Inżynieria Uczenia Maszynowego

Studenci:

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Temat

> "Jakiś czas temu wprowadziliśmy konta premium, które uwalniają użytkowników od słuchania reklam. Nie są one jednak jeszcze zbyt popularne – czy możemy się dowiedzieć, które osoby są bardziej skłonne do zakupu takiego konta?"

```
import itertools
import numpy as np
import pandas as pd
import pickle
import requests
import seaborn as sns

from IPython.display import display
from matplotlib import pyplot as plt
from math import sqrt
from scipy.stats import uniform
from sklearn.impute import SimpleImputer
from sklearn.linear_model import LogisticRegression
from sklearn.dummy import DummyClassifier
from sklearn.model_selection import RandomizedSearchCV, train_test_split
from sklearn.metrics import (
    confusion_matrix,
    roc_auc_score
)
from sklearn.pipeline import Pipeline
from sklearn.preprocessing import StandardScaler
from statistics import stdev, mean
from typing import Any, Dict, Optional
from xgboost import XGBClassifier

from microservice import IUMModel
from utility import Model
```

Cechy i funkcje celu

Do trenowania naszych modeli przygotowaliśmy następujące cechy wygenerowane na podstawie dostarczonych danych:

- `number_of_advertisements`, ilość odtworzonych reklam w danym miesiącu
- `number_of_tracks`, ilość przesłuchanych utworów w danym miesiącu
- `number_of_skips`, ilość pominiętych utworów w danym miesiącu
- `number_of_likes`, liczba danych lików w danym miesiącu
- `number_of_liked_tracks_listened`, liczba przesłuchanych utworów w danym miesiącu, które w momencie odtworzenia były polubione
- `number_of_tracks_in_favourite_genre`, liczba przesłuchanych utworów z ulubionego gatunku w danym miesiącu
- `total_number_of_favourite_genres_listened`, liczba przesłuchanych gatunków w danym miesiącu należących do ulubionych użytkownika
- `average_popularity_in_favourite_genres`, średnia popularność utworów wśród ulubionych gatunków w danym miesiącu

- `total_tracks_duration_ms`, całkowity czas przesłuchanych utworów w danym miesiącu
- `number_of_different_artists`, ilość przesłuchanych artystów w danym miesiącu
- `average_release_date`, średnia data przesłuchanych piosenek w danym miesiącu
- `average_duration_ms`, średni czas trwania utworów przesłuchanych w danym miesiącu
- `explicit_tracks_ratio`, ułamek "wulgarnych" utworów przesłuchanych w danym miesiącu
- `average_popularity`, średnia popularność przesłuchanych utworów w danym miesiącu
- `average_acousticness`, średnia akustyka przesłuchanych utworów w danym miesiącu
- `average_danceability`, średnia taneczność przesłuchanych utworów w danym miesiącu
- `average_energy`, średnia moc przesłuchanych utworów w danym miesiącu
- `average_instrumentalness`, średnia ilość utworów z wokalem przesłuchanych w danym miesiącu
- `average_liveness`, średnie brzmienie utworów na żywo przesłuchanych w danym miesiącu
- `average_loudness`, średnia głośność przesłuchanych utworów w danym miesiącu
- `average_speechiness`, średnia ilość wokalu w utworach przesłuchanych w danym miesiącu
- `average_tempo`, średnia prędkość przesłuchanych utworów w danym miesiącu
- `average_valence`, średnia emocjonalność przesłuchanych utworów w danym miesiącu
- `average_track_name_length`, średnia długość nazwy utworów przesłuchanych w danym miesiącu
- `average_daily_cost`, średni koszt utrzymania przesłuchanych piosenek w danym miesiącu

Posiadamy również dwie funkcje celu:

- `premium_user_numerical`, która określa czy użytkownik kiedykolwiek kupi premium
- `will_buy_premium_next_month_numerical` przedstawiająca to czy użytkownik zakupi premium w przeciągu następnych 30 dni

```
FEATURE_VERSION = 'v1'
FEATURE_PATH = f'features/{FEATURE_VERSION}/feature.csv'

FEATURES = [
    'number_of_advertisements',
    'number_of_tracks',
    'number_of_skips',
    'number_of_likes',
    'number_of_liked_tracks_listened',
    'number_of_tracks_in_favourite_genre',
    'total_number_of_favourite_genres_listened',
    'average_popularity_in_favourite_genres',
    'total_tracks_duration_ms',
    'number_of_different_artists',
    'average_release_date',
    'average_duration_ms',
    'explicit_tracks_ratio',
    'average_popularity',
    'average_acousticness',
    'average_danceability',
    'average_energy',
    'average_instrumentalness',
    'average_liveness',
    'average_loudness',
    'average_speechiness',
    'average_tempo',
    'average_valence',
    'average_track_name_length',
    'average_daily_cost',
]

TARGETS = [
    'premium_user_numerical',
    'will_buy_premium_next_month_numerical'
```

```
]

TARGET_AND_FEATURES = TARGETS + FEATURES
```

```
data_frame = pd.read_csv(FEATURE_PATH)
```

Przykładowe wartości cech oraz funkcji celu

```
data_frame.head()
```

```
   user_id  year  month  premium_user_numerical  \
0      212  2020      2                       1
1      212  2020      7                       1
2      212  2020      1                       1
3      212  2020      3                       1
4      212  2020      8                       1

   will_buy_premium_next_month_numerical  number_of_premium  \
0                                      0                  0
1                                      0                  0
2                                      0                  0
3                                      0                  0
4                                      0                  0

   number_of_advertisements  number_of_tracks  number_of_skips  \
0                        10                30               16
1                         5                16                8
2                        14                39               21
3                         3                20                9
4                        13                40               22

   number_of_likes  ...  average_danceability  average_energy  \
0                8  ...              0.542767        0.600467
1                2  ...              0.499000        0.675250
2               12  ...              0.487000        0.691667
3                6  ...              0.516700        0.637150
4               12  ...              0.513525        0.642350

   average_instrumentalness  average_liveness  average_loudness  \
0                  0.094653          0.179113        -10.158167
1                  0.150966          0.226225         -8.795062
2                  0.119363          0.235690         -9.491795
3                  0.069641          0.189545         -8.409150
4                  0.112645          0.285203         -9.562400

   average_speechiness  average_tempo  average_valence  \
0             0.049070     121.964467         0.588167
1             0.061812     123.069063         0.452131
2             0.064918     123.745769         0.564369
3             0.053715     121.415600         0.586000
4             0.055282     120.922325         0.510517

   average_track_name_length  average_daily_cost
0                  22.233333            0.012134
1                  22.687500            0.014780
2                  19.461538            0.012399
```

```
3                  21.250000            0.012706
4                  24.000000            0.013076

[5 rows x 31 columns]
```

Macierz korelacji cech z wartościami przewidywanymi

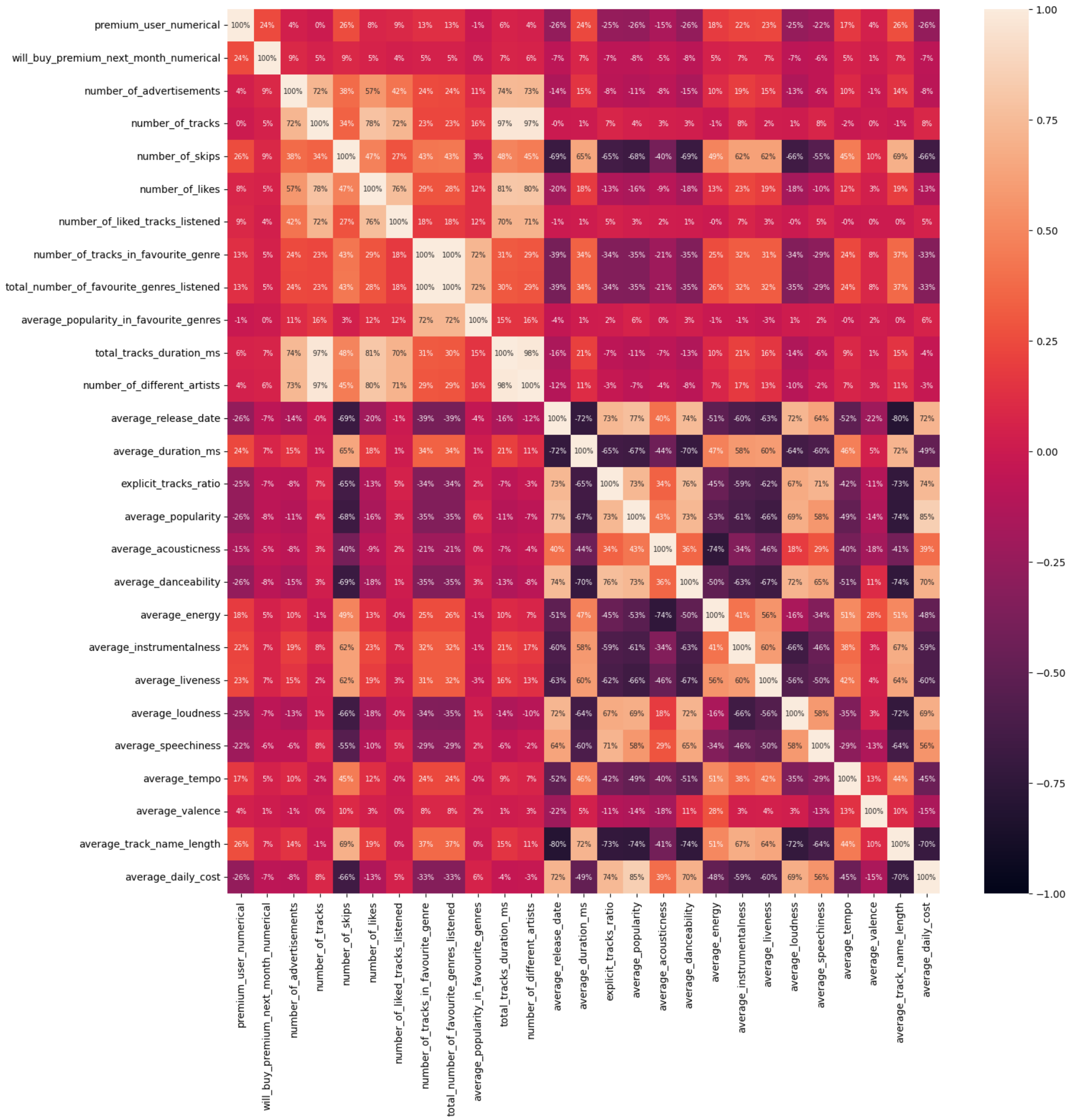
Sprawdzamy korelację cech, które nie są zbytnio skorelowane między sobą, a za to są skorelowane z targetem.

```
correlation_matrix = data_frame.loc[:, TARGET_AND_FEATURES] \
    .corr(method='spearman')

plt.figure(figsize=(16, 16))

sns.heatmap(
    correlation_matrix,
    xticklabels=correlation_matrix.columns,  # type: ignore
    yticklabels=correlation_matrix.columns,  # type: ignore
    annot=True,
    annot_kws={"fontsize": 7},
    fmt=".0%",
    vmin=-1,
    vmax=1,
)

plt.show()
```



Definiujemy pipeline do uzupełnienia danych pustych oraz przeskalowania danych

```
pipeline = Pipeline([
    ("simple_imputer", SimpleImputer()),
    ("standard_scaler", StandardScaler())
])
```

Dzielimy dane na dane trenujące oraz testowe do późniejszych eksperymentów A/B

```
TRAINING_UP_TO = 2023
TRAIN_DATA: pd.DataFrame = data_frame.loc[data_frame.year < TRAINING_UP_TO, :]
TEST_DATA: pd.DataFrame = data_frame.loc[data_frame.year >= TRAINING_UP_TO, :]
TEST_SIZE = 0.33
```

Pipeline uczony jest na podstawie samych danych testowych

```
X_train_temp, X_test_temp, Y_train, Y_test = train_test_split(
    TRAIN_DATA[FEATURES],
    TRAIN_DATA[TARGETS],
    test_size=TEST_SIZE
)
X_train_temp: pd.DataFrame
X_test_temp: pd.DataFrame
Y_train: pd.DataFrame
Y_test: pd.DataFrame

train_data = pipeline.fit_transform(X_train_temp)
test_data = pipeline.transform(X_test_temp)
X_train = pd.DataFrame(train_data, columns=FEATURES)
X_test = pd.DataFrame(test_data, columns=FEATURES)
```

Cechy przetworzone przez pipeline

```
X_train.head()
```

```
   number_of_advertisements  number_of_tracks  number_of_skips  \
0                  0.386860         -0.485850         0.830546
1                 -1.356432         -1.658003        -0.880549
2                  0.635902          0.979341        -0.538330
3                  2.130152          1.370059         0.146108
4                 -1.356432          0.002547        -0.709440

   number_of_likes  number_of_liked_tracks_listened  \
0         0.583458                         0.074885
1        -1.370041                        -1.287405
2         1.141601                         0.269498
3         0.025315                         0.853336
4         0.304387                         0.853336

   number_of_tracks_in_favourite_genre  \
0                             0.863598
1                            -0.641583
2                            -0.453435
3                            -0.453435
4                            -0.641583

   total_number_of_favourite_genres_listened  \
0                                   0.698899
1                                  -0.608941
2                                  -0.445461
3                                  -0.445461
4                                  -0.608941

   average_popularity_in_favourite_genres  total_tracks_duration_ms  \
0                               -0.022313                 -0.435282
1                               -1.010011                 -1.626428
2                                1.421246                  0.666986
3                                1.421246                  1.140734
4                               -1.010011                 -0.253779

   number_of_different_artists  ...  average_danceability  average_energy  \
```

```
0                    -0.501295  ...             -1.659065        1.342909
1                    -1.697606  ...              0.922672       -0.572892
2                     1.293171  ...              0.854068        0.003184
3                     1.053909  ...              0.382945       -0.246091
4                    -0.022771  ...              0.888335       -0.085594

   average_instrumentalness  average_liveness  average_loudness  \
0                  2.449911          0.998213         -0.832375
1                 -1.008311         -1.123035          0.964094
2                 -0.380334         -0.359967          0.729621
3                 -0.668866         -0.455298          0.475303
4                 -0.349358         -0.589086          1.084777

   average_speechiness  average_tempo  average_valence  \
0            -1.197827       1.422952         0.127103
1             1.752697       0.335856        -0.193103
2             0.770775      -0.575114         1.033064
3             0.411620      -1.015395        -0.639460
4             1.112326       0.215161        -0.084959

   average_track_name_length  average_daily_cost
0                   1.804459           -1.246425
1                  -1.031041            0.386880
2                  -0.687234            1.524497
3                  -1.118217            1.030821
4                  -0.747340            0.052786

[5 rows x 25 columns]
```

```
Y_train.head()
```

```
        premium_user_numerical  will_buy_premium_next_month_numerical
64816                        1                                      0
59448                        0                                      0
95390                        0                                      0
77685                        0                                      0
115377                       0                                      0
```

Modele

Do porównywania wybraliśmy cztery modele:

- `Dummy` - naiwny model, który zawsze przewiduje najczęściej występującą klasę
- `Logistic Regression` - model regresji logistycznej z domyślnymi parametrami
- `XGB Classifier` - model XGBoost z domyślnymi parametrami
- `XGB Classifier with Randomized Search` - model XGBoost z Randomized Search. Randomized Search to metoda optymalizacji hiperparametrów, która polega na losowym testowaniu zdefiniowane wartości hiperparametrów i ustaleniu ich najlepszej kombinacji. W ten sposób można znaleźć dobre parametry modelu bez konieczności przeszukiwania całej przestrzeni hiperparametrów. Dodatkowo, aby przeciwdziałać niezbalansowanym danym ustawiliśmy parametr `scale_pos_weight` według zaleceń na stosunek liczby negatywnych rekordów (0) do liczby pozytywnych (1).

```
DUMMY = 'dummy'
LOGISTIC_REG = 'logistic_regression'
XGB = 'xgb_classifier'
XGB_BEST_ESTIMATOR = 'xgb_classifier_best_estimator'
RANDOM = 'randomized_search'
```

```python
MODEL_TYPES = [DUMMY, LOGISTIC_REG, XGB, XGB_BEST_ESTIMATOR]


def construct_dummy(X_train: pd.DataFrame,
                    y_train: pd.DataFrame,
                    params: Optional[Dict[str, Any]] = None) -> DummyClassifier:
    return DummyClassifier().fit(X_train, y_train)


def construct_logistic_reggression(X_train: pd.DataFrame,
                                   y_train: pd.DataFrame,
                                   params: Optional[Dict[str, Any]] = None) -> LogisticRegression:
    return LogisticRegression().fit(X_train, y_train)


def construct_xgb_classifier(X_train: pd.DataFrame,
                             y_train: pd.DataFrame,
                             params: Optional[Dict[str, Any]] = None) -> XGBClassifier:
    return XGBClassifier().fit(X_train, y_train)


def construct_xgb_classifier_with_randomized_search(
    X_train: pd.DataFrame,
    y_train: pd.DataFrame,
    params: Optional[Dict[str, Any]] = None
) -> XGBClassifier:
    if params:
        return XGBClassifier(**params).fit(X_train, y_train)
    scale = y_train.value_counts()
    model = XGBClassifier(scale_pos_weight=scale[0] / scale[1])

    randomized_search_cv = RandomizedSearchCV(
        estimator=model,
        param_distributions={
            'max_depth': range(3, 25),
            'eta': uniform(0, 0.3),
            'gamma': uniform(0, 1),
            'n_estimators': range(10, 100),
        },
        n_iter=120,
        scoring='roc_auc',
        n_jobs=-1,
        verbose=3,
    )
    estimator = randomized_search_cv.fit(X_train, y_train)
    best_estimator = estimator.best_estimator_
    print('Best parameters:', best_estimator.get_params())
    return best_estimator  # type: ignore


MODEL_CONSTRUCTORS = {
    DUMMY: construct_dummy,
    LOGISTIC_REG: construct_logistic_reggression,
    XGB: construct_xgb_classifier,
    XGB_BEST_ESTIMATOR: construct_xgb_classifier_with_randomized_search
```

```
}
MODELS: Dict[str, Dict[str, Model]] = {}

for type in MODEL_TYPES:
    MODELS[type] = {
        target: MODEL_CONSTRUCTORS[type](X_train, Y_train[target])
        for target in TARGETS
    }
```

```
Fitting 5 folds for each of 120 candidates, totalling 600 fits
[CV 3/5] END eta=0.2385983034070887, gamma=0.8103482208523168, max_depth=6, n_estimators=80;, score=0.713 t
[CV 1/5] END eta=0.2385983034070887, gamma=0.8103482208523168, max_depth=6, n_estimators=80;, score=0.718 t
[CV 2/5] END eta=0.2385983034070887, gamma=0.8103482208523168, max_depth=6, n_estimators=80;, score=0.709 t
[CV 1/5] END eta=0.17867436642773724, gamma=0.5916344567009209, max_depth=10, n_estimators=27;, score=0.71
[CV 4/5] END eta=0.2385983034070887, gamma=0.8103482208523168, max_depth=6, n_estimators=80;, score=0.715 t
[CV 5/5] END eta=0.2385983034070887, gamma=0.8103482208523168, max_depth=6, n_estimators=80;, score=0.710 t
[CV 2/5] END eta=0.17867436642773724, gamma=0.5916344567009209, max_depth=10, n_estimators=27;, score=0.70
[CV 3/5] END eta=0.17867436642773724, gamma=0.5916344567009209, max_depth=10, n_estimators=27;, score=0.70
[CV 4/5] END eta=0.17867436642773724, gamma=0.5916344567009209, max_depth=10, n_estimators=27;, score=0.70
[CV 5/5] END eta=0.17867436642773724, gamma=0.5916344567009209, max_depth=10, n_estimators=27;, score=0.70
[CV 1/5] END eta=0.10347542204007788, gamma=0.9539584752919945, max_depth=22, n_estimators=70;, score=0.70
[CV 3/5] END eta=0.10347542204007788, gamma=0.9539584752919945, max_depth=22, n_estimators=70;, score=0.70
[CV 4/5] END eta=0.10347542204007788, gamma=0.9539584752919945, max_depth=22, n_estimators=70;, score=0.70
[CV 2/5] END eta=0.10347542204007788, gamma=0.9539584752919945, max_depth=22, n_estimators=70;, score=0.69
[CV 5/5] END eta=0.10347542204007788, gamma=0.9539584752919945, max_depth=22, n_estimators=70;, score=0.70
[CV 1/5] END eta=0.1915944321997959, gamma=0.41523050683430285, max_depth=9, n_estimators=13;, score=0.717
[CV 2/5] END eta=0.1915944321997959, gamma=0.41523050683430285, max_depth=9, n_estimators=13;, score=0.707
[CV 3/5] END eta=0.1915944321997959, gamma=0.41523050683430285, max_depth=9, n_estimators=13;, score=0.712
[CV 4/5] END eta=0.1915944321997959, gamma=0.41523050683430285, max_depth=9, n_estimators=13;, score=0.713
[CV 5/5] END eta=0.1915944321997959, gamma=0.41523050683430285, max_depth=9, n_estimators=13;, score=0.709
[CV 1/5] END eta=0.017945986710433248, gamma=0.24536758667400416, max_depth=12, n_estimators=74;, score=0.
[CV 2/5] END eta=0.017945986710433248, gamma=0.24536758667400416, max_depth=12, n_estimators=74;, score=0.
[CV 3/5] END eta=0.017945986710433248, gamma=0.24536758667400416, max_depth=12, n_estimators=74;, score=0.
[CV 1/5] END eta=0.23626114564666223, gamma=0.3400039865210531, max_depth=3, n_estimators=72;, score=0.723
[CV 1/5] END eta=0.10391074957481086, gamma=0.45250950322194794, max_depth=11, n_estimators=56;, score=0.7
[CV 2/5] END eta=0.10391074957481086, gamma=0.45250950322194794, max_depth=11, n_estimators=56;, score=0.7
[CV 3/5] END eta=0.10391074957481086, gamma=0.45250950322194794, max_depth=11, n_estimators=56;, score=0.7
[CV 4/5] END eta=0.017945986710433248, gamma=0.24536758667400416, max_depth=12, n_estimators=74;, score=0.
[CV 5/5] END eta=0.017945986710433248, gamma=0.24536758667400416, max_depth=12, n_estimators=74;, score=0.
[CV 2/5] END eta=0.23626114564666223, gamma=0.3400039865210531, max_depth=3, n_estimators=72;, score=0.715
[CV 4/5] END eta=0.10391074957481086, gamma=0.45250950322194794, max_depth=11, n_estimators=56;, score=0.7
[CV 3/5] END eta=0.23626114564666223, gamma=0.3400039865210531, max_depth=3, n_estimators=72;, score=0.718
[CV 4/5] END eta=0.23626114564666223, gamma=0.3400039865210531, max_depth=3, n_estimators=72;, score=0.722
[CV 5/5] END eta=0.10391074957481086, gamma=0.45250950322194794, max_depth=11, n_estimators=56;, score=0.7
[CV 5/5] END eta=0.23626114564666223, gamma=0.3400039865210531, max_depth=3, n_estimators=72;, score=0.716
[CV 1/5] END eta=0.2932373852619067, gamma=0.19710961686764406, max_depth=9, n_estimators=94;, score=0.698
[CV 4/5] END eta=0.2932373852619067, gamma=0.19710961686764406, max_depth=9, n_estimators=94;, score=0.695
[CV 3/5] END eta=0.2932373852619067, gamma=0.19710961686764406, max_depth=9, n_estimators=94;, score=0.692
[CV 2/5] END eta=0.2932373852619067, gamma=0.19710961686764406, max_depth=9, n_estimators=94;, score=0.686
[CV 5/5] END eta=0.2932373852619067, gamma=0.19710961686764406, max_depth=9, n_estimators=94;, score=0.691
[CV 1/5] END eta=0.022688613720181428, gamma=0.7894809898443876, max_depth=14, n_estimators=99;, score=0.7
[CV 2/5] END eta=0.022688613720181428, gamma=0.7894809898443876, max_depth=14, n_estimators=99;, score=0.7
[CV 3/5] END eta=0.022688613720181428, gamma=0.7894809898443876, max_depth=14, n_estimators=99;, score=0.7
[CV 4/5] END eta=0.022688613720181428, gamma=0.7894809898443876, max_depth=14, n_estimators=99;, score=0.7
[CV 5/5] END eta=0.022688613720181428, gamma=0.7894809898443876, max_depth=14, n_estimators=99;, score=0.7
[CV 1/5] END eta=0.21841795443889847, gamma=0.2155300482271787, max_depth=19, n_estimators=54;, score=0.69
```

```
[CV 2/5] END eta=0.13178289550646216, gamma=0.9289619986786226, max_depth=24, n_estimators=85;, score=0.69
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[CV 3/5] END eta=0.1445151570479201, gamma=0.7706738516203467, max_depth=24, n_estimators=35;, score=0.699
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[CV 3/5] END eta=0.09632752294673054, gamma=0.19331398979738945, max_depth=18, n_estimators=95;, score=0.7
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[CV 4/5] END eta=0.16113428893657555, gamma=0.6463952418580692, max_depth=6, n_estimators=98;, score=0.716
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[CV 4/5] END eta=0.13140125688601198, gamma=0.9551577643506246, max_depth=21, n_estimators=80;, score=0.69
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[CV 4/5] END eta=0.14405461236230377, gamma=0.4923929052716448, max_depth=19, n_estimators=44;, score=0.69
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[CV 4/5] END eta=0.2736754096003681, gamma=0.7693947864094339, max_depth=24, n_estimators=53;, score=0.692
[CV 5/5] END eta=0.2736754096003681, gamma=0.7693947864094339, max_depth=24, n_estimators=53;, score=0.689
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[CV 3/5] END eta=0.0458115383212116, gamma=0.31887509820543447, max_depth=17, n_estimators=57;, score=0.70
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[CV 3/5] END eta=0.23602495804132145, gamma=0.6228709165368539, max_depth=23, n_estimators=88;, score=0.68
[CV 2/5] END eta=0.23602495804132145, gamma=0.6228709165368539, max_depth=23, n_estimators=88;, score=0.68
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[CV 2/5] END eta=0.2309311368797531, gamma=0.9063259556173856, max_depth=10, n_estimators=51;, score=0.697
[CV 5/5] END eta=0.23602495804132145, gamma=0.6228709165368539, max_depth=23, n_estimators=88;, score=0.69
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[CV 2/5] END eta=0.25704879292228283, gamma=0.27334379648767027, max_depth=7, n_estimators=32;, score=0.70
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[CV 3/5] END eta=0.25704879292228283, gamma=0.27334379648767027, max_depth=7, n_estimators=32;, score=0.71
[CV 4/5] END eta=0.2309311368797531, gamma=0.9063259556173856, max_depth=10, n_estimators=51;, score=0.705
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[CV 5/5] END eta=0.25704879292228283, gamma=0.27334379648767027, max_depth=7, n_estimators=32;, score=0.71
[CV 5/5] END eta=0.2309311368797531, gamma=0.9063259556173856, max_depth=10, n_estimators=51;, score=0.699
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[CV 4/5] END eta=0.0458115383212116, gamma=0.31887509820543447, max_depth=17, n_estimators=57;, score=0.70
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[CV 2/5] END eta=0.23137784895194893, gamma=0.36959946375583863, max_depth=7, n_estimators=91;, score=0.70
[CV 1/5] END eta=0.23137784895194893, gamma=0.36959946375583863, max_depth=7, n_estimators=91;, score=0.71
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[CV 2/5] END eta=0.08574502489416694, gamma=0.46563933393684453, max_depth=13, n_estimators=60;, score=0.7
[CV 3/5] END eta=0.08574502489416694, gamma=0.46563933393684453, max_depth=13, n_estimators=60;, score=0.7
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[CV 5/5] END eta=0.08574502489416694, gamma=0.46563933393684453, max_depth=13, n_estimators=60;, score=0.7
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[CV 5/5] END eta=0.23137784895194893, gamma=0.36959946375583863, max_depth=7, n_estimators=91;, score=0.70
[CV 4/5] END eta=0.23137784895194893, gamma=0.36959946375583863, max_depth=7, n_estimators=91;, score=0.71
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[CV 3/5] END eta=0.03463727862237776, gamma=0.9112158758105539, max_depth=17, n_estimators=27;, score=0.70
[CV 4/5] END eta=0.03463727862237776, gamma=0.9112158758105539, max_depth=17, n_estimators=27;, score=0.69
[CV 5/5] END eta=0.03463727862237776, gamma=0.9112158758105539, max_depth=17, n_estimators=27;, score=0.70
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[CV 2/5] END eta=0.03580720612701699, gamma=0.8127166736816995, max_depth=16, n_estimators=42;, score=0.70
[CV 3/5] END eta=0.03580720612701699, gamma=0.8127166736816995, max_depth=16, n_estimators=42;, score=0.70
[CV 4/5] END eta=0.03580720612701699, gamma=0.8127166736816995, max_depth=16, n_estimators=42;, score=0.70
[CV 5/5] END eta=0.03580720612701699, gamma=0.8127166736816995, max_depth=16, n_estimators=42;, score=0.70
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[CV 2/5] END eta=0.04883548565077854, gamma=0.36050541913106093, max_depth=12, n_estimators=20;, score=0.7
[CV 3/5] END eta=0.04883548565077854, gamma=0.36050541913106093, max_depth=12, n_estimators=20;, score=0.7
[CV 1/5] END eta=0.14557420272457333, gamma=0.5920584310425133, max_depth=11, n_estimators=97;, score=0.70
[CV 2/5] END eta=0.14557420272457333, gamma=0.5920584310425133, max_depth=11, n_estimators=97;, score=0.69
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[CV 3/5] END eta=0.14557420272457333, gamma=0.5920584310425133, max_depth=11, n_estimators=97;, score=0.70
[CV 4/5] END eta=0.04883548565077854, gamma=0.36050541913106093, max_depth=12, n_estimators=20;, score=0.7
[CV 5/5] END eta=0.04883548565077854, gamma=0.36050541913106093, max_depth=12, n_estimators=20;, score=0.7
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[CV 2/5] END eta=0.09319364532556253, gamma=0.7683010804739026, max_depth=4, n_estimators=47;, score=0.714
[CV 3/5] END eta=0.09319364532556253, gamma=0.7683010804739026, max_depth=4, n_estimators=47;, score=0.717
[CV 4/5] END eta=0.09319364532556253, gamma=0.7683010804739026, max_depth=4, n_estimators=47;, score=0.719
[CV 5/5] END eta=0.09319364532556253, gamma=0.7683010804739026, max_depth=4, n_estimators=47;, score=0.715
[CV 4/5] END eta=0.14557420272457333, gamma=0.5920584310425133, max_depth=11, n_estimators=97;, score=0.70
[CV 5/5] END eta=0.14557420272457333, gamma=0.5920584310425133, max_depth=11, n_estimators=97;, score=0.70
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[CV 2/5] END eta=0.26038488455626757, gamma=0.8280853742042644, max_depth=14, n_estimators=46;, score=0.68
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[CV 2/5] END eta=0.14951033429411953, gamma=0.4206504598297487, max_depth=21, n_estimators=38;, score=0.69
[CV 3/5] END eta=0.14951033429411953, gamma=0.4206504598297487, max_depth=21, n_estimators=38;, score=0.69
[CV 4/5] END eta=0.14951033429411953, gamma=0.4206504598297487, max_depth=21, n_estimators=38;, score=0.69
[CV 5/5] END eta=0.14951033429411953, gamma=0.4206504598297487, max_depth=21, n_estimators=38;, score=0.69
[CV 3/5] END eta=0.26038488455626757, gamma=0.8280853742042644, max_depth=14, n_estimators=46;, score=0.68
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[CV 2/5] END eta=0.2213964750799868, gamma=0.7023589235048623, max_depth=15, n_estimators=28;, score=0.692
[CV 3/5] END eta=0.2213964750799868, gamma=0.7023589235048623, max_depth=15, n_estimators=28;, score=0.694
[CV 4/5] END eta=0.2213964750799868, gamma=0.7023589235048623, max_depth=15, n_estimators=28;, score=0.697
[CV 4/5] END eta=0.26038488455626757, gamma=0.8280853742042644, max_depth=14, n_estimators=46;, score=0.69
[CV 5/5] END eta=0.2213964750799868, gamma=0.7023589235048623, max_depth=15, n_estimators=28;, score=0.694
[CV 5/5] END eta=0.26038488455626757, gamma=0.8280853742042644, max_depth=14, n_estimators=46;, score=0.69
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[CV 2/5] END eta=0.007465194387867113, gamma=0.3436608860431043, max_depth=12, n_estimators=58;, score=0.7
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[CV 4/5] END eta=0.007465194387867113, gamma=0.3436608860431043, max_depth=12, n_estimators=58;, score=0.7
[CV 5/5] END eta=0.007465194387867113, gamma=0.3436608860431043, max_depth=12, n_estimators=58;, score=0.7
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[CV 2/5] END eta=0.11546669156436308, gamma=0.9004998049522286, max_depth=13, n_estimators=92;, score=0.69
[CV 4/5] END eta=0.11546669156436308, gamma=0.9004998049522286, max_depth=13, n_estimators=92;, score=0.70
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[CV 5/5] END eta=0.11546669156436308, gamma=0.9004998049522286, max_depth=13, n_estimators=92;, score=0.70
[CV 2/5] END eta=0.2404454785325968, gamma=0.4538568881041588, max_depth=17, n_estimators=61;, score=0.681
[CV 3/5] END eta=0.2404454785325968, gamma=0.4538568881041588, max_depth=17, n_estimators=61;, score=0.688
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[CV 4/5] END eta=0.2404454785325968, gamma=0.4538568881041588, max_depth=17, n_estimators=61;, score=0.688
[CV 5/5] END eta=0.2404454785325968, gamma=0.4538568881041588, max_depth=17, n_estimators=61;, score=0.686
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[CV 3/5] END eta=0.20069636075242295, gamma=0.44852502395324234, max_depth=10, n_estimators=70;, score=0.7
[CV 4/5] END eta=0.20069636075242295, gamma=0.44852502395324234, max_depth=10, n_estimators=70;, score=0.7
[CV 5/5] END eta=0.20069636075242295, gamma=0.44852502395324234, max_depth=10, n_estimators=70;, score=0.7
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[CV 2/5] END eta=0.17505920287599852, gamma=0.82079967199633, max_depth=15, n_estimators=60;, score=0.692
[CV 4/5] END eta=0.17505920287599852, gamma=0.82079967199633, max_depth=15, n_estimators=60;, score=0.698
[CV 5/5] END eta=0.17505920287599852, gamma=0.82079967199633, max_depth=15, n_estimators=60;, score=0.696
[CV 3/5] END eta=0.17505920287599852, gamma=0.82079967199633, max_depth=15, n_estimators=60;, score=0.695
Best parameters: {'objective': 'binary:logistic', 'use_label_encoder': None, 'base_score': None, 'booster'
Fitting 5 folds for each of 120 candidates, totalling 600 fits
[CV 3/5] END eta=0.09693236484640758, gamma=0.11403207825004424, max_depth=7, n_estimators=61;, score=0.74
[CV 1/5] END eta=0.09693236484640758, gamma=0.11403207825004424, max_depth=7, n_estimators=61;, score=0.72
[CV 2/5] END eta=0.09693236484640758, gamma=0.11403207825004424, max_depth=7, n_estimators=61;, score=0.72
[CV 1/5] END eta=0.02251368197211202, gamma=0.0984119589860577, max_depth=18, n_estimators=19;, score=0.69
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[CV 4/5] END eta=0.09693236484640758, gamma=0.11403207825004424, max_depth=7, n_estimators=61;, score=0.735
[CV 5/5] END eta=0.09693236484640758, gamma=0.11403207825004424, max_depth=7, n_estimators=61;, score=0.737
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[CV 3/5] END eta=0.02251368197211202, gamma=0.0984119589860577, max_depth=18, n_estimators=19;, score=0.712
[CV 4/5] END eta=0.02251368197211202, gamma=0.0984119589860577, max_depth=18, n_estimators=19;, score=0.703
[CV 5/5] END eta=0.02251368197211202, gamma=0.0984119589860577, max_depth=18, n_estimators=19;, score=0.690
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[CV 2/5] END eta=0.16317485523319927, gamma=0.6372689879388659, max_depth=20, n_estimators=96;, score=0.704
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[CV 3/5] END eta=0.2963257743370346, gamma=0.15346225866548835, max_depth=12, n_estimators=26;, score=0.690
[CV 4/5] END eta=0.2963257743370346, gamma=0.15346225866548835, max_depth=12, n_estimators=26;, score=0.664
[CV 5/5] END eta=0.2963257743370346, gamma=0.15346225866548835, max_depth=12, n_estimators=26;, score=0.680
[CV 3/5] END eta=0.14762694687582234, gamma=0.7192787311844973, max_depth=13, n_estimators=63;, score=0.692
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[CV 2/5] END eta=0.20760347912092822, gamma=0.19650095863866135, max_depth=5, n_estimators=61;, score=0.717
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[CV 5/5] END eta=0.20760347912092822, gamma=0.19650095863866135, max_depth=5, n_estimators=61;, score=0.729
[CV 4/5] END eta=0.14762694687582234, gamma=0.7192787311844973, max_depth=13, n_estimators=63;, score=0.685
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[CV 2/5] END eta=0.03521968340442516, gamma=0.08440659692771924, max_depth=4, n_estimators=62;, score=0.743
[CV 3/5] END eta=0.03521968340442516, gamma=0.08440659692771924, max_depth=4, n_estimators=62;, score=0.760
[CV 4/5] END eta=0.03521968340442516, gamma=0.08440659692771924, max_depth=4, n_estimators=62;, score=0.750
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[CV 2/5] END eta=0.12142386972874392, gamma=0.2598792731290279, max_depth=21, n_estimators=68;, score=0.717
[CV 3/5] END eta=0.12142386972874392, gamma=0.2598792731290279, max_depth=21, n_estimators=68;, score=0.730
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[CV 5/5] END eta=0.20015789953373983, gamma=0.7275469806979427, max_depth=16, n_estimators=52;, score=0.712
[CV 2/5] END eta=0.09108181940766612, gamma=0.03808084413078294, max_depth=11, n_estimators=73;, score=0.67
[CV 3/5] END eta=0.09108181940766612, gamma=0.03808084413078294, max_depth=11, n_estimators=73;, score=0.7
[CV 4/5] END eta=0.09108181940766612, gamma=0.03808084413078294, max_depth=11, n_estimators=73;, score=0.69
[CV 5/5] END eta=0.09108181940766612, gamma=0.03808084413078294, max_depth=11, n_estimators=73;, score=0.69
[CV 4/5] END eta=0.11607955833241236, gamma=0.48624519603565564, max_depth=4, n_estimators=56;, score=0.753
[CV 5/5] END eta=0.11607955833241236, gamma=0.48624519603565564, max_depth=4, n_estimators=56;, score=0.752
[CV 1/5] END eta=0.12005042039877628, gamma=0.9925007026467428, max_depth=11, n_estimators=25;, score=0.687
[CV 2/5] END eta=0.12005042039877628, gamma=0.9925007026467428, max_depth=11, n_estimators=25;, score=0.698
[CV 3/5] END eta=0.12005042039877628, gamma=0.9925007026467428, max_depth=11, n_estimators=25;, score=0.720
[CV 4/5] END eta=0.12005042039877628, gamma=0.9925007026467428, max_depth=11, n_estimators=25;, score=0.717
[CV 5/5] END eta=0.12005042039877628, gamma=0.9925007026467428, max_depth=11, n_estimators=25;, score=0.712
```

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[CV 1/5] END eta=0.04246455125327414, gamma=0.06814422876603421, max_depth=10, n_estimators=43;, score=0.69
[CV 2/5] END eta=0.04246455125327414, gamma=0.06814422876603421, max_depth=10, n_estimators=43;, score=0.7
[CV 3/5] END eta=0.04246455125327414, gamma=0.06814422876603421, max_depth=10, n_estimators=43;, score=0.74
[CV 1/5] END eta=0.07629438619063063, gamma=0.9499819193009356, max_depth=19, n_estimators=65;, score=0.714
[CV 2/5] END eta=0.07629438619063063, gamma=0.9499819193009356, max_depth=19, n_estimators=65;, score=0.712
[CV 3/5] END eta=0.07629438619063063, gamma=0.9499819193009356, max_depth=19, n_estimators=65;, score=0.728
[CV 5/5] END eta=0.07629438619063063, gamma=0.9499819193009356, max_depth=19, n_estimators=65;, score=0.728
[CV 4/5] END eta=0.04246455125327414, gamma=0.06814422876603421, max_depth=10, n_estimators=43;, score=0.72
[CV 4/5] END eta=0.07629438619063063, gamma=0.9499819193009356, max_depth=19, n_estimators=65;, score=0.720
[CV 5/5] END eta=0.04246455125327414, gamma=0.06814422876603421, max_depth=10, n_estimators=43;, score=0.72
[CV 1/5] END eta=0.294672026675952, gamma=0.2785126874672528, max_depth=15, n_estimators=27;, score=0.652 t
[CV 2/5] END eta=0.294672026675952, gamma=0.2785126874672528, max_depth=15, n_estimators=27;, score=0.642 t
[CV 3/5] END eta=0.294672026675952, gamma=0.2785126874672528, max_depth=15, n_estimators=27;, score=0.694 t
[CV 4/5] END eta=0.294672026675952, gamma=0.2785126874672528, max_depth=15, n_estimators=27;, score=0.676 t
[CV 5/5] END eta=0.294672026675952, gamma=0.2785126874672528, max_depth=15, n_estimators=27;, score=0.673 t
[CV 1/5] END eta=0.16960870441223452, gamma=0.4796309073156345, max_depth=13, n_estimators=88;, score=0.659
[CV 3/5] END eta=0.16960870441223452, gamma=0.4796309073156345, max_depth=13, n_estimators=88;, score=0.673
[CV 4/5] END eta=0.16960870441223452, gamma=0.4796309073156345, max_depth=13, n_estimators=88;, score=0.693
[CV 2/5] END eta=0.16960870441223452, gamma=0.4796309073156345, max_depth=13, n_estimators=88;, score=0.654
[CV 5/5] END eta=0.16960870441223452, gamma=0.4796309073156345, max_depth=13, n_estimators=88;, score=0.664
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[CV 2/5] END eta=0.17424304522410275, gamma=0.9803260530839696, max_depth=21, n_estimators=46;, score=0.710
[CV 3/5] END eta=0.17424304522410275, gamma=0.9803260530839696, max_depth=21, n_estimators=46;, score=0.713
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[CV 4/5] END eta=0.17424304522410275, gamma=0.9803260530839696, max_depth=21, n_estimators=46;, score=0.724
[CV 2/5] END eta=0.17296333388410712, gamma=0.25898952006491294, max_depth=16, n_estimators=50;, score=0.68
[CV 3/5] END eta=0.17296333388410712, gamma=0.25898952006491294, max_depth=16, n_estimators=50;, score=0.69
[CV 5/5] END eta=0.17424304522410275, gamma=0.9803260530839696, max_depth=21, n_estimators=46;, score=0.719
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[CV 4/5] END eta=0.17296333388410712, gamma=0.25898952006491294, max_depth=16, n_estimators=50;, score=0.69
[CV 2/5] END eta=0.13858766523746618, gamma=0.4563072872463718, max_depth=18, n_estimators=13;, score=0.692
[CV 5/5] END eta=0.17296333388410712, gamma=0.25898952006491294, max_depth=16, n_estimators=50;, score=0.69
[CV 3/5] END eta=0.13858766523746618, gamma=0.4563072872463718, max_depth=18, n_estimators=13;, score=0.715
[CV 4/5] END eta=0.13858766523746618, gamma=0.4563072872463718, max_depth=18, n_estimators=13;, score=0.704
[CV 5/5] END eta=0.13858766523746618, gamma=0.4563072872463718, max_depth=18, n_estimators=13;, score=0.718
[CV 1/5] END eta=0.11048977899349459, gamma=0.5383872190819712, max_depth=16, n_estimators=68;, score=0.689
[CV 2/5] END eta=0.11048977899349459, gamma=0.5383872190819712, max_depth=16, n_estimators=68;, score=0.70
[CV 4/5] END eta=0.11048977899349459, gamma=0.5383872190819712, max_depth=16, n_estimators=68;, score=0.704
[CV 1/5] END eta=0.09841430527579804, gamma=0.7739489775803414, max_depth=7, n_estimators=66;, score=0.724
[CV 5/5] END eta=0.11048977899349459, gamma=0.5383872190819712, max_depth=16, n_estimators=68;, score=0.690
[CV 3/5] END eta=0.11048977899349459, gamma=0.5383872190819712, max_depth=16, n_estimators=68;, score=0.717
[CV 1/5] END eta=0.043409827030113736, gamma=0.23935423945027312, max_depth=3, n_estimators=22;, score=0.74
[CV 2/5] END eta=0.043409827030113736, gamma=0.23935423945027312, max_depth=3, n_estimators=22;, score=0.74
[CV 3/5] END eta=0.043409827030113736, gamma=0.23935423945027312, max_depth=3, n_estimators=22;, score=0.75
[CV 4/5] END eta=0.043409827030113736, gamma=0.23935423945027312, max_depth=3, n_estimators=22;, score=0.75
[CV 5/5] END eta=0.043409827030113736, gamma=0.23935423945027312, max_depth=3, n_estimators=22;, score=0.75
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[CV 3/5] END eta=0.09841430527579804, gamma=0.7739489775803414, max_depth=7, n_estimators=66;, score=0.735
[CV 4/5] END eta=0.09841430527579804, gamma=0.7739489775803414, max_depth=7, n_estimators=66;, score=0.734
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[CV 1/5] END eta=0.2660987942214451, gamma=0.69342076187658, max_depth=23, n_estimators=42;, score=0.703 to
[CV 2/5] END eta=0.21503115647889984, gamma=0.9598108856642485, max_depth=17, n_estimators=57;, score=0.689
[CV 3/5] END eta=0.21503115647889984, gamma=0.9598108856642485, max_depth=17, n_estimators=57;, score=0.690
[CV 1/5] END eta=0.21503115647889984, gamma=0.9598108856642485, max_depth=17, n_estimators=57;, score=0.694
[CV 4/5] END eta=0.21503115647889984, gamma=0.9598108856642485, max_depth=17, n_estimators=57;, score=0.703
[CV 5/5] END eta=0.21503115647889984, gamma=0.9598108856642485, max_depth=17, n_estimators=57;, score=0.698
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[CV 1/5] END eta=0.1483950340638574, gamma=0.6553668285000566, max_depth=3, n_estimators=30;, score=0.750
[CV 2/5] END eta=0.1483950340638574, gamma=0.6553668285000566, max_depth=3, n_estimators=30;, score=0.748
[CV 3/5] END eta=0.1483950340638574, gamma=0.6553668285000566, max_depth=3, n_estimators=30;, score=0.757
[CV 4/5] END eta=0.1483950340638574, gamma=0.6553668285000566, max_depth=3, n_estimators=30;, score=0.760
[CV 5/5] END eta=0.1483950340638574, gamma=0.6553668285000566, max_depth=3, n_estimators=30;, score=0.760
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[CV 3/5] END eta=0.2660987942214451, gamma=0.69342076187658, max_depth=23, n_estimators=42;, score=0.713 t
[CV 1/5] END eta=0.1425734038082952, gamma=0.9312143242401613, max_depth=10, n_estimators=18;, score=0.675
[CV 2/5] END eta=0.1425734038082952, gamma=0.9312143242401613, max_depth=10, n_estimators=18;, score=0.702
[CV 3/5] END eta=0.1425734038082952, gamma=0.9312143242401613, max_depth=10, n_estimators=18;, score=0.727
[CV 4/5] END eta=0.1425734038082952, gamma=0.9312143242401613, max_depth=10, n_estimators=18;, score=0.717
[CV 5/5] END eta=0.1425734038082952, gamma=0.9312143242401613, max_depth=10, n_estimators=18;, score=0.723
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[CV 3/5] END eta=0.2913846115999528, gamma=0.32181736209265344, max_depth=7, n_estimators=72;, score=0.697
[CV 2/5] END eta=0.2913846115999528, gamma=0.32181736209265344, max_depth=7, n_estimators=72;, score=0.671
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[CV 5/5] END eta=0.2913846115999528, gamma=0.32181736209265344, max_depth=7, n_estimators=72;, score=0.684
[CV 4/5] END eta=0.2660987942214451, gamma=0.69342076187658, max_depth=23, n_estimators=42;, score=0.727 t
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[CV 2/5] END eta=0.018236550005457573, gamma=0.8477947245555494, max_depth=22, n_estimators=46;, score=0.6
[CV 3/5] END eta=0.018236550005457573, gamma=0.8477947245555494, max_depth=22, n_estimators=46;, score=0.7
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[CV 5/5] END eta=0.10755754312381414, gamma=0.11811844019660445, max_depth=23, n_estimators=94;, score=0.7
[CV 3/5] END eta=0.10755754312381414, gamma=0.11811844019660445, max_depth=23, n_estimators=94;, score=0.7
[CV 2/5] END eta=0.10755754312381414, gamma=0.11811844019660445, max_depth=23, n_estimators=94;, score=0.7
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[CV 4/5] END eta=0.018236550005457573, gamma=0.8477947245555494, max_depth=22, n_estimators=46;, score=0.7
[CV 5/5] END eta=0.018236550005457573, gamma=0.8477947245555494, max_depth=22, n_estimators=46;, score=0.7
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[CV 3/5] END eta=0.2613367893400521, gamma=0.35234244883596555, max_depth=22, n_estimators=36;, score=0.71
[CV 2/5] END eta=0.2613367893400521, gamma=0.35234244883596555, max_depth=22, n_estimators=36;, score=0.70
[CV 4/5] END eta=0.2613367893400521, gamma=0.35234244883596555, max_depth=22, n_estimators=36;, score=0.72
[CV 3/5] END eta=0.08427065924520084, gamma=0.12090604086046663, max_depth=19, n_estimators=51;, score=0.7
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[CV 5/5] END eta=0.08427065924520084, gamma=0.12090604086046663, max_depth=19, n_estimators=51;, score=0.7
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[CV 4/5] END eta=0.29459186597423453, gamma=0.2569504085121731, max_depth=7, n_estimators=32;, score=0.713
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[CV 4/5] END eta=0.004043498996956962, gamma=0.2185686270867252, max_depth=4, n_estimators=29;, score=0.74
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[CV 5/5] END eta=0.004043498996956962, gamma=0.2185686270867252, max_depth=4, n_estimators=29;, score=0.75
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[CV 2/5] END eta=0.13144295814674797, gamma=0.6507881564056056, max_depth=23, n_estimators=35;, score=0.70
[CV 3/5] END eta=0.13144295814674797, gamma=0.6507881564056056, max_depth=23, n_estimators=35;, score=0.73
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[CV 3/5] END eta=0.17883005829385099, gamma=0.6734677817884738, max_depth=22, n_estimators=80;, score=0.71
[CV 2/5] END eta=0.17883005829385099, gamma=0.6734677817884738, max_depth=22, n_estimators=80;, score=0.71
[CV 5/5] END eta=0.17883005829385099, gamma=0.6734677817884738, max_depth=22, n_estimators=80;, score=0.72
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[CV 4/5] END eta=0.17883005829385099, gamma=0.6734677817884738, max_depth=22, n_estimators=80;, score=0.72
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[CV 5/5] END eta=0.13144295814674797, gamma=0.6507881564056056, max_depth=23, n_estimators=35;, score=0.71
[CV 2/5] END eta=0.20352770488586386, gamma=0.2261720316073914, max_depth=21, n_estimators=29;, score=0.71
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[CV 4/5] END eta=0.20352770488586386, gamma=0.2261720316073914, max_depth=21, n_estimators=29;, score=0.72
[CV 5/5] END eta=0.20352770488586386, gamma=0.2261720316073914, max_depth=21, n_estimators=29;, score=0.73
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[CV 4/5] END eta=0.0493364866279562, gamma=0.12986646273722302, max_depth=15, n_estimators=29;, score=0.71
[CV 5/5] END eta=0.0493364866279562, gamma=0.12986646273722302, max_depth=15, n_estimators=29;, score=0.71
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[CV 5/5] END eta=0.25484168026426185, gamma=0.885072262835186, max_depth=10, n_estimators=35;, score=0.691
[CV 4/5] END eta=0.25484168026426185, gamma=0.885072262835186, max_depth=10, n_estimators=35;, score=0.692
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[CV 2/5] END eta=0.09669830792659002, gamma=0.2801998500433026, max_depth=9, n_estimators=91;, score=0.695
[CV 3/5] END eta=0.09669830792659002, gamma=0.2801998500433026, max_depth=9, n_estimators=91;, score=0.714
[CV 5/5] END eta=0.09669830792659002, gamma=0.2801998500433026, max_depth=9, n_estimators=91;, score=0.711
[CV 4/5] END eta=0.09669830792659002, gamma=0.2801998500433026, max_depth=9, n_estimators=91;, score=0.714
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[CV 2/5] END eta=0.09193095365056625, gamma=0.9294527661482116, max_depth=3, n_estimators=34;, score=0.748
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[CV 4/5] END eta=0.09193095365056625, gamma=0.9294527661482116, max_depth=3, n_estimators=34;, score=0.759
[CV 5/5] END eta=0.09193095365056625, gamma=0.9294527661482116, max_depth=3, n_estimators=34;, score=0.760
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[CV 4/5] END eta=0.2207204890255427, gamma=0.9075199915780773, max_depth=23, n_estimators=53;, score=0.711
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[CV 2/5] END eta=0.1423369120476529, gamma=0.14035973407693403, max_depth=18, n_estimators=69;, score=0.69
[CV 1/5] END eta=0.12925474715024018, gamma=0.49395272137444646, max_depth=23, n_estimators=90;, score=0.7
[CV 3/5] END eta=0.1423369120476529, gamma=0.14035973407693403, max_depth=18, n_estimators=69;, score=0.72
[CV 2/5] END eta=0.12925474715024018, gamma=0.49395272137444646, max_depth=23, n_estimators=90;, score=0.7
[CV 4/5] END eta=0.12925474715024018, gamma=0.49395272137444646, max_depth=23, n_estimators=90;, score=0.7
[CV 5/5] END eta=0.12925474715024018, gamma=0.49395272137444646, max_depth=23, n_estimators=90;, score=0.7
[CV 3/5] END eta=0.12925474715024018, gamma=0.49395272137444646, max_depth=23, n_estimators=90;, score=0.7
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[CV 1/5] END eta=0.08527325279078456, gamma=0.4334501135076593, max_depth=15, n_estimators=51;, score=0.688
[CV 4/5] END eta=0.1423369120476529, gamma=0.14035973407693403, max_depth=18, n_estimators=69;, score=0.718
[CV 2/5] END eta=0.08527325279078456, gamma=0.4334501135076593, max_depth=15, n_estimators=51;, score=0.689
[CV 3/5] END eta=0.08527325279078456, gamma=0.4334501135076593, max_depth=15, n_estimators=51;, score=0.70
[CV 4/5] END eta=0.08527325279078456, gamma=0.4334501135076593, max_depth=15, n_estimators=51;, score=0.702
[CV 5/5] END eta=0.08527325279078456, gamma=0.4334501135076593, max_depth=15, n_estimators=51;, score=0.703
[CV 5/5] END eta=0.1423369120476529, gamma=0.14035973407693403, max_depth=18, n_estimators=69;, score=0.707
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[CV 2/5] END eta=0.09269749098603643, gamma=0.2367826798489997, max_depth=22, n_estimators=65;, score=0.72
[CV 3/5] END eta=0.09269749098603643, gamma=0.2367826798489997, max_depth=22, n_estimators=65;, score=0.73
[CV 4/5] END eta=0.09269749098603643, gamma=0.2367826798489997, max_depth=22, n_estimators=65;, score=0.73
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[CV 2/5] END eta=0.17086849004921897, gamma=0.5604387811264286, max_depth=24, n_estimators=68;, score=0.707
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[CV 2/5] END eta=0.23068472712577986, gamma=0.13664486783996332, max_depth=6, n_estimators=83;, score=0.70
[CV 3/5] END eta=0.23068472712577986, gamma=0.13664486783996332, max_depth=6, n_estimators=83;, score=0.690
[CV 4/5] END eta=0.23068472712577986, gamma=0.13664486783996332, max_depth=6, n_estimators=83;, score=0.72
[CV 5/5] END eta=0.23068472712577986, gamma=0.13664486783996332, max_depth=6, n_estimators=83;, score=0.700
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[CV 1/5] END eta=0.2884501293925244, gamma=0.8321032351068903, max_depth=17, n_estimators=11;, score=0.688
[CV 1/5] END eta=0.0031851641378659143, gamma=0.6681085486971956, max_depth=8, n_estimators=66;, score=0.7
[CV 2/5] END eta=0.0031851641378659143, gamma=0.6681085486971956, max_depth=8, n_estimators=66;, score=0.7
[CV 2/5] END eta=0.2884501293925244, gamma=0.8321032351068903, max_depth=17, n_estimators=11;, score=0.683
[CV 3/5] END eta=0.0031851641378659143, gamma=0.6681085486971956, max_depth=8, n_estimators=66;, score=0.73
[CV 3/5] END eta=0.2884501293925244, gamma=0.8321032351068903, max_depth=17, n_estimators=11;, score=0.693
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[CV 5/5] END eta=0.0031851641378659143, gamma=0.6681085486971956, max_depth=8, n_estimators=66;, score=0.73
[CV 5/5] END eta=0.2884501293925244, gamma=0.8321032351068903, max_depth=17, n_estimators=11;, score=0.706
[CV 4/5] END eta=0.2884501293925244, gamma=0.8321032351068903, max_depth=17, n_estimators=11;, score=0.702
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[CV 2/5] END eta=0.07559297827213188, gamma=0.08942704300486004, max_depth=8, n_estimators=54;, score=0.718
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[CV 4/5] END eta=0.07559297827213188, gamma=0.08942704300486004, max_depth=8, n_estimators=54;, score=0.728
[CV 2/5] END eta=0.23813471144358772, gamma=0.07225388123204568, max_depth=21, n_estimators=51;, score=0.7
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[CV 5/5] END eta=0.23813471144358772, gamma=0.07225388123204568, max_depth=21, n_estimators=51;, score=0.72
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[CV 5/5] END eta=0.17479704709521984, gamma=0.8930516812615447, max_depth=13, n_estimators=53;, score=0.685
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[CV 3/5] END eta=0.06532810136090356, gamma=0.15424517385669456, max_depth=13, n_estimators=38;, score=0.7
[CV 1/5] END eta=0.1606396627140952, gamma=0.9313674886460941, max_depth=16, n_estimators=21;, score=0.688
[CV 2/5] END eta=0.12012470580405304, gamma=0.11442812106133948, max_depth=16, n_estimators=96;, score=0.69
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[CV 4/5] END eta=0.06532810136090356, gamma=0.15424517385669456, max_depth=13, n_estimators=38;, score=0.70
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[CV 2/5] END eta=0.1606396627140952, gamma=0.9313674886460941, max_depth=16, n_estimators=21;, score=0.696
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[CV 4/5] END eta=0.1606396627140952, gamma=0.9313674886460941, max_depth=16, n_estimators=21;, score=0.697
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[CV 4/5] END eta=0.12012470580405304, gamma=0.11442812106133948, max_depth=16, n_estimators=96;, score=0.7
[CV 2/5] END eta=0.05151811364867115, gamma=0.8757791656956474, max_depth=15, n_estimators=22;, score=0.69
[CV 5/5] END eta=0.12012470580405304, gamma=0.11442812106133948, max_depth=16, n_estimators=96;, score=0.6
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[CV 3/5] END eta=0.020011302932463882, gamma=0.9080653888922094, max_depth=19, n_estimators=12;, score=0.7
[CV 4/5] END eta=0.05151811364867115, gamma=0.8757791656956474, max_depth=15, n_estimators=22;, score=0.71
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[CV 5/5] END eta=0.05151811364867115, gamma=0.8757791656956474, max_depth=15, n_estimators=22;, score=0.71
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[CV 2/5] END eta=0.04997772227877956, gamma=0.15917580821595567, max_depth=17, n_estimators=27;, score=0.6
[CV 3/5] END eta=0.04997772227877956, gamma=0.15917580821595567, max_depth=17, n_estimators=27;, score=0.7
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[CV 1/5] END eta=0.1876315818288863, gamma=0.7982113510203064, max_depth=12, n_estimators=78;, score=0.661
[CV 4/5] END eta=0.1876315818288863, gamma=0.7982113510203064, max_depth=12, n_estimators=78;, score=0.693
[CV 5/5] END eta=0.1876315818288863, gamma=0.7982113510203064, max_depth=12, n_estimators=78;, score=0.678
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[CV 5/5] END eta=0.04997772227877956, gamma=0.15917580821595567, max_depth=17, n_estimators=27;, score=0.7
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[CV 4/5] END eta=0.0730205590403857, gamma=0.5558668307345032, max_depth=13, n_estimators=56;, score=0.700
[CV 2/5] END eta=0.2336819050450189, gamma=0.10079783304410594, max_depth=24, n_estimators=10;, score=0.68
[CV 3/5] END eta=0.2336819050450189, gamma=0.10079783304410594, max_depth=24, n_estimators=10;, score=0.69
[CV 4/5] END eta=0.2336819050450189, gamma=0.10079783304410594, max_depth=24, n_estimators=10;, score=0.70
[CV 5/5] END eta=0.2336819050450189, gamma=0.10079783304410594, max_depth=24, n_estimators=10;, score=0.69
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[CV 2/5] END eta=0.1554430901073848, gamma=0.43062669006216847, max_depth=13, n_estimators=28;, score=0.68
[CV 3/5] END eta=0.1554430901073848, gamma=0.43062669006216847, max_depth=13, n_estimators=28;, score=0.70
[CV 4/5] END eta=0.1554430901073848, gamma=0.43062669006216847, max_depth=13, n_estimators=28;, score=0.69
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[CV 5/5] END eta=0.1554430901073848, gamma=0.43062669006216847, max_depth=13, n_estimators=28;, score=0.70
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[CV 1/5] END eta=0.13805606351599833, gamma=0.7695007573749075, max_depth=7, n_estimators=61;, score=0.725
[CV 2/5] END eta=0.13805606351599833, gamma=0.7695007573749075, max_depth=7, n_estimators=61;, score=0.711
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[CV 2/5] END eta=0.2900076980941258, gamma=0.7830568566436567, max_depth=12, n_estimators=90;, score=0.661
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[CV 4/5] END eta=0.2375699788494041, gamma=0.5293474712589399, max_depth=15, n_estimators=19;, score=0.702
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[CV 1/5] END eta=0.21454380437292087, gamma=0.41080491074132874, max_depth=5, n_estimators=96;, score=0.72
[CV 2/5] END eta=0.21454380437292087, gamma=0.41080491074132874, max_depth=5, n_estimators=96;, score=0.70
[CV 3/5] END eta=0.21454380437292087, gamma=0.41080491074132874, max_depth=5, n_estimators=96;, score=0.72
[CV 4/5] END eta=0.21454380437292087, gamma=0.41080491074132874, max_depth=5, n_estimators=96;, score=0.73
[CV 5/5] END eta=0.21454380437292087, gamma=0.41080491074132874, max_depth=5, n_estimators=96;, score=0.71
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[CV 2/5] END eta=0.112399123554582, gamma=0.05839534357880172, max_depth=10, n_estimators=96;, score=0.686
[CV 3/5] END eta=0.112399123554582, gamma=0.05839534357880172, max_depth=10, n_estimators=96;, score=0.698
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[CV 2/5] END eta=0.18223219309901598, gamma=0.8053261397166107, max_depth=15, n_estimators=95;, score=0.67
[CV 3/5] END eta=0.18223219309901598, gamma=0.8053261397166107, max_depth=15, n_estimators=95;, score=0.69
[CV 4/5] END eta=0.18223219309901598, gamma=0.8053261397166107, max_depth=15, n_estimators=95;, score=0.68
[CV 5/5] END eta=0.18223219309901598, gamma=0.8053261397166107, max_depth=15, n_estimators=95;, score=0.68
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[CV 2/5] END eta=0.035788686645664966, gamma=0.4326688519254027, max_depth=12, n_estimators=53;, score=0.7
[CV 3/5] END eta=0.035788686645664966, gamma=0.4326688519254027, max_depth=12, n_estimators=53;, score=0.7
[CV 4/5] END eta=0.112399123554582, gamma=0.05839534357880172, max_depth=10, n_estimators=96;, score=0.701
[CV 5/5] END eta=0.112399123554582, gamma=0.05839534357880172, max_depth=10, n_estimators=96;, score=0.695
[CV 4/5] END eta=0.035788686645664966, gamma=0.4326688519254027, max_depth=12, n_estimators=53;, score=0.7
[CV 5/5] END eta=0.035788686645664966, gamma=0.4326688519254027, max_depth=12, n_estimators=53;, score=0.7
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[CV 2/5] END eta=0.268699645134079, gamma=0.2805648491280701, max_depth=17, n_estimators=62;, score=0.677
[CV 4/5] END eta=0.268699645134079, gamma=0.2805648491280701, max_depth=17, n_estimators=62;, score=0.694
[CV 3/5] END eta=0.268699645134079, gamma=0.2805648491280701, max_depth=17, n_estimators=62;, score=0.699
[CV 5/5] END eta=0.268699645134079, gamma=0.2805648491280701, max_depth=17, n_estimators=62;, score=0.697
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[CV 1/5] END eta=0.24130778003779169, gamma=0.9617423005246225, max_depth=18, n_estimators=73;, score=0.68
[CV 3/5] END eta=0.24130778003779169, gamma=0.9617423005246225, max_depth=18, n_estimators=73;, score=0.70
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[CV 3/5] END eta=0.20374616165152404, gamma=0.6555855849672974, max_depth=20, n_estimators=29;, score=0.70
[CV 4/5] END eta=0.24130778003779169, gamma=0.9617423005246225, max_depth=18, n_estimators=73;, score=0.70
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[CV 2/5] END eta=0.07898061219928888, gamma=0.894810766643326, max_depth=5, n_estimators=11;, score=0.741
[CV 5/5] END eta=0.24130778003779169, gamma=0.9617423005246225, max_depth=18, n_estimators=73;, score=0.72
[CV 3/5] END eta=0.07898061219928888, gamma=0.894810766643326, max_depth=5, n_estimators=11;, score=0.756
[CV 4/5] END eta=0.07898061219928888, gamma=0.894810766643326, max_depth=5, n_estimators=11;, score=0.751
[CV 5/5] END eta=0.07898061219928888, gamma=0.894810766643326, max_depth=5, n_estimators=11;, score=0.753
[CV 1/5] END eta=0.26182742373312773, gamma=0.7562139312852322, max_depth=12, n_estimators=50;, score=0.65
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[CV 2/5] END eta=0.26182742373312773, gamma=0.7562139312852322, max_depth=12, n_estimators=50;, score=0.654
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[CV 2/5] END eta=0.032922401333451125, gamma=0.8385971405266407, max_depth=17, n_estimators=70;, score=0.70
[CV 3/5] END eta=0.032922401333451125, gamma=0.8385971405266407, max_depth=17, n_estimators=70;, score=0.70
[CV 4/5] END eta=0.032922401333451125, gamma=0.8385971405266407, max_depth=17, n_estimators=70;, score=0.70
[CV 5/5] END eta=0.032922401333451125, gamma=0.8385971405266407, max_depth=17, n_estimators=70;, score=0.7
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[CV 5/5] END eta=0.26182742373312773, gamma=0.7562139312852322, max_depth=12, n_estimators=50;, score=0.680
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[CV 1/5] END eta=0.04804389990761055, gamma=0.8214245808854659, max_depth=24, n_estimators=42;, score=0.702
[CV 2/5] END eta=0.28634617345630864, gamma=0.6570524249375538, max_depth=12, n_estimators=36;, score=0.66
[CV 2/5] END eta=0.04804389990761055, gamma=0.8214245808854659, max_depth=24, n_estimators=42;, score=0.700
[CV 3/5] END eta=0.28634617345630864, gamma=0.6570524249375538, max_depth=12, n_estimators=36;, score=0.65
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[CV 3/5] END eta=0.04804389990761055, gamma=0.8214245808854659, max_depth=24, n_estimators=42;, score=0.714
[CV 5/5] END eta=0.04804389990761055, gamma=0.8214245808854659, max_depth=24, n_estimators=42;, score=0.717
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[CV 1/5] END eta=0.1394028780686791, gamma=0.8680310402763275, max_depth=15, n_estimators=33;, score=0.685
[CV 4/5] END eta=0.1394028780686791, gamma=0.8680310402763275, max_depth=15, n_estimators=33;, score=0.697
[CV 5/5] END eta=0.1394028780686791, gamma=0.8680310402763275, max_depth=15, n_estimators=33;, score=0.703
[CV 2/5] END eta=0.13082681542751276, gamma=0.6090337171313777, max_depth=16, n_estimators=13;, score=0.698
[CV 3/5] END eta=0.1394028780686791, gamma=0.8680310402763275, max_depth=15, n_estimators=33;, score=0.701
[CV 3/5] END eta=0.13082681542751276, gamma=0.6090337171313777, max_depth=16, n_estimators=13;, score=0.700
[CV 4/5] END eta=0.13082681542751276, gamma=0.6090337171313777, max_depth=16, n_estimators=13;, score=0.704
[CV 5/5] END eta=0.13082681542751276, gamma=0.6090337171313777, max_depth=16, n_estimators=13;, score=0.709
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[CV 1/5] END eta=0.21226258247637333, gamma=0.6375418460628859, max_depth=7, n_estimators=66;, score=0.704
[CV 3/5] END eta=0.21226258247637333, gamma=0.6375418460628859, max_depth=7, n_estimators=66;, score=0.705
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[CV 4/5] END eta=0.21226258247637333, gamma=0.6375418460628859, max_depth=7, n_estimators=66;, score=0.709
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[CV 2/5] END eta=0.2278424474095212, gamma=0.10431430679990594, max_depth=6, n_estimators=60;, score=0.704
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[CV 5/5] END eta=0.2278424474095212, gamma=0.10431430679990594, max_depth=6, n_estimators=60;, score=0.727
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[CV 5/5] END eta=0.11593763317559308, gamma=0.3686160858236125, max_depth=6, n_estimators=31;, score=0.743
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[CV 2/5] END eta=0.2285414252402157, gamma=0.07434250845145385, max_depth=17, n_estimators=97;, score=0.694
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[CV 4/5] END eta=0.2285414252402157, gamma=0.07434250845145385, max_depth=17, n_estimators=97;, score=0.709
[CV 5/5] END eta=0.2285414252402157, gamma=0.07434250845145385, max_depth=17, n_estimators=97;, score=0.693
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[CV 4/5] END eta=0.18807813874200097, gamma=0.8176086098596294, max_depth=11, n_estimators=35;, score=0.692
[CV 1/5] END eta=0.11293156051487657, gamma=0.20842416300992406, max_depth=6, n_estimators=77;, score=0.730
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[CV 4/5] END eta=0.11293156051487657, gamma=0.20842416300992406, max_depth=6, n_estimators=77;, score=0.740
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[CV 1/5] END eta=0.16413472864319212, gamma=0.6468550309503979, max_depth=16, n_estimators=55;, score=0.672
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[CV 3/5] END eta=0.16413472864319212, gamma=0.6468550309503979, max_depth=16, n_estimators=55;, score=0.710
[CV 4/5] END eta=0.025899428959015414, gamma=0.7878023802179563, max_depth=22, n_estimators=47;, score=0.70
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[CV 5/5] END eta=0.16413472864319212, gamma=0.6468550309503979, max_depth=16, n_estimators=55;, score=0.680
[CV 1/5] END eta=0.03657258236643136, gamma=0.03683173551098695, max_depth=9, n_estimators=47;, score=0.703
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[CV 1/5] END eta=0.2114989803434484, gamma=0.7420608988337946, max_depth=11, n_estimators=86;, score=0.649
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[CV 4/5] END eta=0.28567753655295186, gamma=0.5996100149678935, max_depth=23, n_estimators=98;, score=0.717
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[CV 4/5] END eta=0.2556209084686469, gamma=0.7248437602432636, max_depth=20, n_estimators=10;, score=0.704
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[CV 3/5] END eta=0.20350359677069904, gamma=0.08836083945602691, max_depth=8, n_estimators=50;, score=0.713
[CV 4/5] END eta=0.20350359677069904, gamma=0.08836083945602691, max_depth=8, n_estimators=50;, score=0.710
[CV 1/5] END eta=0.19227057014224777, gamma=0.11505526817799894, max_depth=3, n_estimators=89;, score=0.745
[CV 5/5] END eta=0.20350359677069904, gamma=0.08836083945602691, max_depth=8, n_estimators=50;, score=0.712
[CV 2/5] END eta=0.19227057014224777, gamma=0.11505526817799894, max_depth=3, n_estimators=89;, score=0.742
[CV 1/5] END eta=0.12277308500325282, gamma=0.37462936023273286, max_depth=20, n_estimators=71;, score=0.7
```

```
[CV 3/5] END eta=0.19227057014224777, gamma=0.11505526817799894, max_depth=3, n_estimators=89;, score=0.75
[CV 4/5] END eta=0.19227057014224777, gamma=0.11505526817799894, max_depth=3, n_estimators=89;, score=0.75
[CV 2/5] END eta=0.12277308500325282, gamma=0.37462936023273286, max_depth=20, n_estimators=71;, score=0.7
[CV 3/5] END eta=0.12277308500325282, gamma=0.37462936023273286, max_depth=20, n_estimators=71;, score=0.7
[CV 5/5] END eta=0.12277308500325282, gamma=0.37462936023273286, max_depth=20, n_estimators=71;, score=0.7
[CV 4/5] END eta=0.12277308500325282, gamma=0.37462936023273286, max_depth=20, n_estimators=71;, score=0.7
[CV 5/5] END eta=0.19227057014224777, gamma=0.11505526817799894, max_depth=3, n_estimators=89;, score=0.74
[CV 1/5] END eta=0.21360362806754435, gamma=0.8822085068096533, max_depth=12, n_estimators=19;, score=0.68
[CV 2/5] END eta=0.21360362806754435, gamma=0.8822085068096533, max_depth=12, n_estimators=19;, score=0.68
[CV 3/5] END eta=0.21360362806754435, gamma=0.8822085068096533, max_depth=12, n_estimators=19;, score=0.70
[CV 4/5] END eta=0.21360362806754435, gamma=0.8822085068096533, max_depth=12, n_estimators=19;, score=0.68
[CV 5/5] END eta=0.21360362806754435, gamma=0.8822085068096533, max_depth=12, n_estimators=19;, score=0.70
[CV 1/5] END eta=0.02475073248623384, gamma=0.414868940023256, max_depth=23, n_estimators=55;, score=0.697
[CV 2/5] END eta=0.02475073248623384, gamma=0.414868940023256, max_depth=23, n_estimators=55;, score=0.696
[CV 5/5] END eta=0.02475073248623384, gamma=0.414868940023256, max_depth=23, n_estimators=55;, score=0.716
[CV 3/5] END eta=0.02475073248623384, gamma=0.414868940023256, max_depth=23, n_estimators=55;, score=0.713
[CV 4/5] END eta=0.02475073248623384, gamma=0.414868940023256, max_depth=23, n_estimators=55;, score=0.705
[CV 1/5] END eta=0.025301348258685675, gamma=0.49144009543100886, max_depth=24, n_estimators=70;, score=0.
[CV 1/5] END eta=0.15907535718034352, gamma=0.31638345961372905, max_depth=24, n_estimators=37;, score=0.7
[CV 2/5] END eta=0.15907535718034352, gamma=0.31638345961372905, max_depth=24, n_estimators=37;, score=0.7
[CV 3/5] END eta=0.15907535718034352, gamma=0.31638345961372905, max_depth=24, n_estimators=37;, score=0.7
[CV 2/5] END eta=0.025301348258685675, gamma=0.49144009543100886, max_depth=24, n_estimators=70;, score=0.
[CV 3/5] END eta=0.025301348258685675, gamma=0.49144009543100886, max_depth=24, n_estimators=70;, score=0.
[CV 4/5] END eta=0.15907535718034352, gamma=0.31638345961372905, max_depth=24, n_estimators=37;, score=0.7
[CV 4/5] END eta=0.025301348258685675, gamma=0.49144009543100886, max_depth=24, n_estimators=70;, score=0.
[CV 2/5] END eta=0.23167199322461038, gamma=0.7486373426469876, max_depth=9, n_estimators=77;, score=0.653
[CV 1/5] END eta=0.23167199322461038, gamma=0.7486373426469876, max_depth=9, n_estimators=77;, score=0.659
[CV 3/5] END eta=0.23167199322461038, gamma=0.7486373426469876, max_depth=9, n_estimators=77;, score=0.690
[CV 5/5] END eta=0.025301348258685675, gamma=0.49144009543100886, max_depth=24, n_estimators=70;, score=0.
[CV 5/5] END eta=0.15907535718034352, gamma=0.31638345961372905, max_depth=24, n_estimators=37;, score=0.7
[CV 4/5] END eta=0.23167199322461038, gamma=0.7486373426469876, max_depth=9, n_estimators=77;, score=0.683
[CV 1/5] END eta=0.08458441415808113, gamma=0.7354400800310227, max_depth=19, n_estimators=26;, score=0.69
[CV 1/5] END eta=0.03204525115265431, gamma=0.9984381290333187, max_depth=10, n_estimators=64;, score=0.69
[CV 5/5] END eta=0.23167199322461038, gamma=0.7486373426469876, max_depth=9, n_estimators=77;, score=0.682
[CV 2/5] END eta=0.08458441415808113, gamma=0.7354400800310227, max_depth=19, n_estimators=26;, score=0.69
[CV 2/5] END eta=0.03204525115265431, gamma=0.9984381290333187, max_depth=10, n_estimators=64;, score=0.71
[CV 3/5] END eta=0.03204525115265431, gamma=0.9984381290333187, max_depth=10, n_estimators=64;, score=0.73
[CV 4/5] END eta=0.03204525115265431, gamma=0.9984381290333187, max_depth=10, n_estimators=64;, score=0.72
[CV 5/5] END eta=0.03204525115265431, gamma=0.9984381290333187, max_depth=10, n_estimators=64;, score=0.72
[CV 1/5] END eta=0.15695091283784576, gamma=0.29400911408811015, max_depth=9, n_estimators=24;, score=0.69
[CV 2/5] END eta=0.15695091283784576, gamma=0.29400911408811015, max_depth=9, n_estimators=24;, score=0.70
[CV 4/5] END eta=0.15695091283784576, gamma=0.29400911408811015, max_depth=9, n_estimators=24;, score=0.71
[CV 3/5] END eta=0.15695091283784576, gamma=0.29400911408811015, max_depth=9, n_estimators=24;, score=0.72
[CV 5/5] END eta=0.15695091283784576, gamma=0.29400911408811015, max_depth=9, n_estimators=24;, score=0.70
[CV 3/5] END eta=0.08458441415808113, gamma=0.7354400800310227, max_depth=19, n_estimators=26;, score=0.71
[CV 5/5] END eta=0.08458441415808113, gamma=0.7354400800310227, max_depth=19, n_estimators=26;, score=0.70
[CV 4/5] END eta=0.08458441415808113, gamma=0.7354400800310227, max_depth=19, n_estimators=26;, score=0.71
[CV 1/5] END eta=0.2802901994628969, gamma=0.3464037735276465, max_depth=6, n_estimators=54;, score=0.705
[CV 2/5] END eta=0.2802901994628969, gamma=0.3464037735276465, max_depth=6, n_estimators=54;, score=0.706
[CV 3/5] END eta=0.2802901994628969, gamma=0.3464037735276465, max_depth=6, n_estimators=54;, score=0.728
[CV 4/5] END eta=0.2802901994628969, gamma=0.3464037735276465, max_depth=6, n_estimators=54;, score=0.710
[CV 5/5] END eta=0.2802901994628969, gamma=0.3464037735276465, max_depth=6, n_estimators=54;, score=0.698
[CV 1/5] END eta=0.1580794692311419, gamma=0.6898739371866951, max_depth=22, n_estimators=42;, score=0.715
[CV 2/5] END eta=0.1580794692311419, gamma=0.6898739371866951, max_depth=22, n_estimators=42;, score=0.715
[CV 3/5] END eta=0.1580794692311419, gamma=0.6898739371866951, max_depth=22, n_estimators=42;, score=0.727
[CV 1/5] END eta=0.1848208773854587, gamma=0.6669924100213908, max_depth=20, n_estimators=74;, score=0.705
```

```
[CV 2/5] END eta=0.1848208773854587, gamma=0.6669924100213908, max_depth=20, n_estimators=74;, score=0.715
[CV 3/5] END eta=0.1848208773854587, gamma=0.6669924100213908, max_depth=20, n_estimators=74;, score=0.715
[CV 5/5] END eta=0.1848208773854587, gamma=0.6669924100213908, max_depth=20, n_estimators=74;, score=0.714
[CV 4/5] END eta=0.1848208773854587, gamma=0.6669924100213908, max_depth=20, n_estimators=74;, score=0.722
[CV 1/5] END eta=0.12723547236274071, gamma=0.5285384427200587, max_depth=9, n_estimators=10;, score=0.706
[CV 2/5] END eta=0.12723547236274071, gamma=0.5285384427200587, max_depth=9, n_estimators=10;, score=0.717
[CV 1/5] END eta=0.25626225220753074, gamma=0.7351787600949421, max_depth=12, n_estimators=53;, score=0.65
[CV 3/5] END eta=0.12723547236274071, gamma=0.5285384427200587, max_depth=9, n_estimators=10;, score=0.741
[CV 4/5] END eta=0.12723547236274071, gamma=0.5285384427200587, max_depth=9, n_estimators=10;, score=0.730
[CV 5/5] END eta=0.12723547236274071, gamma=0.5285384427200587, max_depth=9, n_estimators=10;, score=0.739
[CV 4/5] END eta=0.1580794692311419, gamma=0.6898739371866951, max_depth=22, n_estimators=42;, score=0.730
[CV 5/5] END eta=0.1580794692311419, gamma=0.6898739371866951, max_depth=22, n_estimators=42;, score=0.729
[CV 2/5] END eta=0.25626225220753074, gamma=0.7351787600949421, max_depth=12, n_estimators=53;, score=0.65
[CV 3/5] END eta=0.25626225220753074, gamma=0.7351787600949421, max_depth=12, n_estimators=53;, score=0.66
[CV 4/5] END eta=0.25626225220753074, gamma=0.7351787600949421, max_depth=12, n_estimators=53;, score=0.67
[CV 5/5] END eta=0.25626225220753074, gamma=0.7351787600949421, max_depth=12, n_estimators=53;, score=0.66
[CV 1/5] END eta=0.12227672960952518, gamma=0.54949325065031, max_depth=24, n_estimators=43;, score=0.713
[CV 2/5] END eta=0.12227672960952518, gamma=0.54949325065031, max_depth=24, n_estimators=43;, score=0.713
[CV 3/5] END eta=0.12227672960952518, gamma=0.54949325065031, max_depth=24, n_estimators=43;, score=0.728
[CV 2/5] END eta=0.15815769257031012, gamma=0.3695908458431101, max_depth=22, n_estimators=99;, score=0.70
[CV 1/5] END eta=0.15815769257031012, gamma=0.3695908458431101, max_depth=22, n_estimators=99;, score=0.71
[CV 3/5] END eta=0.15815769257031012, gamma=0.3695908458431101, max_depth=22, n_estimators=99;, score=0.72
[CV 4/5] END eta=0.15815769257031012, gamma=0.3695908458431101, max_depth=22, n_estimators=99;, score=0.73
[CV 5/5] END eta=0.15815769257031012, gamma=0.3695908458431101, max_depth=22, n_estimators=99;, score=0.71
[CV 5/5] END eta=0.12227672960952518, gamma=0.54949325065031, max_depth=24, n_estimators=43;, score=0.737
[CV 4/5] END eta=0.12227672960952518, gamma=0.54949325065031, max_depth=24, n_estimators=43;, score=0.733
[CV 1/5] END eta=0.2198602502595678, gamma=0.4676292303210494, max_depth=19, n_estimators=53;, score=0.689
[CV 2/5] END eta=0.2198602502595678, gamma=0.4676292303210494, max_depth=19, n_estimators=53;, score=0.703
[CV 3/5] END eta=0.2198602502595678, gamma=0.4676292303210494, max_depth=19, n_estimators=53;, score=0.712
[CV 5/5] END eta=0.2198602502595678, gamma=0.4676292303210494, max_depth=19, n_estimators=53;, score=0.710
[CV 4/5] END eta=0.2198602502595678, gamma=0.4676292303210494, max_depth=19, n_estimators=53;, score=0.713
[CV 1/5] END eta=0.2611096553513704, gamma=0.6047087479536545, max_depth=12, n_estimators=74;, score=0.662
[CV 2/5] END eta=0.2611096553513704, gamma=0.6047087479536545, max_depth=12, n_estimators=74;, score=0.659
[CV 3/5] END eta=0.2611096553513704, gamma=0.6047087479536545, max_depth=12, n_estimators=74;, score=0.677
[CV 4/5] END eta=0.2611096553513704, gamma=0.6047087479536545, max_depth=12, n_estimators=74;, score=0.665
[CV 5/5] END eta=0.2611096553513704, gamma=0.6047087479536545, max_depth=12, n_estimators=74;, score=0.664
Best parameters: {'objective': 'binary:logistic', 'use_label_encoder': None, 'base_score': None, 'booster'
```

Ocena modeli

Posiadamy niezbalansowane dane, dlatego też do oceny modeli wykorzystaliśmy metrykę `ROC-AUC`, która jest miarą jakości klasyfikatora binarnego.

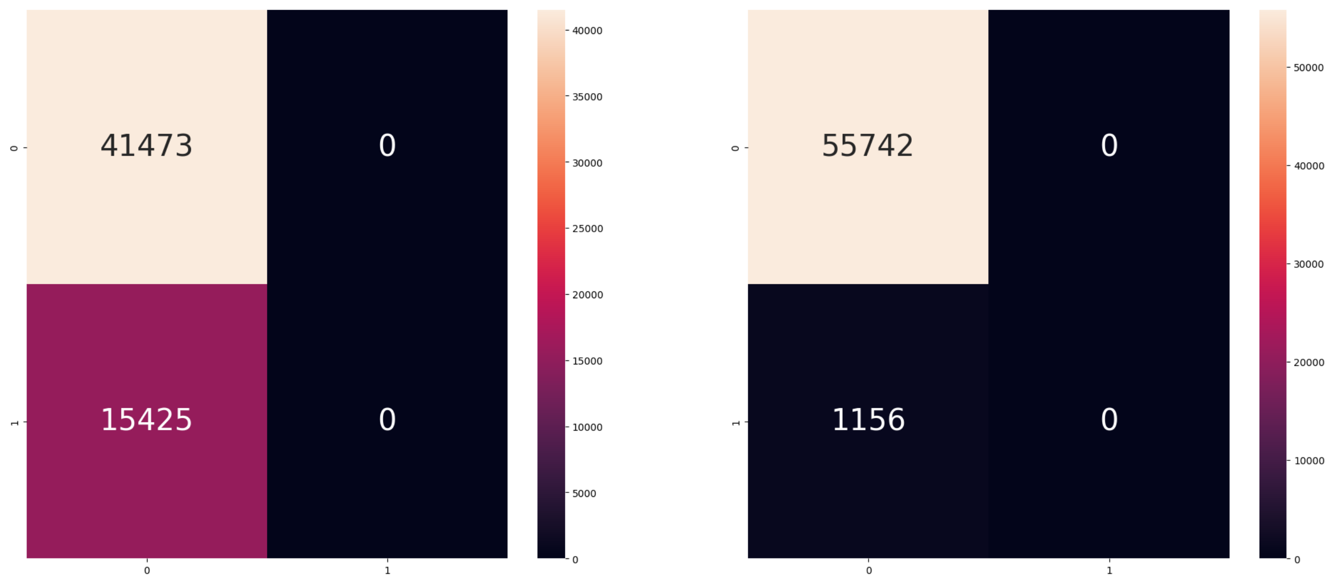
`ROC-AUC` mierzy zdolność modelu do rozróżnienia między dwiema klasami poprzez obliczenie powierzchni pod krzywą ROC. Krzywa ROC przedstawia zależność między wskaźnikiem True Positive Rate = TP / (TP + FN) (czułość) a False Positive Rate = FP / (FP + TN) (specyficzność). Wyższa wartość ROC-AUC oznacza lepszą zdolność modelu do rozróżniania klas.

Nie wykorzystaliśmy metryki `accuracy`, ponieważ w przypadku niezbilansowanych danych, może ona być myląca. Przykładowo, jeśli mamy 1000 obserwacji, z czego 900 należy do klasy 0, a 100 do klasy 1, to model, który zawsze zwraca 0, będzie miał accuracy 90%.

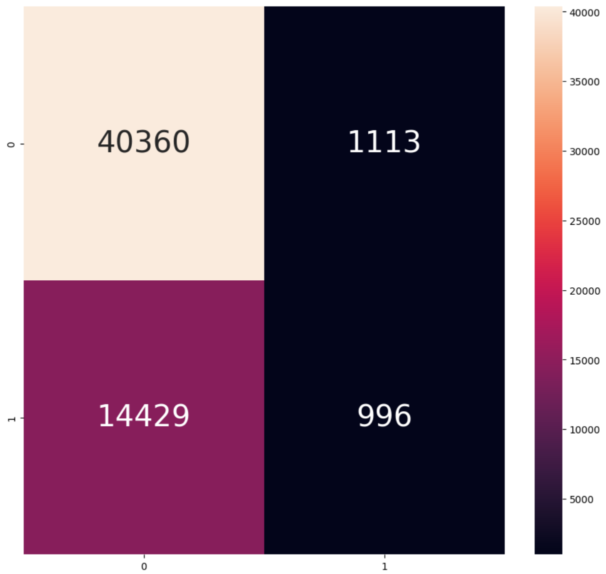
```python
for type in MODEL_TYPES:
    print(type.upper())
    _, axs = plt.subplots(1, 2, figsize=(24, 10))  # type: ignore
    for i, target in enumerate(TARGETS):
        model = MODELS[type][target]
```

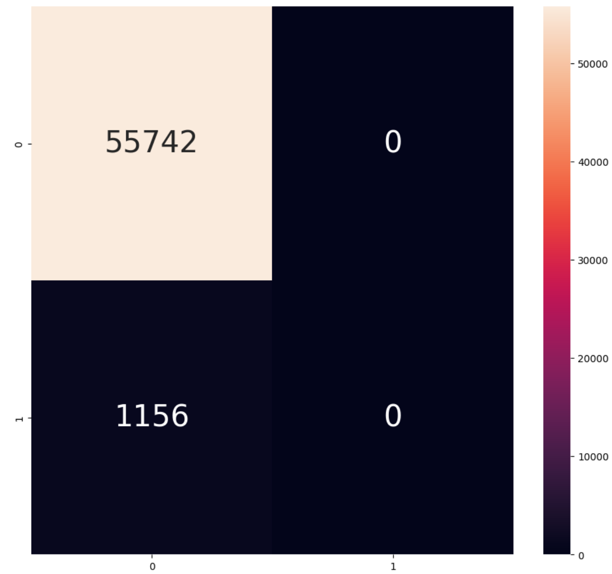
```
        y_predicted = model.predict(X_test)
        y_true = Y_test[target]
        roc_auc_score_value = roc_auc_score(y_true, y_predicted)
        print(f"ROC AUC score for {target}: {roc_auc_score_value}")
        matrix = confusion_matrix(y_true, y_predicted)
        sns.heatmap(
            matrix,
            annot=True,
            annot_kws={"fontsize": 30},
            fmt='g',
            xticklabels=["0", "1"],  # type: ignore
            yticklabels=["0", "1"],  # type: ignore
            ax=axs[i]  # type: ignore
        )
    plt.show()
```

```
DUMMY
ROC AUC score for premium_user_numerical: 0.5
ROC AUC score for will_buy_premium_next_month_numerical: 0.5
```

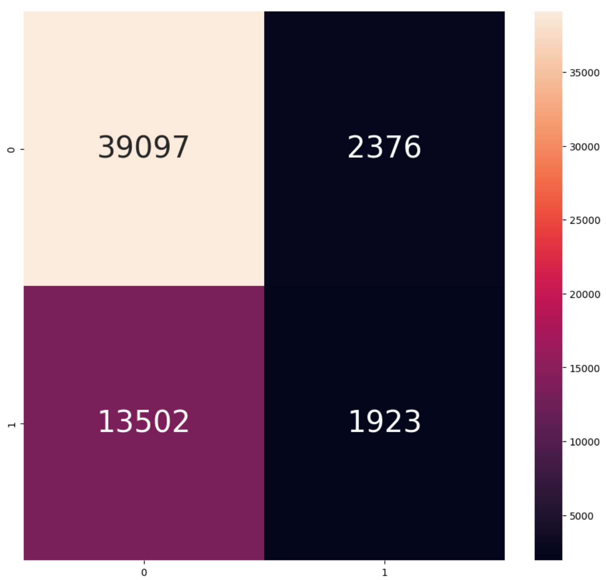


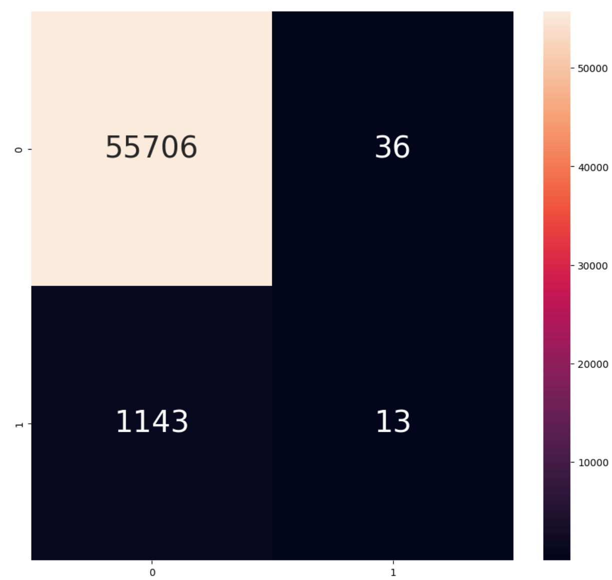

```
LOGISTIC_REGRESSION
ROC AUC score for premium_user_numerical: 0.5188668826384125
ROC AUC score for will_buy_premium_next_month_numerical: 0.5
```



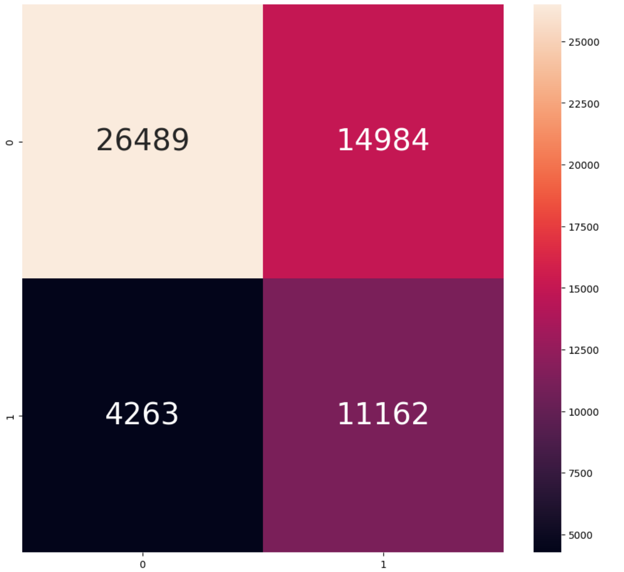


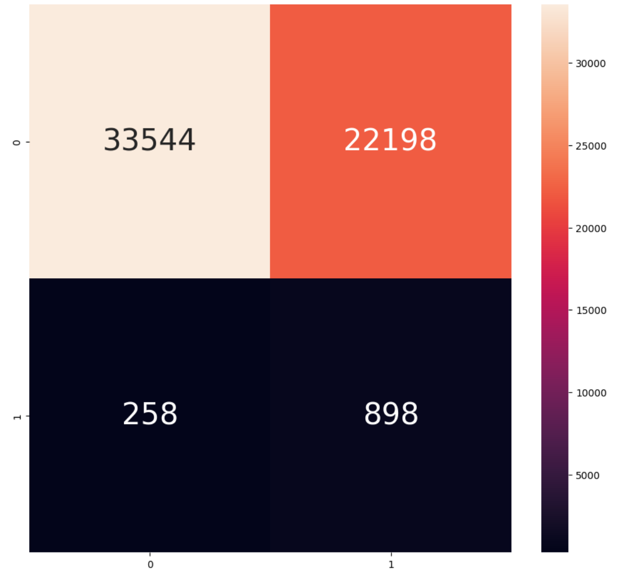

```
XGB_CLASSIFIER
ROC AUC score for premium_user_numerical: 0.5336887309589363
ROC AUC score for will_buy_premium_next_month_numerical: 0.5052999210773211
```






```
XGB_CLASSIFIER_BEST_ESTIMATOR
ROC AUC score for premium_user_numerical: 0.6811675847296093
ROC AUC score for will_buy_premium_next_month_numerical: 0.6892945303243974
```

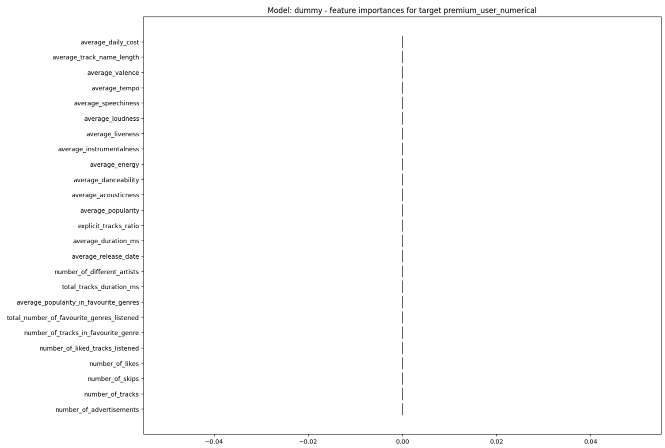


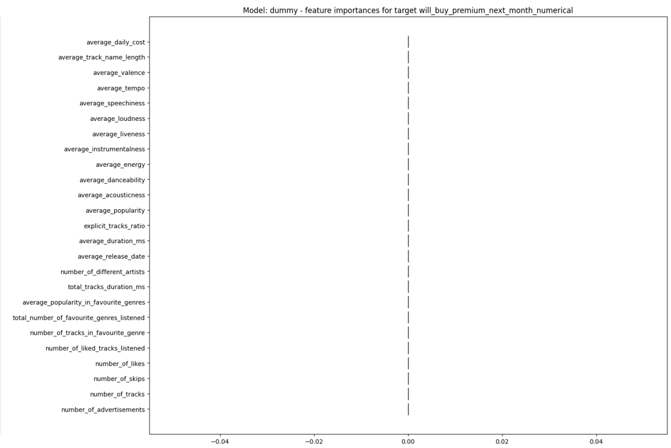


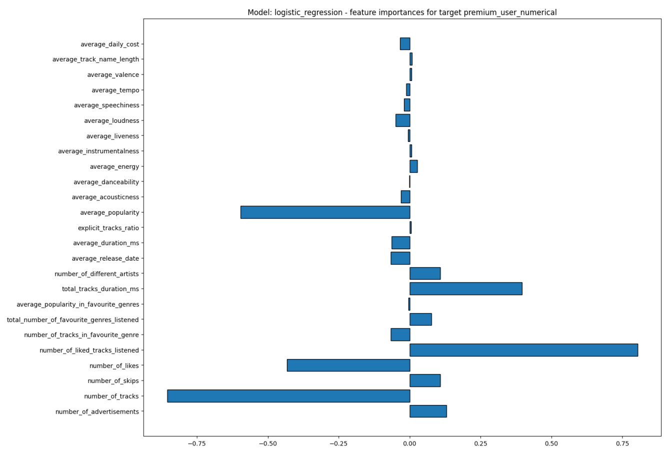
Analizując wyniki możemy zauważyć, że dla przewidywania `premium_user_numerical` (czy użytkownik kiedykolwiek zakupi premium) najgorzej poradził sobie model naiwny `Dummy`, który każdemu przypisuje klasę większościową. Nieznacznie lepsze wyniki na podobnym poziomie, osiągnęły modele `Logistic Regression` oraz `XGB Classifier`. Najlepsze wyniki osiągnął model `XGB Classifier with Randomized Search`, dzięki optymalizacji hiperparametrów. W przypadku `will_buy_premium_next_month_numerical` (czy użytkownik kupi premium w przeciągu miesiąca) modele `Dummy` oraz `Logistic Regression` w każdym przypadku przewidywały klasę większościową. Model `XGB Classifier` był nieznacznie lepszy. Jedynie model `XGB Classifier with Randomized Search` osiągnął lepszy wynik 0.69, jednak kosztem przypisania większej ilości błędnych predykcji w przypadku klasy większościowej.

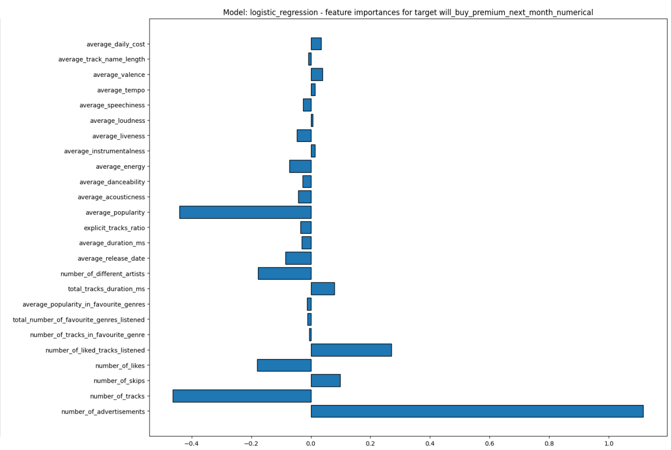
Istotność parametrów

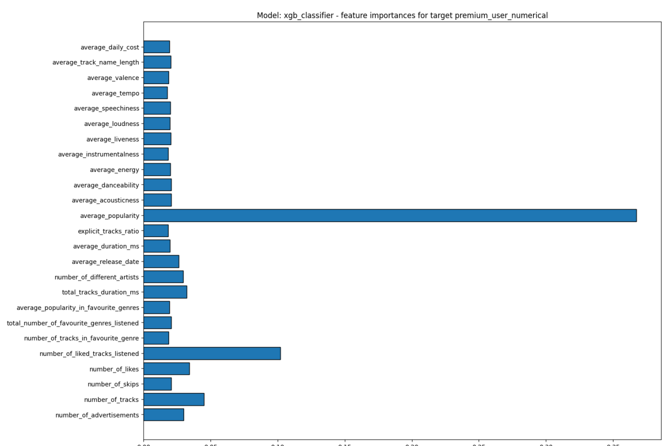
```
def retrieve_weights(model: Model) -> np.ndarray[np.float64]:
    if isinstance(model, LogisticRegression):
        return model.coef_[0]
    if isinstance(model, XGBClassifier):
        return model.feature_importances_
    return np.zeros(len(FEATURES))


for type in MODEL_TYPES:
    _, axs = plt.subplots(1, len(TARGETS), figsize=(
        30, 10), constrained_layout=True)
    for i, target in enumerate(TARGETS):
        model = MODELS[type][target]
        columns = FEATURES
        weights = retrieve_weights(model)
        axs[i].barh(y=columns, width=weights, edgecolor="black")
        axs[i].set_title(
            f"Model: {type} - feature importances for target {target}")
    plt.show()
```

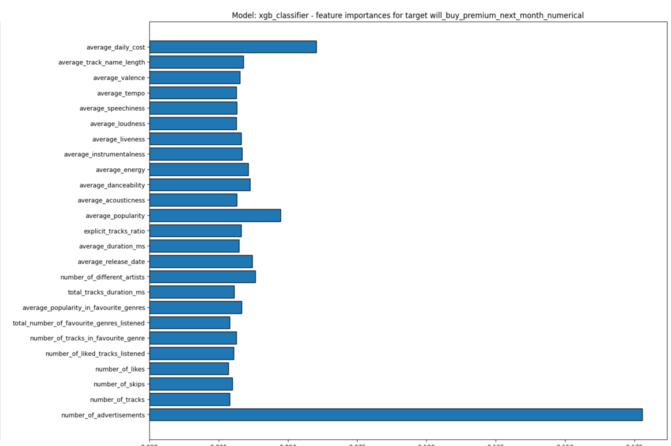

Model: dummy - feature importances for target premium_user_numerical
average_daily_cost
average_track_name_length
average_valence
average_tempo
average_speechiness
average_loudness
average_liveness
average_instrumentalness
average_energy
average_danceability
average_acousticness
average_popularity
explicit_tracks_ratio
average_duration_ms
average_release_date
number_of_different_artists
total_tracks_duration_ms
average_popularity_in_favourite_genres
total_number_of_favourite_genres_listened
number_of_tracks_in_favourite_genre
number_of_liked_tracks_listened
number_of_likes
number_of_skips
number_of_tracks
number_of_advertisements
−0.04
−0.02
0.00
0.02
0.04

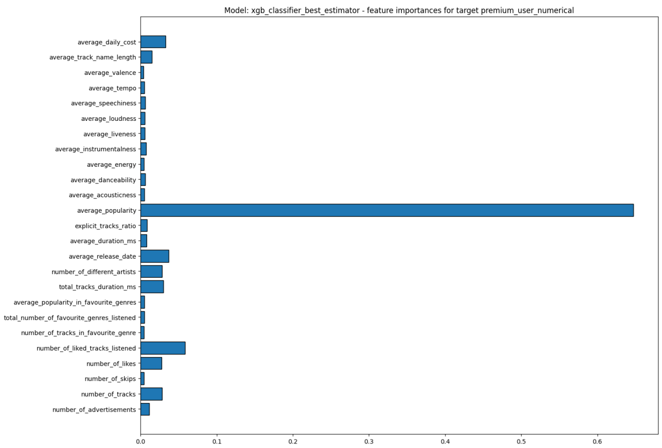

Model: dummy - feature importances for target will_buy_premium_next_month_numerical
average_daily_cost
average_track_name_length
average_valence
average_tempo
average_speechiness
average_loudness
average_liveness
average_instrumentalness
average_energy
average_danceability
average_acousticness
average_popularity
explicit_tracks_ratio
average_duration_ms
average_release_date
number_of_different_artists
total_tracks_duration_ms
average_popularity_in_favourite_genres
total_number_of_favourite_genres_listened
number_of_tracks_in_favourite_genre
number_of_liked_tracks_listened
number_of_likes
number_of_skips
number_of_tracks
number_of_advertisements
−0.04
−0.02
0.00
0.02
0.04

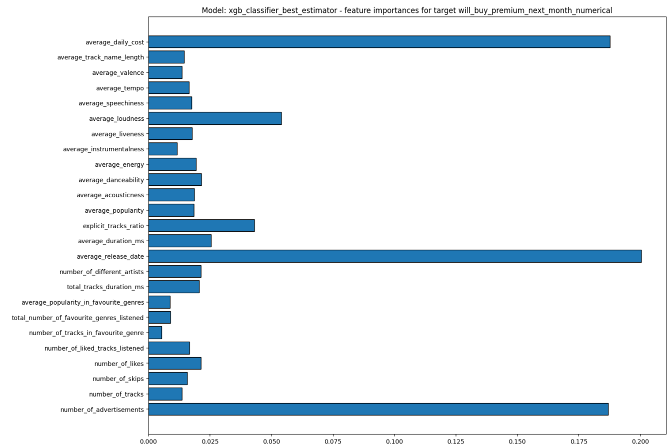

Model: logistic_regression - feature importances for target premium_user_numerical
average_daily_cost
average_track_name_length
average_valence
average_tempo
average_speechiness
average_loudness
average_liveness
average_instrumentalness
average_energy
average_danceability
average_acousticness
average_popularity
explicit_tracks_ratio
average_duration_ms
average_release_date
number_of_different_artists
total_tracks_duration_ms
average_popularity_in_favourite_genres
total_number_of_favourite_genres_listened
number_of_tracks_in_favourite_genre
number_of_liked_tracks_listened
number_of_likes
number_of_skips
number_of_tracks
number_of_advertisements
−0.75
−0.50
−0.25
0.00
0.25
0.50
0.75


Model: logistic_regression - feature importances for target will_buy_premium_next_month_numerical
average_daily_cost
average_track_name_length
average_valence
average_tempo
average_speechiness
average_loudness
average_liveness
average_instrumentalness
average_energy
average_danceability
average_acousticness
average_popularity
explicit_tracks_ratio
average_duration_ms
average_release_date
number_of_different_artists
total_tracks_duration_ms
average_popularity_in_favourite_genres
total_number_of_favourite_genres_listened
number_of_tracks_in_favourite_genre
number_of_liked_tracks_listened
number_of_likes
number_of_skips
number_of_tracks
number_of_advertisements
−0.4
−0.2
0.0
0.2
0.4
0.6
0.8
1.0


Model: xgb_classifier - feature importances for target premium_user_numerical
average_daily_cost
average_track_name_length
average_valence
average_tempo
average_speechiness
average_loudness
average_liveness
average_instrumentalness
average_energy
average_danceability
average_acousticness
average_popularity
explicit_tracks_ratio
average_duration_ms
average_release_date
number_of_different_artists
total_tracks_duration_ms
average_popularity_in_favourite_genres
total_number_of_favourite_genres_listened
number_of_tracks_in_favourite_genre
number_of_liked_tracks_listened
number_of_likes
number_of_skips
number_of_tracks
number_of_advertisements
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35


Model: xgb_classifier - feature importances for target will_buy_premium_next_month_numerical
average_daily_cost
average_track_name_length
average_valence
average_tempo
average_speechiness
average_loudness
average_liveness
average_instrumentalness
average_energy
average_danceability
average_acousticness
average_popularity
explicit_tracks_ratio
average_duration_ms
average_release_date
number_of_different_artists
total_tracks_duration_ms
average_popularity_in_favourite_genres
total_number_of_favourite_genres_listened
number_of_tracks_in_favourite_genre
number_of_liked_tracks_listened
number_of_likes
number_of_skips
number_of_tracks
number_of_advertisements
0.000
0.025
0.050
0.075
0.100
0.125
0.150
0.175





Analizując ważność parametrów możemy zauważyć, że większość parametrów jest brana pod uwagę przez modele, jednakże kilka z nich wyróżnia się na tle pozostałych. W przypadku przewidywania dla tego, czy użytkownik zakupi premium w przeciągu miesiąca najważniejszym parametrem jest `number_of_advertisements`, czyli liczba wyświetlanych reklam. Dodatkowo ostatni wytrenowany model uwzględnia jeszcze `average_release_date` oraz `average_daily_cost`. Możemy z tego wnioskować, że aby użytkownik jak najszybciej zakupił premium powinniśmy manipulować ilością wyświetlanych mu reklam. Natomiast w przypadku przewidywania tego, czy użytkownik kiedykolwiek zakupi premium ważniejsze okazuje się `average_popularity` oraz `number_of_licked_tracks_listened` co oznacza, że użytkownicy, którzy słuchają popularniejszych utworów oraz słuchają polubionych utworów są bardziej skłonni do zakupu premium. Może oznaczać, to, że w długofalowej perspektywie ważniejsze może być proponowanie użytkownikowi utworów, które są popularne oraz utworów, które użytkownik polubił, niż wyświetlanie reklam.

Eksperymenty A/B

Trenujemy wszystkie modele na danych do 2023, a wyniki dla wszystkich modeli zapisujemy do plików pkl. Uruchamiamy mikroserwis, który wczytuje te modele. Następnie dane użytkowników korzystających w roku 2023 dzielimy na różne rzeczywistości i dla każdej z tych grup wykonujemy predykcję z wykorzystaniem naszego mikroserwisu, a następnie przeprowadzamy porównanie za pomocą testu t-studenta.

```
def get_params(model: Model) -> Optional[Dict[str, Any]]:
    if isinstance(model, XGBClassifier):
        return model.get_params()
    return None


X_train = pd.DataFrame(
    pipeline.fit_transform(TRAIN_DATA[FEATURES]),
    columns=FEATURES
)
Y_train = TRAIN_DATA[TARGETS]
for type in MODEL_TYPES:
    estimators = {}
    for target in TARGETS:
        y_train = Y_train[target]
        estimators[target] = MODEL_CONSTRUCTORS[type](
            X_train, y_train, get_params(MODELS[type][target])
        )
    model = IUMModel(pipeline, estimators)
    with open(f'models/{type}.pkl', 'wb') as f:
        pickle.dump(model, f)
```

```
random_ordered_ids = np.random.permutation(TEST_DATA['user_id'].unique())
size = len(random_ordered_ids) // len(MODEL_TYPES)
```

```python
REALITIES: Dict[str, pd.DataFrame] = {}

for i, type in enumerate(MODEL_TYPES):
    ids = random_ordered_ids[i * size:(i + 1) * size]
    mask = TEST_DATA['user_id'].isin(ids)
    REALITIES[type] = TEST_DATA.loc[mask]
```

```python
for type in MODEL_TYPES:
    display(REALITIES[type].head())
```

```
      user_id  year  month  premium_user_numerical  \
942     11621  2023      3                       1
949     11621  2023      1                       1
2378     9065  2023      3                       1
2836    17778  2023      1                       1
2867      583  2023      3                       1

      will_buy_premium_next_month_numerical  number_of_premium  \
942                                       1                  1
949                                       0                  0
2378                                      1                  0
2836                                      1                  0
2867                                      1                  0

      number_of_advertisements  number_of_tracks  number_of_skips  \
942                         15                37                1
949                         13                36                2
2378                        11                36                0
2836                         9                32                1
2867                        11                31               15

      number_of_likes  ...  average_danceability  average_energy  \
942                 5  ...              0.666946        0.577703
949                 8  ...              0.667389        0.615833
2378                8  ...              0.678528        0.589583
2836               10  ...              0.616688        0.566781
2867               11  ...              0.441774        0.660419

      average_instrumentalness  average_liveness  average_loudness  \
942                   0.015345          0.137381         -6.718757
949                   0.029088          0.171839         -6.333861
2378                  0.030580          0.149925         -6.894583
2836                  0.097120          0.207247         -7.540094
2867                  0.066486          0.241710         -8.348548

      average_speechiness  average_tempo  average_valence  \
942              0.084957     108.457351         0.506541
949              0.090872     115.756556         0.561761
2378             0.083008     114.375944         0.515417
2836             0.089953     113.637219         0.393766
2867             0.060265     123.085516         0.419452

      average_track_name_length  average_daily_cost
942                   13.189189            0.023551
949                   13.583333            0.023168
2378                  14.194444            0.022362
```

```
2836                 12.125000           0.024966
2867                 22.258065           0.013564

[5 rows x 31 columns]
      user_id  year  month  premium_user_numerical  \
328      7643  2023      1                       1
331      7643  2023      1                       1
457     18501  2023      1                       1
2943    10173  2023      2                       1
3612    16245  2023      3                       1

      will_buy_premium_next_month_numerical  number_of_premium  \
328                                       0                  0
331                                       0                  0
457                                       1                  0
2943                                      1                  0
3612                                      1                  0

      number_of_advertisements  number_of_tracks  number_of_skips  \
328                         10                26               11
331                          7                26               14
457                         13                28               13
2943                        11                36                2
3612                         9                34               16

      number_of_likes  ...  average_danceability  average_energy  \
328                11  ...              0.481962        0.644192
331                 9  ...              0.499385        0.719962
457                10  ...              0.478964        0.671143
2943                5  ...              0.611306        0.557056
3612               13  ...              0.463882        0.683147

      average_instrumentalness  average_liveness  average_loudness  \
328                   0.122086          0.228292         -9.241962
331                   0.071406          0.198385         -8.612577
457                   0.065366          0.224946         -8.977607
2943                  0.008194          0.135256         -7.189000
3612                  0.080322          0.310679         -8.806382

      average_speechiness  average_tempo  average_valence  \
328              0.066550     125.406462         0.468627
331              0.056546     124.025731         0.591512
457              0.057068     127.819821         0.572821
2943             0.059411     113.502861         0.495778
3612             0.084926     124.870147         0.498176

      average_track_name_length  average_daily_cost
328                   25.692308            0.013864
331                   22.192308            0.012140
457                   21.571429            0.012536
2943                  14.416667            0.022563
3612                  23.264706            0.012730

[5 rows x 31 columns]
      user_id  year  month  premium_user_numerical  \
```

```
41       4074  2023      3                     1
47       4074  2023      1                     1
474      1944  2023      1                     1
483      1944  2023      1                     1
2905     8001  2023      1                     1

      will_buy_premium_next_month_numerical  number_of_premium  \
41                                        1                  0
47                                        0                  0
474                                       1                  0
483                                       1                  0
2905                                      1                  0

      number_of_advertisements  number_of_tracks  number_of_skips  \
41                           1                 6                0
47                          13                37                3
474                          7                27               13
483                          5                13                7
2905                        14                37               19

      number_of_likes  ...  average_danceability  average_energy  \
41                  2  ...              0.626167        0.560333
47                  9  ...              0.673216        0.623946
474                10  ...              0.505333        0.657370
483                 7  ...              0.488308        0.625231
2905                4  ...              0.440108        0.691568

      average_instrumentalness  average_liveness  average_loudness  \
41                    0.005269          0.148200         -6.978667
47                    0.022808          0.185284         -6.816027
474                   0.132346          0.151230         -9.610593
483                   0.189436          0.269831         -9.640538
2905                  0.107200          0.302508         -9.375378

      average_speechiness  average_tempo  average_valence  \
41               0.128867     134.761333         0.527667
47               0.093181     115.215946         0.511486
474              0.081237     129.688852         0.569074
483              0.051131     125.086231         0.607846
2905             0.073959     117.028243         0.418997

      average_track_name_length  average_daily_cost
41                     7.333333            0.019577
47                    11.405405            0.026657
474                   19.925926            0.011697
483                   31.461538            0.012755
2905                  24.783784            0.014111

[5 rows x 31 columns]
      user_id  year  month  premium_user_numerical  \
378     14848  2023      3                       1
443     18214  2023      1                       1
2129     5945  2023      1                       1
2611    15895  2023      3                       1
3385    15047  2023      1                       1
```

```
      will_buy_premium_next_month_numerical  number_of_premium  \
378                                       1                  0
443                                       1                  0
2129                                      1                  1
2611                                      1                  0
3385                                      1                  1

      number_of_advertisements  number_of_tracks  number_of_skips  \
378                         15                36                2
443                          4                16                9
2129                        17                32                0
2611                         2                 5                3
3385                        14                39               19

      number_of_likes  ...  average_danceability  average_energy  \
378                 5  ...              0.648306        0.512556
443                 3  ...              0.480187        0.652187
2129                9  ...              0.654094        0.547312
2611                2  ...              0.513200        0.439800
3385               14  ...              0.487282        0.719385

      average_instrumentalness  average_liveness  average_loudness  \
378                   0.027164          0.155794         -7.668833
443                   0.045305          0.223931         -9.035750
2129                  0.045521          0.120609         -7.680031
2611                  0.025822          0.216700        -12.256600
3385                  0.127397          0.201549         -8.873872

      average_speechiness  average_tempo  average_valence  \
378              0.087006     106.619583         0.463817
443              0.043562     115.447125         0.474750
2129             0.067134     111.153844         0.473512
2611             0.040380     129.347000         0.483400
3385             0.063238     125.130744         0.527464

      average_track_name_length  average_daily_cost
378                   13.333333            0.023180
443                   24.375000            0.014265
2129                  12.312500            0.023636
2611                  34.600000            0.011271
3385                  23.615385            0.012737

[5 rows x 31 columns]
```

```python
result = {
    type: {
        target: pd.DataFrame({
            "guess": [],
            "ground_truth": [],
            "model": [],
            "year": [],
            "month": [],
            "user_id": [],
        })
        for target in TARGETS
    }
    for type in MODEL_TYPES
```

```python
}

for type in MODEL_TYPES:
    url = f'http://127.0.0.1:5000/predict/{type}'
    for i in range(0, len(TEST_DATA)):
        row = TEST_DATA.iloc[i].to_dict()
        response = requests.post(url, json=row).json()
        for target in TARGETS:
            current = pd.DataFrame({
                "guess": [1 if response[target] else 0],
                "ground_truth": [row[target]],
                "model": [type],
                "year": [row['year']],
                "month": [row['month']],
                "user_id": [row['user_id']],
            })
            result[type][target] = pd.concat(
                [result[type][target], current], ignore_index=True
            )
```

```python
for type in MODEL_TYPES:
    print(type.upper())
    for target in TARGETS:
        print(target)
        print()
        print(result[type][target].guess.value_counts())
        print()
        print(result[type][target].ground_truth.value_counts())
        roc_auc_score_value = roc_auc_score(
            result[type][target].ground_truth, result[type][target].guess
        )
        print()
        print('ROC AUC score = ', roc_auc_score_value)
        print()
```

```
DUMMY
premium_user_numerical

0.0    9972
Name: guess, dtype: int64

0.0    9707
1.0     265
Name: ground_truth, dtype: int64

ROC AUC score =  0.5

will_buy_premium_next_month_numerical

0.0    9972
Name: guess, dtype: int64

0.0    9808
1.0     164
Name: ground_truth, dtype: int64

ROC AUC score =  0.5
```

```
LOGISTIC_REGRESSION
premium_user_numerical

0.0    9809
1.0     163
Name: guess, dtype: int64

0.0    9707
1.0     265
Name: ground_truth, dtype: int64

ROC AUC score =  0.5303700305750956

will_buy_premium_next_month_numerical

0.0    9972
Name: guess, dtype: int64

0.0    9808
1.0     164
Name: ground_truth, dtype: int64

ROC AUC score =  0.5

XGB_CLASSIFIER
premium_user_numerical

0.0    9600
1.0     372
Name: guess, dtype: int64

0.0    9707
1.0     265
Name: ground_truth, dtype: int64

ROC AUC score =  0.5389876202934665

will_buy_premium_next_month_numerical

0.0    9967
1.0       5
Name: guess, dtype: int64

0.0    9808
1.0     164
Name: ground_truth, dtype: int64

ROC AUC score =  0.5090443838777703

XGB_CLASSIFIER_BEST_ESTIMATOR
premium_user_numerical

0.0    6858
1.0    3114
Name: guess, dtype: int64
```

```
0.0    9707
1.0     265
Name: ground_truth, dtype: int64

ROC AUC score =  0.6380987460906447

will_buy_premium_next_month_numerical

0.0    6630
1.0    3342
Name: guess, dtype: int64

0.0    9808
1.0     164
Name: ground_truth, dtype: int64

ROC AUC score =  0.6737021545378585
```

```
for type in MODEL_TYPES:
    for target in TARGETS:
        result[type][target].to_csv(f'ab_experiment/{type}-{target}.csv')
```

Ustalamy hipotezę zerową H_0 mówiącą, że pierwszy model nie jest lepszy od drugiego oraz hipotezę alternatywną H_1 głoszącą, że model pierwszy jest lepszy od modelu drugiego.

Na podstawie tabeli rozkładu t-studenta, przyjętego istotności statystycznej jako 0.05 oraz stopni swobody $12+12-2 = 22$ ustaliliśmy wartość parametru t_α jako 2.074

$$t = \frac{\overline{q}_A - \overline{q}_B}{s_p\sqrt{\frac{1}{n_A} + \frac{1}{n_B}}}$$

$$s_p = \sqrt{\frac{(n_A - 1)\sigma^2 + (n_B - 1)\sigma^2}{n_A + n_B - 2}}$$

```
BUCKETS = 12
T_ALPHA = 2.074


def s_p(sigma_A: float, sigma_B: float) -> float:
    return sqrt(
        (BUCKETS - 1) * (sigma_A ** 2) + (BUCKETS - 1) * (sigma_B ** 2)
        / (BUCKETS + BUCKETS - 2)
    )


def t(q_A: float, q_B: float, s_p_value: float) -> float:
    return (q_A - q_B) / (s_p_value * sqrt(1 / BUCKETS + 1 / BUCKETS))
```

```
for type_A, type_B in itertools.product(MODEL_TYPES, MODEL_TYPES):
    if type_A == type_B:
        continue
    print(f'{type_A} vs {type_B}'.upper())
    print()
    for target in TARGETS:
        print(target)
```

```python
        reality_A: pd.DataFrame = result[type_A][target]
        reality_B: pd.DataFrame = result[type_B][target]

        data = pd.concat([reality_A, reality_B])
        random_ordered_ids = np.random.permutation(
            data['user_id'].unique()
        )
        size = len(random_ordered_ids) // BUCKETS

        reality_A_score = []
        reality_B_score = []

        for bucket in range(BUCKETS):
            ids = random_ordered_ids[bucket * size:(i + 1) * size]
            mask = data['user_id'].isin(ids)
            bucket_data = data.loc[mask]
            reality_A_data = bucket_data.loc[bucket_data['model'] == type_A]
            reality_B_data = bucket_data.loc[bucket_data['model'] == type_B]

            reality_A_score.append(
                roc_auc_score(
                    reality_A_data['ground_truth'],
                    reality_A_data['guess'],
                )
            )
            reality_B_score.append(
                roc_auc_score(
                    reality_B_data['ground_truth'],
                    reality_B_data['guess']
                )
            )

        s_p_value = s_p(stdev(reality_A_score), stdev(reality_B_score))
        if s_p_value != 0:
            t_value = t(mean(reality_A_score), mean(
                reality_B_score), s_p_value)
        else:
            t_value = 0

        if t_value > T_ALPHA:
            print(f'{type_A} is better than {type_B}')
        else:
            print(f'We can\'t say that {type_A} is better than {type_B}')
        print()
```

```
DUMMY VS LOGISTIC_REGRESSION

premium_user_numerical
We can't say that dummy is better than logistic_regression

will_buy_premium_next_month_numerical
We can't say that dummy is better than logistic_regression

DUMMY VS XGB_CLASSIFIER

premium_user_numerical
```

```
We can't say that dummy is better than xgb_classifier

will_buy_premium_next_month_numerical
We can't say that dummy is better than xgb_classifier

DUMMY VS XGB_CLASSIFIER_BEST_ESTIMATOR

premium_user_numerical
We can't say that dummy is better than xgb_classifier_best_estimator

will_buy_premium_next_month_numerical
We can't say that dummy is better than xgb_classifier_best_estimator

LOGISTIC_REGRESSION VS DUMMY

premium_user_numerical
We can't say that logistic_regression is better than dummy

will_buy_premium_next_month_numerical
We can't say that logistic_regression is better than dummy

LOGISTIC_REGRESSION VS XGB_CLASSIFIER

premium_user_numerical
We can't say that logistic_regression is better than xgb_classifier

will_buy_premium_next_month_numerical
We can't say that logistic_regression is better than xgb_classifier

LOGISTIC_REGRESSION VS XGB_CLASSIFIER_BEST_ESTIMATOR

premium_user_numerical
We can't say that logistic_regression is better than xgb_classifier_best_estimator

will_buy_premium_next_month_numerical
We can't say that logistic_regression is better than xgb_classifier_best_estimator

XGB_CLASSIFIER VS DUMMY

premium_user_numerical
We can't say that xgb_classifier is better than dummy

will_buy_premium_next_month_numerical
We can't say that xgb_classifier is better than dummy

XGB_CLASSIFIER VS LOGISTIC_REGRESSION

premium_user_numerical
We can't say that xgb_classifier is better than logistic_regression

will_buy_premium_next_month_numerical
We can't say that xgb_classifier is better than logistic_regression

XGB_CLASSIFIER VS XGB_CLASSIFIER_BEST_ESTIMATOR

premium_user_numerical
```

```
We can't say that xgb_classifier is better than xgb_classifier_best_estimator

will_buy_premium_next_month_numerical
We can't say that xgb_classifier is better than xgb_classifier_best_estimator

XGB_CLASSIFIER_BEST_ESTIMATOR VS DUMMY

premium_user_numerical
xgb_classifier_best_estimator is better than dummy

will_buy_premium_next_month_numerical
xgb_classifier_best_estimator is better than dummy

XGB_CLASSIFIER_BEST_ESTIMATOR VS LOGISTIC_REGRESSION

premium_user_numerical
We can't say that xgb_classifier_best_estimator is better than logistic_regression

will_buy_premium_next_month_numerical
xgb_classifier_best_estimator is better than logistic_regression

XGB_CLASSIFIER_BEST_ESTIMATOR VS XGB_CLASSIFIER

premium_user_numerical
We can't say that xgb_classifier_best_estimator is better than xgb_classifier

will_buy_premium_next_month_numerical
xgb_classifier_best_estimator is better than xgb_classifier
```

Z przeprowadzonego eksperymentu wynika, że model `XGB Classifier with Randomized Search` jest lepszy od reszty modeli w przewidywaniu wartości `will_buy_premium_next_month_numerical` oraz jest lepszy od modelu naiwnego `Dummy` w przypadku przewidywania wartości `premium_user_numerical`.