.5s    remaining: 3m 28s
48:     learn: 0.4121711        total: 10.7s    remaining: 3m 28s
49:     learn: 0.4120944        total: 10.9s    remaining: 3m 27s
50:     learn: 0.4120003        total: 11.2s    remaining: 3m 28s
51:     learn: 0.4119157        total: 11.4s    remaining: 3m 28s
52:     learn: 0.4118710        total: 11.6s    remaining: 3m 27s
53:     learn: 0.4117106        total: 11.9s    remaining: 3m 27s
54:     learn: 0.4116283        total: 12.1s    remaining: 3m 28s
55:     learn: 0.4115617        total: 12.4s    remaining: 3m 28s
56:     learn: 0.4115376        total: 12.6s    remaining: 3m 28s
57:     learn: 0.4114261        total: 12.8s    remaining: 3m 28s
```

```
58:     learn: 0.4113178        total: 13.1s    remaining: 3m 28s
59:     learn: 0.4112835        total: 13.4s    remaining: 3m 29s
60:     learn: 0.4112375        total: 13.6s    remaining: 3m 29s
61:     learn: 0.4111765        total: 13.8s    remaining: 3m 29s
62:     learn: 0.4110480        total: 14.2s    remaining: 3m 30s
63:     learn: 0.4110022        total: 14.4s    remaining: 3m 31s
64:     learn: 0.4109316        total: 14.9s    remaining: 3m 33s
65:     learn: 0.4108577        total: 15.2s    remaining: 3m 34s
66:     learn: 0.4107676        total: 15.5s    remaining: 3m 35s
67:     learn: 0.4106700        total: 15.8s    remaining: 3m 36s
68:     learn: 0.4105561        total: 16.1s    remaining: 3m 37s
69:     learn: 0.4105163        total: 16.5s    remaining: 3m 38s
70:     learn: 0.4104150        total: 16.8s    remaining: 3m 40s
71:     learn: 0.4103828        total: 17.2s    remaining: 3m 41s
72:     learn: 0.4102453        total: 17.5s    remaining: 3m 42s
73:     learn: 0.4101556        total: 17.8s    remaining: 3m 43s
74:     learn: 0.4101179        total: 18.2s    remaining: 3m 44s
75:     learn: 0.4100612        total: 18.6s    remaining: 3m 45s
76:     learn: 0.4099731        total: 18.9s    remaining: 3m 46s
77:     learn: 0.4098977        total: 19.1s    remaining: 3m 46s
78:     learn: 0.4098373        total: 19.3s    remaining: 3m 45s
79:     learn: 0.4097720        total: 19.5s    remaining: 3m 44s
80:     learn: 0.4097240        total: 19.8s    remaining: 3m 44s
81:     learn: 0.4096137        total: 20s      remaining: 3m 43s
82:     learn: 0.4095649        total: 20.2s    remaining: 3m 42s
83:     learn: 0.4095271        total: 20.4s    remaining: 3m 42s
84:     learn: 0.4094921        total: 20.6s    remaining: 3m 41s
85:     learn: 0.4094402        total: 20.8s    remaining: 3m 40s
86:     learn: 0.4093803        total: 21s      remaining: 3m 40s
87:     learn: 0.4092884        total: 21.2s    remaining: 3m 39s
88:     learn: 0.4092372        total: 21.5s    remaining: 3m 39s
89:     learn: 0.4091567        total: 21.7s    remaining: 3m 39s
90:     learn: 0.4091229        total: 21.9s    remaining: 3m 38s
91:     learn: 0.4091006        total: 22.1s    remaining: 3m 37s
92:     learn: 0.4090737        total: 22.3s    remaining: 3m 37s
93:     learn: 0.4090340        total: 22.5s    remaining: 3m 36s
94:     learn: 0.4089990        total: 22.7s    remaining: 3m 35s
95:     learn: 0.4089723        total: 22.9s    remaining: 3m 35s
96:     learn: 0.4088957        total: 23.1s    remaining: 3m 35s
97:     learn: 0.4088538        total: 23.3s    remaining: 3m 34s
98:     learn: 0.4088058        total: 23.6s    remaining: 3m 34s
99:     learn: 0.4087818        total: 23.8s    remaining: 3m 34s
100:    learn: 0.4087388        total: 24s      remaining: 3m 33s
101:    learn: 0.4086906        total: 24.2s    remaining: 3m 33s
102:    learn: 0.4086492        total: 24.4s    remaining: 3m 32s
103:    learn: 0.4086265        total: 24.6s    remaining: 3m 32s
104:    learn: 0.4085876        total: 24.8s    remaining: 3m 31s
105:    learn: 0.4085429        total: 25s      remaining: 3m 31s
```

```
106:    learn: 0.4084917        total: 25.3s    remaining: 3m 30s
107:    learn: 0.4084537        total: 25.5s    remaining: 3m 30s
108:    learn: 0.4084092        total: 25.7s    remaining: 3m 29s
109:    learn: 0.4083451        total: 25.9s    remaining: 3m 29s
110:    learn: 0.4083154        total: 26.1s    remaining: 3m 29s
111:    learn: 0.4082757        total: 26.3s    remaining: 3m 28s
112:    learn: 0.4082531        total: 26.6s    remaining: 3m 28s
113:    learn: 0.4082184        total: 26.8s    remaining: 3m 28s
114:    learn: 0.4081724        total: 27s      remaining: 3m 27s
115:    learn: 0.4081503        total: 27.2s    remaining: 3m 27s
116:    learn: 0.4081357        total: 27.4s    remaining: 3m 26s
117:    learn: 0.4080655        total: 27.6s    remaining: 3m 26s
118:    learn: 0.4080417        total: 27.8s    remaining: 3m 26s
119:    learn: 0.4080179        total: 28s      remaining: 3m 25s
120:    learn: 0.4080007        total: 28.2s    remaining: 3m 25s
121:    learn: 0.4079785        total: 28.4s    remaining: 3m 24s
122:    learn: 0.4079478        total: 28.7s    remaining: 3m 24s
123:    learn: 0.4079144        total: 28.9s    remaining: 3m 23s
124:    learn: 0.4078750        total: 29.1s    remaining: 3m 23s
125:    learn: 0.4078398        total: 29.3s    remaining: 3m 23s
126:    learn: 0.4078000        total: 29.5s    remaining: 3m 22s
127:    learn: 0.4077733        total: 29.7s    remaining: 3m 22s
128:    learn: 0.4077444        total: 30s      remaining: 3m 22s
129:    learn: 0.4076883        total: 30.2s    remaining: 3m 22s
130:    learn: 0.4076662        total: 30.4s    remaining: 3m 21s
131:    learn: 0.4076328        total: 30.7s    remaining: 3m 21s
132:    learn: 0.4076176        total: 30.9s    remaining: 3m 21s
133:    learn: 0.4075565        total: 31.1s    remaining: 3m 21s
134:    learn: 0.4075280        total: 31.3s    remaining: 3m 20s
135:    learn: 0.4074894        total: 31.6s    remaining: 3m 21s
136:    learn: 0.4074472        total: 32s      remaining: 3m 21s
137:    learn: 0.4074319        total: 32.3s    remaining: 3m 21s
138:    learn: 0.4074043        total: 32.5s    remaining: 3m 21s
139:    learn: 0.4073753        total: 32.7s    remaining: 3m 20s
140:    learn: 0.4073439        total: 33s      remaining: 3m 20s
141:    learn: 0.4073318        total: 33.2s    remaining: 3m 20s
142:    learn: 0.4072999        total: 33.4s    remaining: 3m 20s
143:    learn: 0.4072732        total: 33.6s    remaining: 3m 19s
144:    learn: 0.4072630        total: 33.8s    remaining: 3m 19s
145:    learn: 0.4072472        total: 34s      remaining: 3m 19s
146:    learn: 0.4072141        total: 34.2s    remaining: 3m 18s
147:    learn: 0.4071776        total: 34.5s    remaining: 3m 18s
148:    learn: 0.4071652        total: 34.7s    remaining: 3m 18s
149:    learn: 0.4071312        total: 34.9s    remaining: 3m 17s
150:    learn: 0.4071084        total: 35.2s    remaining: 3m 17s
151:    learn: 0.4070794        total: 35.4s    remaining: 3m 17s
152:    learn: 0.4070640        total: 35.6s    remaining: 3m 17s
153:    learn: 0.4070345        total: 35.8s    remaining: 3m 16s
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154:    learn: 0.4069977        total: 36.1s    remaining: 3m 16s
155:    learn: 0.4069743        total: 36.3s    remaining: 3m 16s
156:    learn: 0.4069504        total: 36.5s    remaining: 3m 15s
157:    learn: 0.4069286        total: 36.7s    remaining: 3m 15s
158:    learn: 0.4068965        total: 36.9s    remaining: 3m 15s
159:    learn: 0.4068773        total: 37.2s    remaining: 3m 15s
160:    learn: 0.4068513        total: 37.4s    remaining: 3m 14s
161:    learn: 0.4068374        total: 37.6s    remaining: 3m 14s
162:    learn: 0.4068174        total: 37.8s    remaining: 3m 14s
163:    learn: 0.4068034        total: 38s      remaining: 3m 13s
164:    learn: 0.4067877        total: 38.2s    remaining: 3m 13s
165:    learn: 0.4067633        total: 38.4s    remaining: 3m 13s
166:    learn: 0.4067357        total: 38.6s    remaining: 3m 12s
167:    learn: 0.4067110        total: 38.9s    remaining: 3m 12s
168:    learn: 0.4066987        total: 39.1s    remaining: 3m 12s
169:    learn: 0.4066886        total: 39.3s    remaining: 3m 11s
170:    learn: 0.4066533        total: 39.5s    remaining: 3m 11s
171:    learn: 0.4066345        total: 39.8s    remaining: 3m 11s
172:    learn: 0.4066089        total: 40s      remaining: 3m 11s
173:    learn: 0.4065808        total: 40.2s    remaining: 3m 10s
174:    learn: 0.4065537        total: 40.4s    remaining: 3m 10s
175:    learn: 0.4065433        total: 40.6s    remaining: 3m 10s
176:    learn: 0.4065240        total: 40.9s    remaining: 3m 9s
177:    learn: 0.4064885        total: 41.1s    remaining: 3m 9s
178:    learn: 0.4064755        total: 41.3s    remaining: 3m 9s
179:    learn: 0.4064459        total: 41.5s    remaining: 3m 9s
180:    learn: 0.4064299        total: 41.7s    remaining: 3m 8s
181:    learn: 0.4064031        total: 42s      remaining: 3m 8s
182:    learn: 0.4063876        total: 42.2s    remaining: 3m 8s
183:    learn: 0.4063384        total: 42.4s    remaining: 3m 7s
184:    learn: 0.4063215        total: 42.6s    remaining: 3m 7s
185:    learn: 0.4062923        total: 42.8s    remaining: 3m 7s
186:    learn: 0.4062749        total: 43s      remaining: 3m 7s
187:    learn: 0.4062672        total: 43.2s    remaining: 3m 6s
188:    learn: 0.4062549        total: 43.5s    remaining: 3m 6s
189:    learn: 0.4062397        total: 43.7s    remaining: 3m 6s
190:    learn: 0.4062136        total: 43.9s    remaining: 3m 5s
191:    learn: 0.4062005        total: 44.1s    remaining: 3m 5s
192:    learn: 0.4061774        total: 44.3s    remaining: 3m 5s
193:    learn: 0.4061610        total: 44.6s    remaining: 3m 5s
194:    learn: 0.4061446        total: 44.8s    remaining: 3m 5s
195:    learn: 0.4061208        total: 45s      remaining: 3m 4s
196:    learn: 0.4060996        total: 45.3s    remaining: 3m 4s
197:    learn: 0.4060861        total: 45.5s    remaining: 3m 4s
198:    learn: 0.4060670        total: 45.7s    remaining: 3m 4s
199:    learn: 0.4060516        total: 45.9s    remaining: 3m 3s
200:    learn: 0.4060291        total: 46.2s    remaining: 3m 3s
201:    learn: 0.4060139        total: 46.4s    remaining: 3m 3s
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202:    learn: 0.4059953        total: 46.6s    remaining: 3m 2s
203:    learn: 0.4059759        total: 46.8s    remaining: 3m 2s
204:    learn: 0.4059664        total: 47s      remaining: 3m 2s
205:    learn: 0.4059429        total: 47.2s    remaining: 3m 2s
206:    learn: 0.4059226        total: 47.4s    remaining: 3m 1s
207:    learn: 0.4059115        total: 47.7s    remaining: 3m 1s
208:    learn: 0.4058949        total: 47.9s    remaining: 3m 1s
209:    learn: 0.4058798        total: 48.1s    remaining: 3m
210:    learn: 0.4058673        total: 48.3s    remaining: 3m
211:    learn: 0.4058561        total: 48.5s    remaining: 3m
212:    learn: 0.4058360        total: 48.8s    remaining: 3m
213:    learn: 0.4058271        total: 49s      remaining: 2m 59s
214:    learn: 0.4058121        total: 49.2s    remaining: 2m 59s
215:    learn: 0.4057984        total: 49.4s    remaining: 2m 59s
216:    learn: 0.4057882        total: 49.6s    remaining: 2m 58s
217:    learn: 0.4057719        total: 49.8s    remaining: 2m 58s
218:    learn: 0.4057617        total: 50s      remaining: 2m 58s
219:    learn: 0.4057519        total: 50.2s    remaining: 2m 58s
220:    learn: 0.4057273        total: 50.4s    remaining: 2m 57s
221:    learn: 0.4056960        total: 50.6s    remaining: 2m 57s
222:    learn: 0.4056795        total: 50.9s    remaining: 2m 57s
223:    learn: 0.4056680        total: 51.1s    remaining: 2m 56s
224:    learn: 0.4056563        total: 51.3s    remaining: 2m 56s
225:    learn: 0.4056457        total: 51.6s    remaining: 2m 56s
226:    learn: 0.4056328        total: 51.8s    remaining: 2m 56s
227:    learn: 0.4056212        total: 52s      remaining: 2m 55s
228:    learn: 0.4056033        total: 52.2s    remaining: 2m 55s
229:    learn: 0.4055903        total: 52.4s    remaining: 2m 55s
230:    learn: 0.4055802        total: 52.6s    remaining: 2m 55s
231:    learn: 0.4055721        total: 52.9s    remaining: 2m 54s
232:    learn: 0.4055312        total: 53.1s    remaining: 2m 54s
233:    learn: 0.4055076        total: 53.3s    remaining: 2m 54s
234:    learn: 0.4054938        total: 53.5s    remaining: 2m 54s
235:    learn: 0.4054813        total: 53.7s    remaining: 2m 53s
236:    learn: 0.4054677        total: 54s      remaining: 2m 53s
237:    learn: 0.4054590        total: 54.2s    remaining: 2m 53s
238:    learn: 0.4054464        total: 54.4s    remaining: 2m 53s
239:    learn: 0.4054315        total: 54.6s    remaining: 2m 53s
240:    learn: 0.4054149        total: 54.9s    remaining: 2m 52s
241:    learn: 0.4053760        total: 55.1s    remaining: 2m 52s
242:    learn: 0.4053650        total: 55.3s    remaining: 2m 52s
243:    learn: 0.4053556        total: 55.6s    remaining: 2m 52s
244:    learn: 0.4053454        total: 55.8s    remaining: 2m 51s
245:    learn: 0.4053390        total: 56s      remaining: 2m 51s
246:    learn: 0.4053257        total: 56.2s    remaining: 2m 51s
247:    learn: 0.4053130        total: 56.4s    remaining: 2m 51s
248:    learn: 0.4053038        total: 56.6s    remaining: 2m 50s
249:    learn: 0.4052820        total: 56.8s    remaining: 2m 50s
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250:    learn: 0.4052560        total: 57s      remaining: 2m 50s
251:    learn: 0.4052438        total: 57.3s    remaining: 2m 49s
252:    learn: 0.4052355        total: 57.5s    remaining: 2m 49s
253:    learn: 0.4052228        total: 57.7s    remaining: 2m 49s
254:    learn: 0.4051931        total: 57.9s    remaining: 2m 49s
255:    learn: 0.4051823        total: 58.1s    remaining: 2m 48s
256:    learn: 0.4051648        total: 58.3s    remaining: 2m 48s
257:    learn: 0.4051546        total: 58.5s    remaining: 2m 48s
258:    learn: 0.4051246        total: 58.8s    remaining: 2m 48s
259:    learn: 0.4051168        total: 59s      remaining: 2m 47s
260:    learn: 0.4051040        total: 59.2s    remaining: 2m 47s
261:    learn: 0.4050899        total: 59.4s    remaining: 2m 47s
262:    learn: 0.4050770        total: 59.6s    remaining: 2m 46s
263:    learn: 0.4050651        total: 59.8s    remaining: 2m 46s
264:    learn: 0.4050544        total: 60s      remaining: 2m 46s
265:    learn: 0.4050407        total: 1m       remaining: 2m 46s
266:    learn: 0.4050311        total: 1m       remaining: 2m 45s
267:    learn: 0.4050281        total: 1m       remaining: 2m 45s
268:    learn: 0.4050195        total: 1m       remaining: 2m 45s
269:    learn: 0.4050085        total: 1m 1s    remaining: 2m 45s
270:    learn: 0.4050033        total: 1m 1s    remaining: 2m 44s
271:    learn: 0.4049935        total: 1m 1s    remaining: 2m 44s
272:    learn: 0.4049822        total: 1m 1s    remaining: 2m 44s
273:    learn: 0.4049738        total: 1m 1s    remaining: 2m 44s
274:    learn: 0.4049665        total: 1m 2s    remaining: 2m 43s
275:    learn: 0.4049579        total: 1m 2s    remaining: 2m 43s
276:    learn: 0.4049482        total: 1m 2s    remaining: 2m 43s
277:    learn: 0.4049412        total: 1m 2s    remaining: 2m 43s
278:    learn: 0.4049282        total: 1m 2s    remaining: 2m 42s
279:    learn: 0.4049244        total: 1m 3s    remaining: 2m 42s
280:    learn: 0.4049184        total: 1m 3s    remaining: 2m 42s
281:    learn: 0.4049084        total: 1m 3s    remaining: 2m 41s
282:    learn: 0.4048928        total: 1m 3s    remaining: 2m 41s
283:    learn: 0.4048869        total: 1m 4s    remaining: 2m 41s
284:    learn: 0.4048683        total: 1m 4s    remaining: 2m 41s
285:    learn: 0.4048518        total: 1m 4s    remaining: 2m 41s
286:    learn: 0.4048329        total: 1m 4s    remaining: 2m 40s
287:    learn: 0.4048286        total: 1m 4s    remaining: 2m 40s
288:    learn: 0.4048170        total: 1m 5s    remaining: 2m 40s
289:    learn: 0.4048022        total: 1m 5s    remaining: 2m 40s
290:    learn: 0.4047942        total: 1m 5s    remaining: 2m 39s
291:    learn: 0.4047865        total: 1m 5s    remaining: 2m 39s
292:    learn: 0.4047767        total: 1m 5s    remaining: 2m 39s
293:    learn: 0.4047712        total: 1m 6s    remaining: 2m 38s
294:    learn: 0.4047599        total: 1m 6s    remaining: 2m 38s
295:    learn: 0.4047497        total: 1m 6s    remaining: 2m 38s
296:    learn: 0.4047346        total: 1m 6s    remaining: 2m 38s
297:    learn: 0.4047153        total: 1m 7s    remaining: 2m 37s
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298:    learn: 0.4047060        total: 1m 7s    remaining: 2m 37s
299:    learn: 0.4047011        total: 1m 7s    remaining: 2m 37s
300:    learn: 0.4046944        total: 1m 7s    remaining: 2m 37s
301:    learn: 0.4046841        total: 1m 7s    remaining: 2m 36s
302:    learn: 0.4046742        total: 1m 8s    remaining: 2m 36s
303:    learn: 0.4046664        total: 1m 8s    remaining: 2m 36s
304:    learn: 0.4046568        total: 1m 8s    remaining: 2m 36s
305:    learn: 0.4046493        total: 1m 8s    remaining: 2m 35s
306:    learn: 0.4046417        total: 1m 8s    remaining: 2m 35s
307:    learn: 0.4046333        total: 1m 9s    remaining: 2m 35s
308:    learn: 0.4046233        total: 1m 9s    remaining: 2m 35s
309:    learn: 0.4046101        total: 1m 9s    remaining: 2m 34s
310:    learn: 0.4045998        total: 1m 9s    remaining: 2m 34s
311:    learn: 0.4045916        total: 1m 10s   remaining: 2m 34s
312:    learn: 0.4045847        total: 1m 10s   remaining: 2m 34s
313:    learn: 0.4045777        total: 1m 10s   remaining: 2m 33s
314:    learn: 0.4045701        total: 1m 10s   remaining: 2m 33s
315:    learn: 0.4045600        total: 1m 10s   remaining: 2m 33s
316:    learn: 0.4045482        total: 1m 11s   remaining: 2m 33s
317:    learn: 0.4045382        total: 1m 11s   remaining: 2m 32s
318:    learn: 0.4045285        total: 1m 11s   remaining: 2m 32s
319:    learn: 0.4045192        total: 1m 11s   remaining: 2m 32s
320:    learn: 0.4045016        total: 1m 11s   remaining: 2m 32s
321:    learn: 0.4044942        total: 1m 12s   remaining: 2m 31s
322:    learn: 0.4044870        total: 1m 12s   remaining: 2m 31s
323:    learn: 0.4044795        total: 1m 12s   remaining: 2m 31s
324:    learn: 0.4044713        total: 1m 12s   remaining: 2m 31s
325:    learn: 0.4044562        total: 1m 12s   remaining: 2m 30s
326:    learn: 0.4044477        total: 1m 13s   remaining: 2m 30s
327:    learn: 0.4044398        total: 1m 13s   remaining: 2m 30s
328:    learn: 0.4044316        total: 1m 13s   remaining: 2m 30s
329:    learn: 0.4044225        total: 1m 13s   remaining: 2m 29s
330:    learn: 0.4044170        total: 1m 14s   remaining: 2m 29s
331:    learn: 0.4044082        total: 1m 14s   remaining: 2m 29s
332:    learn: 0.4043991        total: 1m 14s   remaining: 2m 29s
333:    learn: 0.4043951        total: 1m 14s   remaining: 2m 28s
334:    learn: 0.4043878        total: 1m 14s   remaining: 2m 28s
335:    learn: 0.4043777        total: 1m 15s   remaining: 2m 28s
336:    learn: 0.4043654        total: 1m 15s   remaining: 2m 28s
337:    learn: 0.4043588        total: 1m 15s   remaining: 2m 28s
338:    learn: 0.4043501        total: 1m 15s   remaining: 2m 27s
339:    learn: 0.4043456        total: 1m 16s   remaining: 2m 27s
340:    learn: 0.4043331        total: 1m 16s   remaining: 2m 27s
341:    learn: 0.4043244        total: 1m 16s   remaining: 2m 27s
342:    learn: 0.4043182        total: 1m 16s   remaining: 2m 26s
343:    learn: 0.4043133        total: 1m 16s   remaining: 2m 26s
344:    learn: 0.4043056        total: 1m 17s   remaining: 2m 26s
345:    learn: 0.4042980        total: 1m 17s   remaining: 2m 26s
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346:    learn: 0.4042896        total: 1m 17s   remaining: 2m 25s
347:    learn: 0.4042847        total: 1m 17s   remaining: 2m 25s
348:    learn: 0.4042792        total: 1m 17s   remaining: 2m 25s
349:    learn: 0.4042700        total: 1m 18s   remaining: 2m 25s
350:    learn: 0.4042587        total: 1m 18s   remaining: 2m 24s
351:    learn: 0.4042526        total: 1m 18s   remaining: 2m 24s
352:    learn: 0.4042446        total: 1m 18s   remaining: 2m 24s
353:    learn: 0.4042339        total: 1m 18s   remaining: 2m 24s
354:    learn: 0.4042270        total: 1m 19s   remaining: 2m 23s
355:    learn: 0.4042166        total: 1m 19s   remaining: 2m 23s
356:    learn: 0.4042099        total: 1m 19s   remaining: 2m 23s
357:    learn: 0.4042053        total: 1m 19s   remaining: 2m 23s
358:    learn: 0.4041939        total: 1m 20s   remaining: 2m 22s
359:    learn: 0.4041841        total: 1m 20s   remaining: 2m 22s
360:    learn: 0.4041781        total: 1m 20s   remaining: 2m 22s
361:    learn: 0.4041533        total: 1m 20s   remaining: 2m 22s
362:    learn: 0.4041413        total: 1m 20s   remaining: 2m 22s
363:    learn: 0.4041387        total: 1m 21s   remaining: 2m 21s
364:    learn: 0.4041178        total: 1m 21s   remaining: 2m 21s
365:    learn: 0.4041116        total: 1m 21s   remaining: 2m 21s
366:    learn: 0.4041036        total: 1m 21s   remaining: 2m 21s
367:    learn: 0.4040965        total: 1m 22s   remaining: 2m 20s
368:    learn: 0.4040894        total: 1m 22s   remaining: 2m 20s
369:    learn: 0.4040849        total: 1m 22s   remaining: 2m 20s
370:    learn: 0.4040799        total: 1m 22s   remaining: 2m 20s
371:    learn: 0.4040747        total: 1m 22s   remaining: 2m 19s
372:    learn: 0.4040620        total: 1m 23s   remaining: 2m 19s
373:    learn: 0.4040541        total: 1m 23s   remaining: 2m 19s
374:    learn: 0.4040487        total: 1m 23s   remaining: 2m 19s
375:    learn: 0.4040389        total: 1m 23s   remaining: 2m 19s
376:    learn: 0.4040325        total: 1m 24s   remaining: 2m 18s
377:    learn: 0.4040226        total: 1m 24s   remaining: 2m 18s
378:    learn: 0.4040149        total: 1m 24s   remaining: 2m 18s
379:    learn: 0.4040036        total: 1m 24s   remaining: 2m 18s
380:    learn: 0.4039975        total: 1m 24s   remaining: 2m 17s
381:    learn: 0.4039907        total: 1m 25s   remaining: 2m 17s
382:    learn: 0.4039751        total: 1m 25s   remaining: 2m 17s
383:    learn: 0.4039666        total: 1m 25s   remaining: 2m 17s
384:    learn: 0.4039637        total: 1m 25s   remaining: 2m 17s
385:    learn: 0.4039527        total: 1m 25s   remaining: 2m 16s
386:    learn: 0.4039453        total: 1m 26s   remaining: 2m 16s
387:    learn: 0.4039395        total: 1m 26s   remaining: 2m 16s
388:    learn: 0.4039329        total: 1m 26s   remaining: 2m 16s
389:    learn: 0.4039139        total: 1m 26s   remaining: 2m 15s
390:    learn: 0.4039024        total: 1m 27s   remaining: 2m 15s
391:    learn: 0.4038922        total: 1m 27s   remaining: 2m 15s
392:    learn: 0.4038837        total: 1m 27s   remaining: 2m 15s
393:    learn: 0.4038770        total: 1m 27s   remaining: 2m 14s
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394:    learn: 0.4038738        total: 1m 27s   remaining: 2m 14s
395:    learn: 0.4038686        total: 1m 28s   remaining: 2m 14s
396:    learn: 0.4038600        total: 1m 28s   remaining: 2m 14s
397:    learn: 0.4038522        total: 1m 28s   remaining: 2m 14s
398:    learn: 0.4038489        total: 1m 28s   remaining: 2m 13s
399:    learn: 0.4038430        total: 1m 29s   remaining: 2m 13s
400:    learn: 0.4038402        total: 1m 29s   remaining: 2m 13s
401:    learn: 0.4038236        total: 1m 29s   remaining: 2m 13s
402:    learn: 0.4038122        total: 1m 29s   remaining: 2m 12s
403:    learn: 0.4038069        total: 1m 29s   remaining: 2m 12s
404:    learn: 0.4037984        total: 1m 30s   remaining: 2m 12s
405:    learn: 0.4037915        total: 1m 30s   remaining: 2m 12s
406:    learn: 0.4037868        total: 1m 30s   remaining: 2m 11s
407:    learn: 0.4037812        total: 1m 30s   remaining: 2m 11s
408:    learn: 0.4037663        total: 1m 30s   remaining: 2m 11s
409:    learn: 0.4037614        total: 1m 31s   remaining: 2m 11s
410:    learn: 0.4037561        total: 1m 31s   remaining: 2m 10s
411:    learn: 0.4037523        total: 1m 31s   remaining: 2m 10s
412:    learn: 0.4037438        total: 1m 31s   remaining: 2m 10s
413:    learn: 0.4037360        total: 1m 32s   remaining: 2m 10s
414:    learn: 0.4037307        total: 1m 32s   remaining: 2m 10s
415:    learn: 0.4037230        total: 1m 32s   remaining: 2m 9s
416:    learn: 0.4037179        total: 1m 32s   remaining: 2m 9s
417:    learn: 0.4037112        total: 1m 32s   remaining: 2m 9s
418:    learn: 0.4037058        total: 1m 33s   remaining: 2m 9s
419:    learn: 0.4036983        total: 1m 33s   remaining: 2m 9s
420:    learn: 0.4036899        total: 1m 33s   remaining: 2m 9s
421:    learn: 0.4036855        total: 1m 34s   remaining: 2m 8s
422:    learn: 0.4036775        total: 1m 34s   remaining: 2m 8s
423:    learn: 0.4036693        total: 1m 34s   remaining: 2m 8s
424:    learn: 0.4036594        total: 1m 34s   remaining: 2m 8s
425:    learn: 0.4036503        total: 1m 35s   remaining: 2m 8s
426:    learn: 0.4036436        total: 1m 35s   remaining: 2m 7s
427:    learn: 0.4036339        total: 1m 35s   remaining: 2m 7s
428:    learn: 0.4036271        total: 1m 35s   remaining: 2m 7s
429:    learn: 0.4036212        total: 1m 36s   remaining: 2m 7s
430:    learn: 0.4036081        total: 1m 36s   remaining: 2m 7s
431:    learn: 0.4035991        total: 1m 36s   remaining: 2m 6s
432:    learn: 0.4035927        total: 1m 36s   remaining: 2m 6s
433:    learn: 0.4035819        total: 1m 36s   remaining: 2m 6s
434:    learn: 0.4035750        total: 1m 37s   remaining: 2m 6s
435:    learn: 0.4035671        total: 1m 37s   remaining: 2m 5s
436:    learn: 0.4035594        total: 1m 37s   remaining: 2m 5s
437:    learn: 0.4035505        total: 1m 37s   remaining: 2m 5s
438:    learn: 0.4035362        total: 1m 37s   remaining: 2m 5s
439:    learn: 0.4035278        total: 1m 38s   remaining: 2m 4s
440:    learn: 0.4035191        total: 1m 38s   remaining: 2m 4s
441:    learn: 0.4035073        total: 1m 38s   remaining: 2m 4s
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442:    learn: 0.4034928        total: 1m 38s   remaining: 2m 4s
443:    learn: 0.4034908        total: 1m 39s   remaining: 2m 4s
444:    learn: 0.4034849        total: 1m 39s   remaining: 2m 3s
445:    learn: 0.4034825        total: 1m 39s   remaining: 2m 3s
446:    learn: 0.4034709        total: 1m 39s   remaining: 2m 3s
447:    learn: 0.4034659        total: 1m 39s   remaining: 2m 3s
448:    learn: 0.4034608        total: 1m 40s   remaining: 2m 2s
449:    learn: 0.4034547        total: 1m 40s   remaining: 2m 2s
450:    learn: 0.4034493        total: 1m 40s   remaining: 2m 2s
451:    learn: 0.4034411        total: 1m 40s   remaining: 2m 2s
452:    learn: 0.4034367        total: 1m 40s   remaining: 2m 1s
453:    learn: 0.4034324        total: 1m 41s   remaining: 2m 1s
454:    learn: 0.4034201        total: 1m 41s   remaining: 2m 1s
455:    learn: 0.4034119        total: 1m 41s   remaining: 2m 1s
456:    learn: 0.4034057        total: 1m 41s   remaining: 2m
457:    learn: 0.4034007        total: 1m 42s   remaining: 2m
458:    learn: 0.4033971        total: 1m 42s   remaining: 2m
459:    learn: 0.4033943        total: 1m 42s   remaining: 2m
460:    learn: 0.4033897        total: 1m 42s   remaining: 2m
461:    learn: 0.4033815        total: 1m 42s   remaining: 1m 59s
462:    learn: 0.4033740        total: 1m 43s   remaining: 1m 59s
463:    learn: 0.4033700        total: 1m 43s   remaining: 1m 59s
464:    learn: 0.4033637        total: 1m 43s   remaining: 1m 59s
465:    learn: 0.4033566        total: 1m 43s   remaining: 1m 58s
466:    learn: 0.4033492        total: 1m 43s   remaining: 1m 58s
467:    learn: 0.4033378        total: 1m 44s   remaining: 1m 58s
468:    learn: 0.4033315        total: 1m 44s   remaining: 1m 58s
469:    learn: 0.4033267        total: 1m 44s   remaining: 1m 57s
470:    learn: 0.4033203        total: 1m 44s   remaining: 1m 57s
471:    learn: 0.4033163        total: 1m 45s   remaining: 1m 57s
472:    learn: 0.4033119        total: 1m 45s   remaining: 1m 57s
473:    learn: 0.4033059        total: 1m 45s   remaining: 1m 56s
474:    learn: 0.4032999        total: 1m 45s   remaining: 1m 56s
475:    learn: 0.4032937        total: 1m 45s   remaining: 1m 56s
476:    learn: 0.4032887        total: 1m 46s   remaining: 1m 56s
477:    learn: 0.4032820        total: 1m 46s   remaining: 1m 56s
478:    learn: 0.4032790        total: 1m 46s   remaining: 1m 55s
479:    learn: 0.4032735        total: 1m 46s   remaining: 1m 55s
480:    learn: 0.4032705        total: 1m 46s   remaining: 1m 55s
481:    learn: 0.4032659        total: 1m 47s   remaining: 1m 55s
482:    learn: 0.4032555        total: 1m 47s   remaining: 1m 54s
483:    learn: 0.4032477        total: 1m 47s   remaining: 1m 54s
484:    learn: 0.4032417        total: 1m 47s   remaining: 1m 54s
485:    learn: 0.4032333        total: 1m 48s   remaining: 1m 54s
486:    learn: 0.4032280        total: 1m 48s   remaining: 1m 54s
487:    learn: 0.4032244        total: 1m 48s   remaining: 1m 53s
488:    learn: 0.4032136        total: 1m 48s   remaining: 1m 53s
489:    learn: 0.4032055        total: 1m 48s   remaining: 1m 53s
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490:    learn: 0.4031998        total: 1m 49s   remaining: 1m 53s
491:    learn: 0.4031979        total: 1m 49s   remaining: 1m 52s
492:    learn: 0.4031886        total: 1m 49s   remaining: 1m 52s
493:    learn: 0.4031808        total: 1m 49s   remaining: 1m 52s
494:    learn: 0.4031771        total: 1m 50s   remaining: 1m 52s
495:    learn: 0.4031680        total: 1m 50s   remaining: 1m 52s
496:    learn: 0.4031602        total: 1m 50s   remaining: 1m 51s
497:    learn: 0.4031575        total: 1m 50s   remaining: 1m 51s
498:    learn: 0.4031538        total: 1m 50s   remaining: 1m 51s
499:    learn: 0.4031491        total: 1m 51s   remaining: 1m 51s
500:    learn: 0.4031455        total: 1m 51s   remaining: 1m 50s
501:    learn: 0.4031383        total: 1m 51s   remaining: 1m 50s
502:    learn: 0.4031360        total: 1m 51s   remaining: 1m 50s
503:    learn: 0.4031290        total: 1m 51s   remaining: 1m 50s
504:    learn: 0.4031216        total: 1m 52s   remaining: 1m 49s
505:    learn: 0.4031173        total: 1m 52s   remaining: 1m 49s
506:    learn: 0.4031090        total: 1m 52s   remaining: 1m 49s
507:    learn: 0.4031009        total: 1m 52s   remaining: 1m 49s
508:    learn: 0.4030906        total: 1m 53s   remaining: 1m 49s
509:    learn: 0.4030846        total: 1m 53s   remaining: 1m 48s
510:    learn: 0.4030787        total: 1m 53s   remaining: 1m 48s
511:    learn: 0.4030740        total: 1m 53s   remaining: 1m 48s
512:    learn: 0.4030682        total: 1m 53s   remaining: 1m 48s
513:    learn: 0.4030635        total: 1m 54s   remaining: 1m 47s
514:    learn: 0.4030552        total: 1m 54s   remaining: 1m 47s
515:    learn: 0.4030497        total: 1m 54s   remaining: 1m 47s
516:    learn: 0.4030449        total: 1m 54s   remaining: 1m 47s
517:    learn: 0.4030383        total: 1m 54s   remaining: 1m 46s
518:    learn: 0.4030321        total: 1m 55s   remaining: 1m 46s
519:    learn: 0.4030269        total: 1m 55s   remaining: 1m 46s
520:    learn: 0.4030122        total: 1m 55s   remaining: 1m 46s
521:    learn: 0.4030080        total: 1m 55s   remaining: 1m 46s
522:    learn: 0.4030037        total: 1m 56s   remaining: 1m 45s
523:    learn: 0.4029985        total: 1m 56s   remaining: 1m 45s
524:    learn: 0.4029909        total: 1m 56s   remaining: 1m 45s
525:    learn: 0.4029862        total: 1m 56s   remaining: 1m 45s
526:    learn: 0.4029821        total: 1m 56s   remaining: 1m 44s
527:    learn: 0.4029769        total: 1m 57s   remaining: 1m 44s
528:    learn: 0.4029694        total: 1m 57s   remaining: 1m 44s
529:    learn: 0.4029649        total: 1m 57s   remaining: 1m 44s
530:    learn: 0.4029612        total: 1m 57s   remaining: 1m 44s
531:    learn: 0.4029518        total: 1m 57s   remaining: 1m 43s
532:    learn: 0.4029481        total: 1m 58s   remaining: 1m 43s
533:    learn: 0.4029448        total: 1m 58s   remaining: 1m 43s
534:    learn: 0.4029389        total: 1m 58s   remaining: 1m 43s
535:    learn: 0.4029338        total: 1m 58s   remaining: 1m 42s
536:    learn: 0.4029284        total: 1m 59s   remaining: 1m 42s
537:    learn: 0.4029233        total: 1m 59s   remaining: 1m 42s
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538:    learn: 0.4029179        total: 1m 59s   remaining: 1m 42s
539:    learn: 0.4029124        total: 1m 59s   remaining: 1m 41s
540:    learn: 0.4029079        total: 1m 59s   remaining: 1m 41s
541:    learn: 0.4029042        total: 2m       remaining: 1m 41s
542:    learn: 0.4029000        total: 2m       remaining: 1m 41s
543:    learn: 0.4028950        total: 2m       remaining: 1m 41s
544:    learn: 0.4028910        total: 2m       remaining: 1m 40s
545:    learn: 0.4028850        total: 2m 1s    remaining: 1m 40s
546:    learn: 0.4028800        total: 2m 1s    remaining: 1m 40s
547:    learn: 0.4028706        total: 2m 1s    remaining: 1m 40s
548:    learn: 0.4028653        total: 2m 1s    remaining: 1m 40s
549:    learn: 0.4028552        total: 2m 2s    remaining: 1m 39s
550:    learn: 0.4028488        total: 2m 2s    remaining: 1m 39s
551:    learn: 0.4028436        total: 2m 2s    remaining: 1m 39s
552:    learn: 0.4028375        total: 2m 2s    remaining: 1m 39s
553:    learn: 0.4028321        total: 2m 2s    remaining: 1m 38s
554:    learn: 0.4028267        total: 2m 3s    remaining: 1m 38s
555:    learn: 0.4028197        total: 2m 3s    remaining: 1m 38s
556:    learn: 0.4028123        total: 2m 3s    remaining: 1m 38s
557:    learn: 0.4028078        total: 2m 3s    remaining: 1m 38s
558:    learn: 0.4028030        total: 2m 3s    remaining: 1m 37s
559:    learn: 0.4027996        total: 2m 4s    remaining: 1m 37s
560:    learn: 0.4027905        total: 2m 4s    remaining: 1m 37s
561:    learn: 0.4027852        total: 2m 4s    remaining: 1m 37s
562:    learn: 0.4027780        total: 2m 4s    remaining: 1m 36s
563:    learn: 0.4027714        total: 2m 5s    remaining: 1m 36s
564:    learn: 0.4027650        total: 2m 5s    remaining: 1m 36s
565:    learn: 0.4027556        total: 2m 5s    remaining: 1m 36s
566:    learn: 0.4027503        total: 2m 5s    remaining: 1m 36s
567:    learn: 0.4027432        total: 2m 6s    remaining: 1m 35s
568:    learn: 0.4027354        total: 2m 6s    remaining: 1m 35s
569:    learn: 0.4027322        total: 2m 6s    remaining: 1m 35s
570:    learn: 0.4027298        total: 2m 6s    remaining: 1m 35s
571:    learn: 0.4027265        total: 2m 6s    remaining: 1m 34s
572:    learn: 0.4027239        total: 2m 7s    remaining: 1m 34s
573:    learn: 0.4027158        total: 2m 7s    remaining: 1m 34s
574:    learn: 0.4027115        total: 2m 7s    remaining: 1m 34s
575:    learn: 0.4027060        total: 2m 7s    remaining: 1m 34s
576:    learn: 0.4027023        total: 2m 7s    remaining: 1m 33s
577:    learn: 0.4026939        total: 2m 8s    remaining: 1m 33s
578:    learn: 0.4026832        total: 2m 8s    remaining: 1m 33s
579:    learn: 0.4026789        total: 2m 8s    remaining: 1m 33s
580:    learn: 0.4026739        total: 2m 8s    remaining: 1m 32s
581:    learn: 0.4026658        total: 2m 9s    remaining: 1m 32s
582:    learn: 0.4026614        total: 2m 9s    remaining: 1m 32s
583:    learn: 0.4026569        total: 2m 9s    remaining: 1m 32s
584:    learn: 0.4026536        total: 2m 9s    remaining: 1m 32s
585:    learn: 0.4026498        total: 2m 9s    remaining: 1m 31s
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586:    learn: 0.4026459        total: 2m 10s   remaining: 1m 31s
587:    learn: 0.4026422        total: 2m 10s   remaining: 1m 31s
588:    learn: 0.4026398        total: 2m 10s   remaining: 1m 31s
589:    learn: 0.4026385        total: 2m 10s   remaining: 1m 30s
590:    learn: 0.4026339        total: 2m 10s   remaining: 1m 30s
591:    learn: 0.4026287        total: 2m 11s   remaining: 1m 30s
592:    learn: 0.4026234        total: 2m 11s   remaining: 1m 30s
593:    learn: 0.4026174        total: 2m 11s   remaining: 1m 29s
594:    learn: 0.4026088        total: 2m 11s   remaining: 1m 29s
595:    learn: 0.4026010        total: 2m 12s   remaining: 1m 29s
596:    learn: 0.4025992        total: 2m 12s   remaining: 1m 29s
597:    learn: 0.4025964        total: 2m 12s   remaining: 1m 29s
598:    learn: 0.4025917        total: 2m 12s   remaining: 1m 28s
599:    learn: 0.4025833        total: 2m 12s   remaining: 1m 28s
600:    learn: 0.4025678        total: 2m 13s   remaining: 1m 28s
601:    learn: 0.4025607        total: 2m 13s   remaining: 1m 28s
602:    learn: 0.4025555        total: 2m 13s   remaining: 1m 27s
603:    learn: 0.4025469        total: 2m 13s   remaining: 1m 27s
604:    learn: 0.4025411        total: 2m 13s   remaining: 1m 27s
605:    learn: 0.4025354        total: 2m 14s   remaining: 1m 27s
606:    learn: 0.4025300        total: 2m 14s   remaining: 1m 27s
607:    learn: 0.4025222        total: 2m 14s   remaining: 1m 26s
608:    learn: 0.4025186        total: 2m 14s   remaining: 1m 26s
609:    learn: 0.4025103        total: 2m 15s   remaining: 1m 26s
610:    learn: 0.4025074        total: 2m 15s   remaining: 1m 26s
611:    learn: 0.4024992        total: 2m 15s   remaining: 1m 25s
612:    learn: 0.4024919        total: 2m 15s   remaining: 1m 25s
613:    learn: 0.4024857        total: 2m 15s   remaining: 1m 25s
614:    learn: 0.4024817        total: 2m 16s   remaining: 1m 25s
615:    learn: 0.4024690        total: 2m 16s   remaining: 1m 25s
616:    learn: 0.4024657        total: 2m 16s   remaining: 1m 24s
617:    learn: 0.4024609        total: 2m 16s   remaining: 1m 24s
618:    learn: 0.4024567        total: 2m 17s   remaining: 1m 24s
619:    learn: 0.4024507        total: 2m 17s   remaining: 1m 24s
620:    learn: 0.4024448        total: 2m 17s   remaining: 1m 23s
621:    learn: 0.4024375        total: 2m 17s   remaining: 1m 23s
622:    learn: 0.4024319        total: 2m 17s   remaining: 1m 23s
623:    learn: 0.4024246        total: 2m 18s   remaining: 1m 23s
624:    learn: 0.4024197        total: 2m 18s   remaining: 1m 23s
625:    learn: 0.4024156        total: 2m 18s   remaining: 1m 22s
626:    learn: 0.4024014        total: 2m 18s   remaining: 1m 22s
627:    learn: 0.4023957        total: 2m 19s   remaining: 1m 22s
628:    learn: 0.4023900        total: 2m 19s   remaining: 1m 22s
629:    learn: 0.4023866        total: 2m 19s   remaining: 1m 21s
630:    learn: 0.4023829        total: 2m 19s   remaining: 1m 21s
631:    learn: 0.4023789        total: 2m 19s   remaining: 1m 21s
632:    learn: 0.4023748        total: 2m 20s   remaining: 1m 21s
633:    learn: 0.4023691        total: 2m 20s   remaining: 1m 21s
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634:    learn: 0.4023654        total: 2m 20s   remaining: 1m 20s
635:    learn: 0.4023537        total: 2m 20s   remaining: 1m 20s
636:    learn: 0.4023527        total: 2m 21s   remaining: 1m 20s
637:    learn: 0.4023477        total: 2m 21s   remaining: 1m 20s
638:    learn: 0.4023416        total: 2m 21s   remaining: 1m 19s
639:    learn: 0.4023368        total: 2m 21s   remaining: 1m 19s
640:    learn: 0.4023307        total: 2m 21s   remaining: 1m 19s
641:    learn: 0.4023279        total: 2m 22s   remaining: 1m 19s
642:    learn: 0.4023220        total: 2m 22s   remaining: 1m 19s
643:    learn: 0.4023163        total: 2m 22s   remaining: 1m 18s
644:    learn: 0.4023124        total: 2m 22s   remaining: 1m 18s
645:    learn: 0.4023072        total: 2m 22s   remaining: 1m 18s
646:    learn: 0.4023025        total: 2m 23s   remaining: 1m 18s
647:    learn: 0.4022968        total: 2m 23s   remaining: 1m 17s
648:    learn: 0.4022916        total: 2m 23s   remaining: 1m 17s
649:    learn: 0.4022886        total: 2m 23s   remaining: 1m 17s
650:    learn: 0.4022810        total: 2m 24s   remaining: 1m 17s
651:    learn: 0.4022769        total: 2m 24s   remaining: 1m 17s
652:    learn: 0.4022710        total: 2m 24s   remaining: 1m 16s
653:    learn: 0.4022655        total: 2m 24s   remaining: 1m 16s
654:    learn: 0.4022588        total: 2m 24s   remaining: 1m 16s
655:    learn: 0.4022559        total: 2m 25s   remaining: 1m 16s
656:    learn: 0.4022499        total: 2m 25s   remaining: 1m 15s
657:    learn: 0.4022455        total: 2m 25s   remaining: 1m 15s
658:    learn: 0.4022432        total: 2m 25s   remaining: 1m 15s
659:    learn: 0.4022402        total: 2m 25s   remaining: 1m 15s
660:    learn: 0.4022363        total: 2m 26s   remaining: 1m 14s
661:    learn: 0.4022313        total: 2m 26s   remaining: 1m 14s
662:    learn: 0.4022284        total: 2m 26s   remaining: 1m 14s
663:    learn: 0.4022242        total: 2m 26s   remaining: 1m 14s
664:    learn: 0.4022204        total: 2m 27s   remaining: 1m 14s
665:    learn: 0.4022142        total: 2m 27s   remaining: 1m 13s
666:    learn: 0.4022075        total: 2m 27s   remaining: 1m 13s
667:    learn: 0.4022011        total: 2m 27s   remaining: 1m 13s
668:    learn: 0.4021965        total: 2m 27s   remaining: 1m 13s
669:    learn: 0.4021950        total: 2m 28s   remaining: 1m 12s
670:    learn: 0.4021920        total: 2m 28s   remaining: 1m 12s
671:    learn: 0.4021856        total: 2m 28s   remaining: 1m 12s
672:    learn: 0.4021782        total: 2m 28s   remaining: 1m 12s
673:    learn: 0.4021734        total: 2m 28s   remaining: 1m 12s
674:    learn: 0.4021722        total: 2m 29s   remaining: 1m 11s
675:    learn: 0.4021692        total: 2m 29s   remaining: 1m 11s
676:    learn: 0.4021640        total: 2m 29s   remaining: 1m 11s
677:    learn: 0.4021611        total: 2m 29s   remaining: 1m 11s
678:    learn: 0.4021553        total: 2m 30s   remaining: 1m 10s
679:    learn: 0.4021496        total: 2m 30s   remaining: 1m 10s
680:    learn: 0.4021425        total: 2m 30s   remaining: 1m 10s
681:    learn: 0.4021355        total: 2m 30s   remaining: 1m 10s
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682:    learn: 0.4021307        total: 2m 30s   remaining: 1m 10s
683:    learn: 0.4021251        total: 2m 31s   remaining: 1m 9s
684:    learn: 0.4021213        total: 2m 31s   remaining: 1m 9s
685:    learn: 0.4021174        total: 2m 31s   remaining: 1m 9s
686:    learn: 0.4021132        total: 2m 31s   remaining: 1m 9s
687:    learn: 0.4021068        total: 2m 31s   remaining: 1m 8s
688:    learn: 0.4021040        total: 2m 32s   remaining: 1m 8s
689:    learn: 0.4020947        total: 2m 32s   remaining: 1m 8s
690:    learn: 0.4020900        total: 2m 32s   remaining: 1m 8s
691:    learn: 0.4020852        total: 2m 32s   remaining: 1m 8s
692:    learn: 0.4020796        total: 2m 33s   remaining: 1m 7s
693:    learn: 0.4020768        total: 2m 33s   remaining: 1m 7s
694:    learn: 0.4020718        total: 2m 33s   remaining: 1m 7s
695:    learn: 0.4020690        total: 2m 33s   remaining: 1m 7s
696:    learn: 0.4020645        total: 2m 33s   remaining: 1m 6s
697:    learn: 0.4020590        total: 2m 34s   remaining: 1m 6s
698:    learn: 0.4020456        total: 2m 34s   remaining: 1m 6s
699:    learn: 0.4020410        total: 2m 34s   remaining: 1m 6s
700:    learn: 0.4020380        total: 2m 34s   remaining: 1m 6s
701:    learn: 0.4020311        total: 2m 35s   remaining: 1m 5s
702:    learn: 0.4020263        total: 2m 35s   remaining: 1m 5s
703:    learn: 0.4020234        total: 2m 35s   remaining: 1m 5s
704:    learn: 0.4020158        total: 2m 35s   remaining: 1m 5s
705:    learn: 0.4020080        total: 2m 35s   remaining: 1m 4s
706:    learn: 0.4020018        total: 2m 36s   remaining: 1m 4s
707:    learn: 0.4019939        total: 2m 36s   remaining: 1m 4s
708:    learn: 0.4019894        total: 2m 36s   remaining: 1m 4s
709:    learn: 0.4019869        total: 2m 36s   remaining: 1m 4s
710:    learn: 0.4019819        total: 2m 37s   remaining: 1m 3s
711:    learn: 0.4019770        total: 2m 37s   remaining: 1m 3s
712:    learn: 0.4019721        total: 2m 37s   remaining: 1m 3s
713:    learn: 0.4019647        total: 2m 37s   remaining: 1m 3s
714:    learn: 0.4019566        total: 2m 37s   remaining: 1m 2s
715:    learn: 0.4019520        total: 2m 38s   remaining: 1m 2s
716:    learn: 0.4019477        total: 2m 38s   remaining: 1m 2s
717:    learn: 0.4019418        total: 2m 38s   remaining: 1m 2s
718:    learn: 0.4019384        total: 2m 38s   remaining: 1m 2s
719:    learn: 0.4019311        total: 2m 39s   remaining: 1m 1s
720:    learn: 0.4019257        total: 2m 39s   remaining: 1m 1s
721:    learn: 0.4019202        total: 2m 39s   remaining: 1m 1s
722:    learn: 0.4019164        total: 2m 39s   remaining: 1m 1s
723:    learn: 0.4019100        total: 2m 39s   remaining: 1m
724:    learn: 0.4019044        total: 2m 40s   remaining: 1m
725:    learn: 0.4019015        total: 2m 40s   remaining: 1m
726:    learn: 0.4018971        total: 2m 40s   remaining: 1m
727:    learn: 0.4018935        total: 2m 40s   remaining: 1m
728:    learn: 0.4018887        total: 2m 40s   remaining: 59.8s
729:    learn: 0.4018851        total: 2m 41s   remaining: 59.6s
```

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730:    learn: 0.4018792        total: 2m 41s   remaining: 59.4s
731:    learn: 0.4018761        total: 2m 41s   remaining: 59.2s
732:    learn: 0.4018729        total: 2m 41s   remaining: 59s
733:    learn: 0.4018677        total: 2m 42s   remaining: 58.7s
734:    learn: 0.4018572        total: 2m 42s   remaining: 58.5s
735:    learn: 0.4018527        total: 2m 42s   remaining: 58.3s
736:    learn: 0.4018468        total: 2m 42s   remaining: 58.1s
737:    learn: 0.4018422        total: 2m 42s   remaining: 57.9s
738:    learn: 0.4018386        total: 2m 43s   remaining: 57.6s
739:    learn: 0.4018359        total: 2m 43s   remaining: 57.4s
740:    learn: 0.4018319        total: 2m 43s   remaining: 57.2s
741:    learn: 0.4018288        total: 2m 43s   remaining: 57s
742:    learn: 0.4018234        total: 2m 44s   remaining: 56.7s
743:    learn: 0.4018181        total: 2m 44s   remaining: 56.5s
744:    learn: 0.4018149        total: 2m 44s   remaining: 56.3s
745:    learn: 0.4018088        total: 2m 44s   remaining: 56.1s
746:    learn: 0.4018040        total: 2m 44s   remaining: 55.9s
747:    learn: 0.4017997        total: 2m 45s   remaining: 55.6s
748:    learn: 0.4017950        total: 2m 45s   remaining: 55.4s
749:    learn: 0.4017926        total: 2m 45s   remaining: 55.2s
750:    learn: 0.4017865        total: 2m 45s   remaining: 55s
751:    learn: 0.4017787        total: 2m 45s   remaining: 54.7s
752:    learn: 0.4017728        total: 2m 46s   remaining: 54.5s
753:    learn: 0.4017659        total: 2m 46s   remaining: 54.3s
754:    learn: 0.4017614        total: 2m 46s   remaining: 54.1s
755:    learn: 0.4017559        total: 2m 46s   remaining: 53.8s
756:    learn: 0.4017512        total: 2m 47s   remaining: 53.6s
757:    learn: 0.4017490        total: 2m 47s   remaining: 53.4s
758:    learn: 0.4017445        total: 2m 47s   remaining: 53.2s
759:    learn: 0.4017391        total: 2m 47s   remaining: 52.9s
760:    learn: 0.4017271        total: 2m 47s   remaining: 52.7s
761:    learn: 0.4017206        total: 2m 48s   remaining: 52.5s
762:    learn: 0.4017158        total: 2m 48s   remaining: 52.3s
763:    learn: 0.4017060        total: 2m 48s   remaining: 52.1s
764:    learn: 0.4017040        total: 2m 48s   remaining: 51.8s
765:    learn: 0.4016992        total: 2m 48s   remaining: 51.6s
766:    learn: 0.4016949        total: 2m 49s   remaining: 51.4s
767:    learn: 0.4016901        total: 2m 49s   remaining: 51.2s
768:    learn: 0.4016871        total: 2m 49s   remaining: 50.9s
769:    learn: 0.4016831        total: 2m 49s   remaining: 50.7s
770:    learn: 0.4016785        total: 2m 49s   remaining: 50.5s
771:    learn: 0.4016708        total: 2m 50s   remaining: 50.3s
772:    learn: 0.4016663        total: 2m 50s   remaining: 50.1s
773:    learn: 0.4016604        total: 2m 50s   remaining: 49.8s
774:    learn: 0.4016554        total: 2m 50s   remaining: 49.6s
775:    learn: 0.4016511        total: 2m 51s   remaining: 49.4s
776:    learn: 0.4016486        total: 2m 51s   remaining: 49.2s
777:    learn: 0.4016432        total: 2m 51s   remaining: 48.9s
```

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778:    learn: 0.4016379        total: 2m 51s   remaining: 48.7s
779:    learn: 0.4016317        total: 2m 51s   remaining: 48.5s
780:    learn: 0.4016288        total: 2m 52s   remaining: 48.3s
781:    learn: 0.4016251        total: 2m 52s   remaining: 48s
782:    learn: 0.4016214        total: 2m 52s   remaining: 47.8s
783:    learn: 0.4016151        total: 2m 52s   remaining: 47.6s
784:    learn: 0.4016078        total: 2m 53s   remaining: 47.4s
785:    learn: 0.4016044        total: 2m 53s   remaining: 47.2s
786:    learn: 0.4016003        total: 2m 53s   remaining: 46.9s
787:    learn: 0.4015964        total: 2m 53s   remaining: 46.7s
788:    learn: 0.4015921        total: 2m 53s   remaining: 46.5s
789:    learn: 0.4015875        total: 2m 54s   remaining: 46.3s
790:    learn: 0.4015830        total: 2m 54s   remaining: 46.1s
791:    learn: 0.4015765        total: 2m 54s   remaining: 45.8s
792:    learn: 0.4015748        total: 2m 54s   remaining: 45.6s
793:    learn: 0.4015702        total: 2m 54s   remaining: 45.4s
794:    learn: 0.4015674        total: 2m 55s   remaining: 45.2s
795:    learn: 0.4015625        total: 2m 55s   remaining: 45s
796:    learn: 0.4015586        total: 2m 55s   remaining: 44.7s
797:    learn: 0.4015544        total: 2m 55s   remaining: 44.5s
798:    learn: 0.4015492        total: 2m 56s   remaining: 44.3s
799:    learn: 0.4015448        total: 2m 56s   remaining: 44.1s
800:    learn: 0.4015407        total: 2m 56s   remaining: 43.8s
801:    learn: 0.4015382        total: 2m 56s   remaining: 43.6s
802:    learn: 0.4015358        total: 2m 56s   remaining: 43.4s
803:    learn: 0.4015296        total: 2m 57s   remaining: 43.2s
804:    learn: 0.4015263        total: 2m 57s   remaining: 43s
805:    learn: 0.4015228        total: 2m 57s   remaining: 42.7s
806:    learn: 0.4015176        total: 2m 57s   remaining: 42.5s
807:    learn: 0.4015132        total: 2m 58s   remaining: 42.3s
808:    learn: 0.4015057        total: 2m 58s   remaining: 42.1s
809:    learn: 0.4015017        total: 2m 58s   remaining: 41.9s
810:    learn: 0.4014946        total: 2m 58s   remaining: 41.6s
811:    learn: 0.4014929        total: 2m 58s   remaining: 41.4s
812:    learn: 0.4014885        total: 2m 59s   remaining: 41.2s
813:    learn: 0.4014833        total: 2m 59s   remaining: 41s
814:    learn: 0.4014807        total: 2m 59s   remaining: 40.7s
815:    learn: 0.4014699        total: 2m 59s   remaining: 40.5s
816:    learn: 0.4014681        total: 2m 59s   remaining: 40.3s
817:    learn: 0.4014655        total: 3m       remaining: 40.1s
818:    learn: 0.4014600        total: 3m       remaining: 39.8s
819:    learn: 0.4014553        total: 3m       remaining: 39.6s
820:    learn: 0.4014530        total: 3m       remaining: 39.4s
821:    learn: 0.4014512        total: 3m       remaining: 39.2s
822:    learn: 0.4014482        total: 3m 1s    remaining: 39s
823:    learn: 0.4014429        total: 3m 1s    remaining: 38.7s
824:    learn: 0.4014374        total: 3m 1s    remaining: 38.5s
825:    learn: 0.4014346        total: 3m 1s    remaining: 38.3s
```

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826:    learn: 0.4014299        total: 3m 2s    remaining: 38.1s
827:    learn: 0.4014284        total: 3m 2s    remaining: 37.9s
828:    learn: 0.4014254        total: 3m 2s    remaining: 37.6s
829:    learn: 0.4014201        total: 3m 2s    remaining: 37.4s
830:    learn: 0.4014158        total: 3m 2s    remaining: 37.2s
831:    learn: 0.4014121        total: 3m 3s    remaining: 37s
832:    learn: 0.4014099        total: 3m 3s    remaining: 36.8s
833:    learn: 0.4014082        total: 3m 3s    remaining: 36.5s
834:    learn: 0.4014062        total: 3m 3s    remaining: 36.3s
835:    learn: 0.4014044        total: 3m 3s    remaining: 36.1s
836:    learn: 0.4013981        total: 3m 4s    remaining: 35.9s
837:    learn: 0.4013933        total: 3m 4s    remaining: 35.7s
838:    learn: 0.4013896        total: 3m 4s    remaining: 35.4s
839:    learn: 0.4013847        total: 3m 4s    remaining: 35.2s
840:    learn: 0.4013804        total: 3m 5s    remaining: 35s
841:    learn: 0.4013758        total: 3m 5s    remaining: 34.8s
842:    learn: 0.4013723        total: 3m 5s    remaining: 34.5s
843:    learn: 0.4013658        total: 3m 5s    remaining: 34.3s
844:    learn: 0.4013637        total: 3m 5s    remaining: 34.1s
845:    learn: 0.4013611        total: 3m 6s    remaining: 33.9s
846:    learn: 0.4013592        total: 3m 6s    remaining: 33.7s
847:    learn: 0.4013551        total: 3m 6s    remaining: 33.4s
848:    learn: 0.4013507        total: 3m 6s    remaining: 33.2s
849:    learn: 0.4013440        total: 3m 6s    remaining: 33s
850:    learn: 0.4013402        total: 3m 7s    remaining: 32.8s
851:    learn: 0.4013355        total: 3m 7s    remaining: 32.6s
852:    learn: 0.4013293        total: 3m 7s    remaining: 32.3s
853:    learn: 0.4013255        total: 3m 7s    remaining: 32.1s
854:    learn: 0.4013212        total: 3m 8s    remaining: 31.9s
855:    learn: 0.4013167        total: 3m 8s    remaining: 31.7s
856:    learn: 0.4013128        total: 3m 8s    remaining: 31.4s
857:    learn: 0.4013090        total: 3m 8s    remaining: 31.2s
858:    learn: 0.4013047        total: 3m 8s    remaining: 31s
859:    learn: 0.4012984        total: 3m 9s    remaining: 30.8s
860:    learn: 0.4012943        total: 3m 9s    remaining: 30.6s
861:    learn: 0.4012906        total: 3m 9s    remaining: 30.4s
862:    learn: 0.4012894        total: 3m 9s    remaining: 30.1s
863:    learn: 0.4012861        total: 3m 10s   remaining: 29.9s
864:    learn: 0.4012822        total: 3m 10s   remaining: 29.7s
865:    learn: 0.4012794        total: 3m 10s   remaining: 29.5s
866:    learn: 0.4012738        total: 3m 10s   remaining: 29.2s
867:    learn: 0.4012684        total: 3m 10s   remaining: 29s
868:    learn: 0.4012652        total: 3m 11s   remaining: 28.8s
869:    learn: 0.4012616        total: 3m 11s   remaining: 28.6s
870:    learn: 0.4012576        total: 3m 11s   remaining: 28.4s
871:    learn: 0.4012544        total: 3m 11s   remaining: 28.1s
872:    learn: 0.4012502        total: 3m 11s   remaining: 27.9s
873:    learn: 0.4012453        total: 3m 12s   remaining: 27.7s
```

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874:    learn: 0.4012389        total: 3m 12s   remaining: 27.5s
875:    learn: 0.4012346        total: 3m 12s   remaining: 27.3s
876:    learn: 0.4012262        total: 3m 12s   remaining: 27s
877:    learn: 0.4012231        total: 3m 12s   remaining: 26.8s
878:    learn: 0.4012193        total: 3m 13s   remaining: 26.6s
879:    learn: 0.4012160        total: 3m 13s   remaining: 26.4s
880:    learn: 0.4012107        total: 3m 13s   remaining: 26.2s
881:    learn: 0.4012039        total: 3m 13s   remaining: 25.9s
882:    learn: 0.4011989        total: 3m 14s   remaining: 25.7s
883:    learn: 0.4011959        total: 3m 14s   remaining: 25.5s
884:    learn: 0.4011931        total: 3m 14s   remaining: 25.3s
885:    learn: 0.4011916        total: 3m 14s   remaining: 25.1s
886:    learn: 0.4011881        total: 3m 14s   remaining: 24.8s
887:    learn: 0.4011848        total: 3m 15s   remaining: 24.6s
888:    learn: 0.4011804        total: 3m 15s   remaining: 24.4s
889:    learn: 0.4011764        total: 3m 15s   remaining: 24.2s
890:    learn: 0.4011700        total: 3m 15s   remaining: 24s
891:    learn: 0.4011665        total: 3m 16s   remaining: 23.7s
892:    learn: 0.4011632        total: 3m 16s   remaining: 23.5s
893:    learn: 0.4011601        total: 3m 16s   remaining: 23.3s
894:    learn: 0.4011591        total: 3m 16s   remaining: 23.1s
895:    learn: 0.4011551        total: 3m 16s   remaining: 22.9s
896:    learn: 0.4011517        total: 3m 17s   remaining: 22.6s
897:    learn: 0.4011462        total: 3m 17s   remaining: 22.4s
898:    learn: 0.4011418        total: 3m 17s   remaining: 22.2s
899:    learn: 0.4011396        total: 3m 17s   remaining: 22s
900:    learn: 0.4011369        total: 3m 17s   remaining: 21.8s
901:    learn: 0.4011350        total: 3m 18s   remaining: 21.5s
902:    learn: 0.4011314        total: 3m 18s   remaining: 21.3s
903:    learn: 0.4011271        total: 3m 18s   remaining: 21.1s
904:    learn: 0.4011235        total: 3m 18s   remaining: 20.9s
905:    learn: 0.4011203        total: 3m 19s   remaining: 20.7s
906:    learn: 0.4011158        total: 3m 19s   remaining: 20.4s
907:    learn: 0.4011128        total: 3m 19s   remaining: 20.2s
908:    learn: 0.4011078        total: 3m 19s   remaining: 20s
909:    learn: 0.4011048        total: 3m 19s   remaining: 19.8s
910:    learn: 0.4011017        total: 3m 20s   remaining: 19.6s
911:    learn: 0.4010986        total: 3m 20s   remaining: 19.3s
912:    learn: 0.4010958        total: 3m 20s   remaining: 19.1s
913:    learn: 0.4010938        total: 3m 20s   remaining: 18.9s
914:    learn: 0.4010915        total: 3m 20s   remaining: 18.7s
915:    learn: 0.4010890        total: 3m 21s   remaining: 18.5s
916:    learn: 0.4010866        total: 3m 21s   remaining: 18.2s
917:    learn: 0.4010818        total: 3m 21s   remaining: 18s
918:    learn: 0.4010787        total: 3m 21s   remaining: 17.8s
919:    learn: 0.4010766        total: 3m 22s   remaining: 17.6s
920:    learn: 0.4010721        total: 3m 22s   remaining: 17.4s
921:    learn: 0.4010696        total: 3m 22s   remaining: 17.1s
```

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922:    learn: 0.4010624        total: 3m 22s   remaining: 16.9s
923:    learn: 0.4010603        total: 3m 22s   remaining: 16.7s
924:    learn: 0.4010581        total: 3m 23s   remaining: 16.5s
925:    learn: 0.4010561        total: 3m 23s   remaining: 16.3s
926:    learn: 0.4010481        total: 3m 23s   remaining: 16s
927:    learn: 0.4010457        total: 3m 23s   remaining: 15.8s
928:    learn: 0.4010420        total: 3m 23s   remaining: 15.6s
929:    learn: 0.4010401        total: 3m 24s   remaining: 15.4s
930:    learn: 0.4010350        total: 3m 24s   remaining: 15.1s
931:    learn: 0.4010328        total: 3m 24s   remaining: 14.9s
932:    learn: 0.4010302        total: 3m 24s   remaining: 14.7s
933:    learn: 0.4010278        total: 3m 25s   remaining: 14.5s
934:    learn: 0.4010234        total: 3m 25s   remaining: 14.3s
935:    learn: 0.4010209        total: 3m 25s   remaining: 14s
936:    learn: 0.4010126        total: 3m 25s   remaining: 13.8s
937:    learn: 0.4010085        total: 3m 25s   remaining: 13.6s
938:    learn: 0.4010022        total: 3m 26s   remaining: 13.4s
939:    learn: 0.4009975        total: 3m 26s   remaining: 13.2s
940:    learn: 0.4009920        total: 3m 26s   remaining: 12.9s
941:    learn: 0.4009906        total: 3m 26s   remaining: 12.7s
942:    learn: 0.4009880        total: 3m 26s   remaining: 12.5s
943:    learn: 0.4009843        total: 3m 27s   remaining: 12.3s
944:    learn: 0.4009805        total: 3m 27s   remaining: 12.1s
945:    learn: 0.4009745        total: 3m 27s   remaining: 11.9s
946:    learn: 0.4009715        total: 3m 27s   remaining: 11.6s
947:    learn: 0.4009701        total: 3m 28s   remaining: 11.4s
948:    learn: 0.4009651        total: 3m 28s   remaining: 11.2s
949:    learn: 0.4009610        total: 3m 28s   remaining: 11s
950:    learn: 0.4009577        total: 3m 28s   remaining: 10.8s
951:    learn: 0.4009535        total: 3m 28s   remaining: 10.5s
952:    learn: 0.4009499        total: 3m 29s   remaining: 10.3s
953:    learn: 0.4009459        total: 3m 29s   remaining: 10.1s
954:    learn: 0.4009423        total: 3m 29s   remaining: 9.87s
955:    learn: 0.4009383        total: 3m 29s   remaining: 9.65s
956:    learn: 0.4009354        total: 3m 29s   remaining: 9.43s
957:    learn: 0.4009319        total: 3m 30s   remaining: 9.21s
958:    learn: 0.4009284        total: 3m 30s   remaining: 8.99s
959:    learn: 0.4009220        total: 3m 30s   remaining: 8.77s
960:    learn: 0.4009189        total: 3m 30s   remaining: 8.55s
961:    learn: 0.4009149        total: 3m 31s   remaining: 8.34s
962:    learn: 0.4009116        total: 3m 31s   remaining: 8.12s
963:    learn: 0.4009098        total: 3m 31s   remaining: 7.9s
964:    learn: 0.4009053        total: 3m 31s   remaining: 7.68s
965:    learn: 0.4009020        total: 3m 31s   remaining: 7.46s
966:    learn: 0.4008986        total: 3m 32s   remaining: 7.24s
967:    learn: 0.4008957        total: 3m 32s   remaining: 7.02s
968:    learn: 0.4008931        total: 3m 32s   remaining: 6.8s
969:    learn: 0.4008887        total: 3m 32s   remaining: 6.58s
```

```
970:    learn: 0.4008854        total: 3m 32s   remaining: 6.36s
971:    learn: 0.4008822        total: 3m 33s   remaining: 6.14s
972:    learn: 0.4008781        total: 3m 33s   remaining: 5.92s
973:    learn: 0.4008764        total: 3m 33s   remaining: 5.7s
974:    learn: 0.4008710        total: 3m 33s   remaining: 5.48s
975:    learn: 0.4008671        total: 3m 34s   remaining: 5.26s
976:    learn: 0.4008628        total: 3m 34s   remaining: 5.04s
977:    learn: 0.4008539        total: 3m 34s   remaining: 4.82s
978:    learn: 0.4008506        total: 3m 34s   remaining: 4.6s
979:    learn: 0.4008460        total: 3m 34s   remaining: 4.38s
980:    learn: 0.4008407        total: 3m 35s   remaining: 4.17s
981:    learn: 0.4008379        total: 3m 35s   remaining: 3.95s
982:    learn: 0.4008349        total: 3m 35s   remaining: 3.73s
983:    learn: 0.4008288        total: 3m 35s   remaining: 3.51s
984:    learn: 0.4008264        total: 3m 35s   remaining: 3.29s
985:    learn: 0.4008220        total: 3m 36s   remaining: 3.07s
986:    learn: 0.4008187        total: 3m 36s   remaining: 2.85s
987:    learn: 0.4008168        total: 3m 36s   remaining: 2.63s
988:    learn: 0.4008143        total: 3m 36s   remaining: 2.41s
989:    learn: 0.4008076        total: 3m 37s   remaining: 2.19s
990:    learn: 0.4007979        total: 3m 37s   remaining: 1.97s
991:    learn: 0.4007951        total: 3m 37s   remaining: 1.75s
992:    learn: 0.4007883        total: 3m 37s   remaining: 1.53s
993:    learn: 0.4007845        total: 3m 37s   remaining: 1.31s
994:    learn: 0.4007806        total: 3m 38s   remaining: 1.1s
995:    learn: 0.4007787        total: 3m 38s   remaining: 877ms
996:    learn: 0.4007758        total: 3m 38s   remaining: 658ms
997:    learn: 0.4007712        total: 3m 38s   remaining: 438ms
998:    learn: 0.4007676        total: 3m 38s   remaining: 219ms
999:    learn: 0.4007641        total: 3m 39s   remaining: 0us
```

[ ]:
```
<catboost.core.CatBoostClassifier at 0x7fc0acbd3fa0>
```

[ ]:
```
y_pred_ctb=ctb.predict_proba(X_val)[:, 1]
```

[ ]:
```
log_loss(y_val, y_pred_ctb)
```

[ ]:
```
0.40239392328189716
```

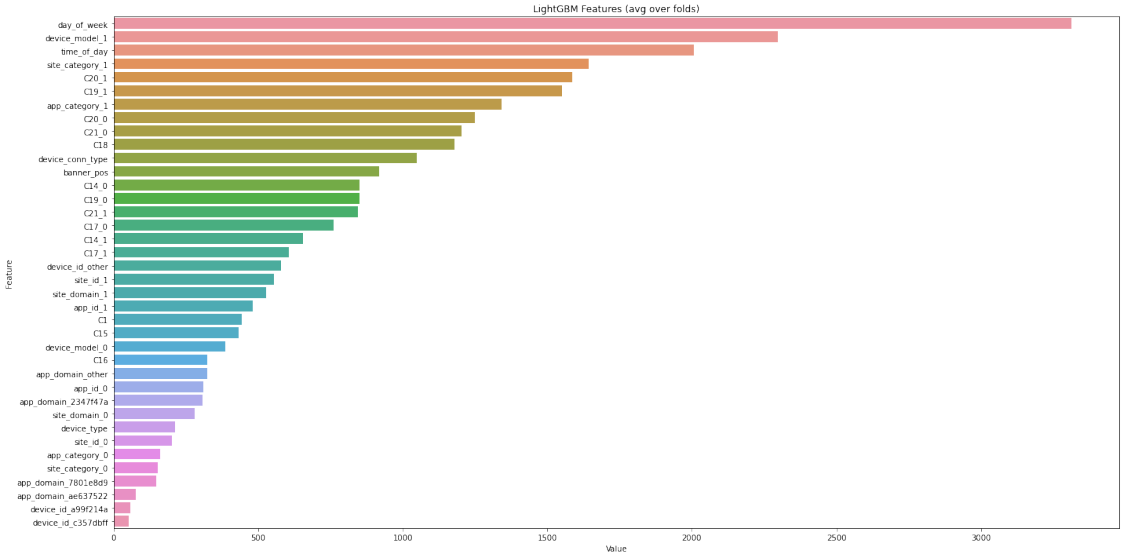
4 Final Result

Lightgbm

4.1 Feature Importance

[ ]:
```
feature_imp = pd.DataFrame(sorted(zip(lgb.feature_importances_,X_train.
↪columns)), columns=['Value','Feature'])
```

[ ]:
```
plt.figure(figsize=(20, 10))
sns.barplot(x="Value", y="Feature", data=feature_imp.sort_values(by="Value",␣
↪ascending=False))
plt.title('LightGBM Features (avg over folds)')
plt.tight_layout()
plt.show()
plt.savefig('lgbm_importances-01.png')
```



<Figure size 432x288 with 0 Axes>

4.2 ROC

[ ]:
```
################################## Import Libraries & Modules␣
↪#################################
from sklearn.metrics import roc_curve, auc
from numpy import interp
from sklearn.model_selection import StratifiedKFold
lgb = LGBMClassifier(learning_rate=0.1,num_leaves = 300,random_state=42, metric␣
↪= 'binary_logloss',cat_smooth= 35)
```

[ ]:
```
###################################### Cross - Validation␣
↪######################################
```

```
# This cross-validation object is a variation of KFold that returns stratified␣
 ↪folds
# The folds are made by preserving the percentage of samples for each class
cv = list(StratifiedKFold(n_splits=5,                 # number of folds. Must␣
 ↪be at least 2
                          ).split(X_train, y_train))  # generate indices to␣
 ↪split data into training and test set
```

[ ]:
```
##################################### Visualization␣
 ↪#####################################

fig = plt.figure(figsize=(7, 5)) # set figure size

mean_tpr = 0.0
mean_fpr = np.linspace(0, 1, 100)
all_tpr = []

for i, (train, test) in enumerate(cv): # enumarate allows us to loop over␣
 ↪something and have an automatic counter (e.g, 0, 1, 2, etc.)
    probas = lgb.fit(X_train.iloc[train],y_train.iloc[train]).
 ↪predict_proba(X_train.iloc[test]) # make predictions based on classifiers

    # roc_curve will compute Receiver operating characteristic (ROC)
    fpr, tpr, thresholds = roc_curve(y_train.iloc[test], # data for ROC curves␣
 ↪(true labels)
                                     probas[:, 1],  # predictions based on␣
 ↪estimators
                                     pos_label=1)   # the label of the positive␣
 ↪class
    mean_tpr += interp(mean_fpr, fpr, tpr)          # one-dimensional linear␣
 ↪interpolation (continuous ROC curve)

    mean_tpr[0] = 0.0
    # auc will compute Area Under the Curve (AUC)
    roc_auc = auc(fpr, tpr)
    plt.plot(fpr,                                   # the horizontal␣
 ↪coordinates of the data points
             tpr,                                   # the vertical coordinates␣
 ↪of the data points
             label='ROC fold %d (area = %0.2f)'
                   % (i+1, roc_auc))

plt.plot([0, 1],                                    # plot random guessing␣
 ↪classifier
         [0, 1],
         linestyle='--',
```

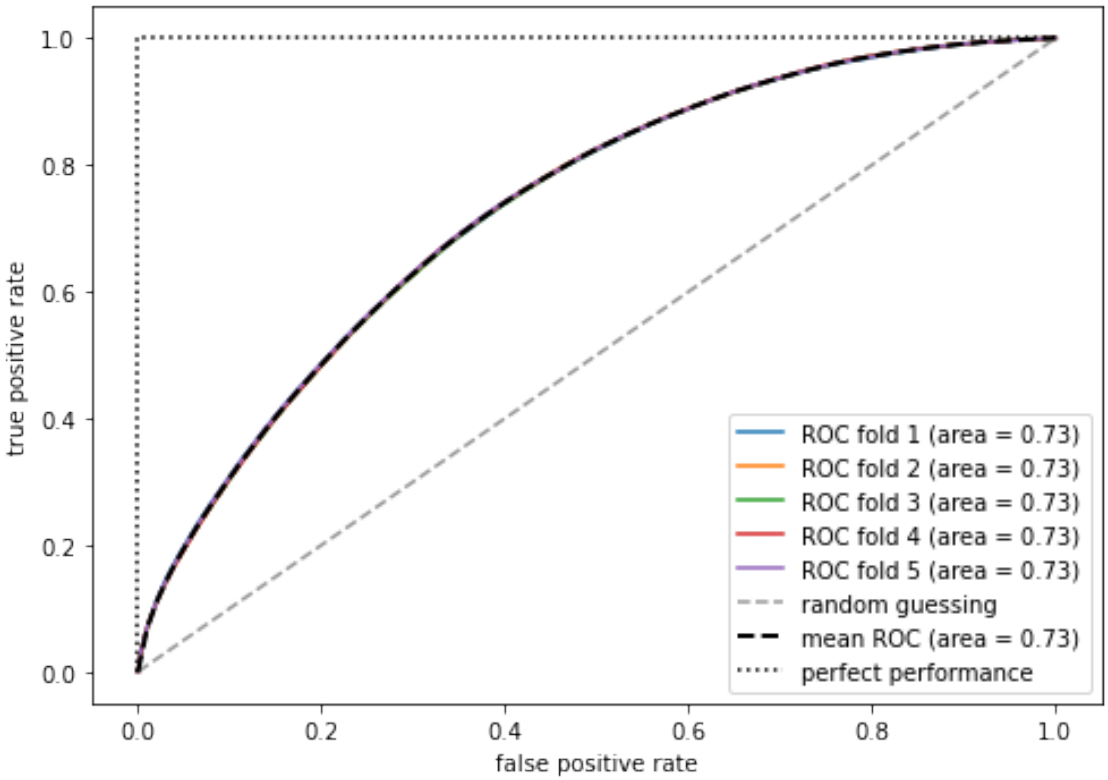
```
         color=(0.6, 0.6, 0.6),
         label='random guessing')

mean_tpr /= len(cv)                                    # plot mearn ROC curve
mean_tpr[-1] = 1.0
mean_auc = auc(mean_fpr, mean_tpr)
plt.plot(mean_fpr,
         mean_tpr,
         'k--',
         label='mean ROC (area = %0.2f)' % mean_auc, lw=2)

plt.plot([0, 0, 1],                                    # plot perfect classifier
         [0, 1, 1],
         linestyle=':',
         color='black',
         label='perfect performance')

# Figure paramaters: x axis limits, y axis limits, labels of axes, legend␣
 ↪position
plt.xlim([-0.05, 1.05])
plt.ylim([-0.05, 1.05])
plt.xlabel('false positive rate')
plt.ylabel('true positive rate')
plt.legend(loc="lower right")

plt.tight_layout()
# plt.savefig('ROC_CrossValidation_Oneclassifier.png', dpi=300)
plt.show()                                             # display figure
```



4.3 Submission

[ ]:
```
y_sub = lgb.predict_proba(X_test)[:,1]
```

[ ]:
```
# Import the submission data
sub = pd.read_csv('Project Data/ProjectSubmission-Team4.csv')
```

[ ]:
```
sub.iloc[:,1] = y_sub
```

[ ]:
```
sub.to_csv('ProjectSubmission-Team4.csv',index = False)
```

[ ]:
```

```