

## 2-rdt-xgboost-model

February 19, 2024

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[ ]: import pandas as pd
import seaborn as sns
import matplotlib.pyplot as plt
import xgboost as xgb
import optuna
from sklearn.model_selection import train_test_split
from sklearn.metrics import root_mean_squared_error
```

```
[ ]: # load data
df = pd.read_csv("../data/processed/contra_contacts_processed.csv")
df.drop(columns=["DATE", "AGE_CATEGORY"], inplace=True)
df.head()
```

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[ ]:
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	AGE	DURATION_MIN	CONTACT_COUNT_TOTAL	SYMPTOMATIC	SYMPTOM_COUNT
0	21.0	17.8	5	True	4
1	86.0	9.3	0	False	0
2	12.0	6.5	3	False	0
3	93.0	2.6	0	False	0
4	24.0	9.1	4	True	3

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[ ]: # setting seed
seed = 42

# define target and predictor columns
target_col = "CONTACT_COUNT_TOTAL"
X = df.loc[:, df.columns != target_col]
y = df.loc[:, target_col]
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[ ]: # defining optuna optimizations study
def objective(trial, data=X, target=y):
    X_train, X_test, y_train, y_test = train_test_split(
        X, y, test_size=0.3, random_state=seed
    )

    params = {
        "lambda": trial.suggest_float("lambda", 1e-3, 10.0),
        "alpha": trial.suggest_float("alpha", 1e-3, 10.0),
        "colsample_bytree": trial.suggest_categorical(
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        "colsample_bytree", [0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0]
    ),
    "subsample": trial.suggest_categorical(
        "subsample", [0.4, 0.5, 0.6, 0.7, 0.8, 1.0]
    ),
    "learning_rate": trial.suggest_categorical(
        "learning_rate", [0.008, 0.01, 0.012, 0.014, 0.016, 0.018, 0.02]
    ),
    "n_estimators": 10000,
    "max_depth": trial.suggest_categorical("max_depth", [5, 7, 9, 11, 13, 15, 17]),
    "random_state": trial.suggest_categorical("random_state", [2020]),
    "min_child_weight": trial.suggest_int("min_child_weight", 1, 300),
}

model = xgb.XGBRegressor(**params)

model.fit(X_train, y_train, eval_set=[(X_test, y_test)], verbose=False)

y_pred = model.predict(X_test)

rmse = root_mean_squared_error(y_test, y_pred)

return rmse

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[ ]: # running optuna optimizations study
study = optuna.create_study(direction="minimize")
study.optimize(objective, n_trials=50)
print("Number of finished trials:", len(study.trials))
print("Best trial:", study.best_trial.params)

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[I 2024-02-19 14:05:32,249] A new study created in memory with name: no-
name-d56bcd4-2b7e-41b8-9f67-f6b283bdac75
[I 2024-02-19 14:06:04,961] Trial 0 finished with value: 2.2416799535379983 and
parameters: {'lambda': 6.970411210243374, 'alpha': 0.6819516557395895,
'colsample_bytree': 1.0, 'subsample': 0.7, 'learning_rate': 0.008, 'max_depth':
5, 'random_state': 2020, 'min_child_weight': 167}. Best is trial 0 with value:
2.2416799535379983.
[I 2024-02-19 14:07:08,642] Trial 1 finished with value: 2.307081604454937 and
parameters: {'lambda': 8.048048387429079, 'alpha': 9.808825429721319,
'colsample_bytree': 0.8, 'subsample': 0.6, 'learning_rate': 0.008, 'max_depth':
11, 'random_state': 2020, 'min_child_weight': 40}. Best is trial 0 with value:
2.2416799535379983.
[I 2024-02-19 14:08:46,893] Trial 2 finished with value: 2.4622087219792412 and
parameters: {'lambda': 2.911287763590079, 'alpha': 3.936835194932718,
'colsample_bytree': 0.8, 'subsample': 0.5, 'learning_rate': 0.016, 'max_depth':
17, 'random_state': 2020, 'min_child_weight': 24}. Best is trial 0 with value:
2.2416799535379983.

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[I 2024-02-19 14:09:15,657] Trial 3 finished with value: 2.2480902755369834 and parameters: {'lambda': 2.484065700090125, 'alpha': 4.767543913571595, 'colsample\_bytree': 0.3, 'subsample': 1.0, 'learning\_rate': 0.01, 'max\_depth': 5, 'random\_state': 2020, 'min\_child\_weight': 187}. Best is trial 0 with value: 2.2416799535379983.

[I 2024-02-19 14:10:01,969] Trial 4 finished with value: 2.253857288853599 and parameters: {'lambda': 3.6456165100169433, 'alpha': 9.635481911722913, 'colsample\_bytree': 1.0, 'subsample': 0.6, 'learning\_rate': 0.012, 'max\_depth': 7, 'random\_state': 2020, 'min\_child\_weight': 268}. Best is trial 0 with value: 2.2416799535379983.

[I 2024-02-19 14:11:00,280] Trial 5 finished with value: 2.2491163506831695 and parameters: {'lambda': 0.1279412902442483, 'alpha': 8.403976228782177, 'colsample\_bytree': 0.7, 'subsample': 1.0, 'learning\_rate': 0.014, 'max\_depth': 13, 'random\_state': 2020, 'min\_child\_weight': 261}. Best is trial 0 with value: 2.2416799535379983.

[I 2024-02-19 14:11:46,853] Trial 6 finished with value: 2.280609525913521 and parameters: {'lambda': 1.696318188672847, 'alpha': 7.89272560193515, 'colsample\_bytree': 1.0, 'subsample': 0.4, 'learning\_rate': 0.01, 'max\_depth': 7, 'random\_state': 2020, 'min\_child\_weight': 42}. Best is trial 0 with value: 2.2416799535379983.

[I 2024-02-19 14:12:38,113] Trial 7 finished with value: 2.249663195976092 and parameters: {'lambda': 3.6903747307917456, 'alpha': 8.549494168620374, 'colsample\_bytree': 0.3, 'subsample': 0.6, 'learning\_rate': 0.016, 'max\_depth': 17, 'random\_state': 2020, 'min\_child\_weight': 59}. Best is trial 0 with value: 2.2416799535379983.

[I 2024-02-19 14:13:09,834] Trial 8 finished with value: 2.2483619749548445 and parameters: {'lambda': 3.9304767031951022, 'alpha': 4.542930323088112, 'colsample\_bytree': 0.4, 'subsample': 0.8, 'learning\_rate': 0.014, 'max\_depth': 5, 'random\_state': 2020, 'min\_child\_weight': 257}. Best is trial 0 with value: 2.2416799535379983.

[I 2024-02-19 14:14:40,352] Trial 9 finished with value: 2.3447271719988683 and parameters: {'lambda': 0.950097196629629, 'alpha': 5.6626772777479495, 'colsample\_bytree': 1.0, 'subsample': 0.8, 'learning\_rate': 0.02, 'max\_depth': 17, 'random\_state': 2020, 'min\_child\_weight': 209}. Best is trial 0 with value: 2.2416799535379983.

[I 2024-02-19 14:15:59,179] Trial 10 finished with value: 2.2638167285901156 and parameters: {'lambda': 6.983945543643193, 'alpha': 0.017107642789387256, 'colsample\_bytree': 0.5, 'subsample': 0.7, 'learning\_rate': 0.008, 'max\_depth': 15, 'random\_state': 2020, 'min\_child\_weight': 120}. Best is trial 0 with value: 2.2416799535379983.

[I 2024-02-19 14:16:36,157] Trial 11 finished with value: 2.2486161920962746 and parameters: {'lambda': 6.304543471767977, 'alpha': 0.15390405727749967, 'colsample\_bytree': 0.3, 'subsample': 0.7, 'learning\_rate': 0.018, 'max\_depth': 5, 'random\_state': 2020, 'min\_child\_weight': 166}. Best is trial 0 with value: 2.2416799535379983.

[I 2024-02-19 14:17:22,569] Trial 12 finished with value: 2.2575135041241845 and parameters: {'lambda': 9.145333478715905, 'alpha': 2.153461615339623, 'colsample\_bytree': 0.9, 'subsample': 1.0, 'learning\_rate': 0.01, 'max\_depth':

9, 'random\_state': 2020, 'min\_child\_weight': 145}. Best is trial 0 with value: 2.2416799535379983.

[I 2024-02-19 14:17:55,842] Trial 13 finished with value: 2.2480346550215557 and parameters: {'lambda': 5.405443700426302, 'alpha': 2.229618618555489, 'colsample\_bytree': 0.3, 'subsample': 0.7, 'learning\_rate': 0.008, 'max\_depth': 5, 'random\_state': 2020, 'min\_child\_weight': 205}. Best is trial 0 with value: 2.2416799535379983.

[I 2024-02-19 14:18:31,963] Trial 14 finished with value: 2.2347716548038496 and parameters: {'lambda': 5.811735997560085, 'alpha': 1.9181948881398794, 'colsample\_bytree': 0.6, 'subsample': 0.7, 'learning\_rate': 0.008, 'max\_depth': 5, 'random\_state': 2020, 'min\_child\_weight': 113}. Best is trial 14 with value: 2.2347716548038496.

[I 2024-02-19 14:19:06,822] Trial 15 finished with value: 2.2353804872247056 and parameters: {'lambda': 7.422591607201745, 'alpha': 1.6392153032228234, 'colsample\_bytree': 0.6, 'subsample': 0.7, 'learning\_rate': 0.008, 'max\_depth': 5, 'random\_state': 2020, 'min\_child\_weight': 93}. Best is trial 14 with value: 2.2347716548038496.

[I 2024-02-19 14:20:17,568] Trial 16 finished with value: 2.265597053171299 and parameters: {'lambda': 9.913640573956727, 'alpha': 2.5061890813792767, 'colsample\_bytree': 0.6, 'subsample': 0.7, 'learning\_rate': 0.008, 'max\_depth': 13, 'random\_state': 2020, 'min\_child\_weight': 88}. Best is trial 14 with value: 2.2347716548038496.

[I 2024-02-19 14:21:09,153] Trial 17 finished with value: 2.2510360789076915 and parameters: {'lambda': 5.50792882509936, 'alpha': 3.3166071605837812, 'colsample\_bytree': 0.6, 'subsample': 0.4, 'learning\_rate': 0.012, 'max\_depth': 9, 'random\_state': 2020, 'min\_child\_weight': 95}. Best is trial 14 with value: 2.2347716548038496.

[I 2024-02-19 14:22:08,682] Trial 18 finished with value: 2.2697526774556187 and parameters: {'lambda': 8.349659820648306, 'alpha': 6.103611049453539, 'colsample\_bytree': 0.6, 'subsample': 0.5, 'learning\_rate': 0.018, 'max\_depth': 11, 'random\_state': 2020, 'min\_child\_weight': 80}. Best is trial 14 with value: 2.2347716548038496.

[I 2024-02-19 14:23:21,999] Trial 19 finished with value: 2.2829685412419702 and parameters: {'lambda': 4.627383967531788, 'alpha': 1.2565493100710126, 'colsample\_bytree': 0.6, 'subsample': 0.7, 'learning\_rate': 0.02, 'max\_depth': 15, 'random\_state': 2020, 'min\_child\_weight': 126}. Best is trial 14 with value: 2.2347716548038496.

[I 2024-02-19 14:23:56,272] Trial 20 finished with value: 2.2348109559309632 and parameters: {'lambda': 7.7421688206753, 'alpha': 1.4118567271666254, 'colsample\_bytree': 0.6, 'subsample': 0.7, 'learning\_rate': 0.008, 'max\_depth': 5, 'random\_state': 2020, 'min\_child\_weight': 112}. Best is trial 14 with value: 2.2347716548038496.

[I 2024-02-19 14:24:31,233] Trial 21 finished with value: 2.244857093845034 and parameters: {'lambda': 7.675783207756011, 'alpha': 1.4287967562629584, 'colsample\_bytree': 0.6, 'subsample': 0.7, 'learning\_rate': 0.008, 'max\_depth': 5, 'random\_state': 2020, 'min\_child\_weight': 1}. Best is trial 14 with value: 2.2347716548038496.

[I 2024-02-19 14:25:06,155] Trial 22 finished with value: 2.2346286533327078 and

parameters: {'lambda': 6.207119112012074, 'alpha': 3.1327331846522792, 'colsample\_bytree': 0.6, 'subsample': 0.7, 'learning\_rate': 0.008, 'max\_depth': 5, 'random\_state': 2020, 'min\_child\_weight': 119}. Best is trial 22 with value: 2.2346286533327078.

[I 2024-02-19 14:25:40,936] Trial 23 finished with value: 2.2335887140660033 and parameters: {'lambda': 6.303436542489944, 'alpha': 3.201242151637115, 'colsample\_bytree': 0.6, 'subsample': 0.7, 'learning\_rate': 0.008, 'max\_depth': 5, 'random\_state': 2020, 'min\_child\_weight': 139}. Best is trial 23 with value: 2.2335887140660033.

[I 2024-02-19 14:26:15,052] Trial 24 finished with value: 2.2339988889893125 and parameters: {'lambda': 5.908623148573082, 'alpha': 3.1817440006670257, 'colsample\_bytree': 0.7, 'subsample': 0.7, 'learning\_rate': 0.008, 'max\_depth': 5, 'random\_state': 2020, 'min\_child\_weight': 132}. Best is trial 23 with value: 2.2335887140660033.

[I 2024-02-19 14:26:49,750] Trial 25 finished with value: 2.233348845227297 and parameters: {'lambda': 6.4937619142814516, 'alpha': 3.298432168867441, 'colsample\_bytree': 0.7, 'subsample': 0.7, 'learning\_rate': 0.008, 'max\_depth': 5, 'random\_state': 2020, 'min\_child\_weight': 150}. Best is trial 25 with value: 2.233348845227297.

[I 2024-02-19 14:27:25,350] Trial 26 finished with value: 2.2317058510047847 and parameters: {'lambda': 4.937846217870659, 'alpha': 3.578416122563689, 'colsample\_bytree': 0.7, 'subsample': 0.5, 'learning\_rate': 0.008, 'max\_depth': 5, 'random\_state': 2020, 'min\_child\_weight': 222}. Best is trial 26 with value: 2.2317058510047847.

[I 2024-02-19 14:28:22,034] Trial 27 finished with value: 2.247790276897355 and parameters: {'lambda': 4.717255667275292, 'alpha': 6.1269156324557645, 'colsample\_bytree': 0.7, 'subsample': 0.5, 'learning\_rate': 0.014, 'max\_depth': 11, 'random\_state': 2020, 'min\_child\_weight': 226}. Best is trial 26 with value: 2.2317058510047847.

[I 2024-02-19 14:29:28,162] Trial 28 finished with value: 2.247780460617853 and parameters: {'lambda': 6.68711513671064, 'alpha': 4.03460578668891, 'colsample\_bytree': 0.7, 'subsample': 0.5, 'learning\_rate': 0.012, 'max\_depth': 13, 'random\_state': 2020, 'min\_child\_weight': 235}. Best is trial 26 with value: 2.2317058510047847.

[I 2024-02-19 14:30:05,336] Trial 29 finished with value: 2.2308354083599675 and parameters: {'lambda': 8.58600777460456, 'alpha': 5.322150421377522, 'colsample\_bytree': 0.7, 'subsample': 0.5, 'learning\_rate': 0.008, 'max\_depth': 5, 'random\_state': 2020, 'min\_child\_weight': 296}. Best is trial 29 with value: 2.2308354083599675.

[I 2024-02-19 14:30:48,175] Trial 30 finished with value: 2.240028107686812 and parameters: {'lambda': 9.030754726684261, 'alpha': 6.94748658869946, 'colsample\_bytree': 0.7, 'subsample': 0.5, 'learning\_rate': 0.018, 'max\_depth': 7, 'random\_state': 2020, 'min\_child\_weight': 297}. Best is trial 29 with value: 2.2308354083599675.

[I 2024-02-19 14:31:24,076] Trial 31 finished with value: 2.232208268153954 and parameters: {'lambda': 8.679711848948786, 'alpha': 5.369093679910319, 'colsample\_bytree': 0.7, 'subsample': 0.5, 'learning\_rate': 0.008, 'max\_depth': 5, 'random\_state': 2020, 'min\_child\_weight': 169}. Best is trial 29 with value:

2.2308354083599675.

[I 2024-02-19 14:31:58,998] Trial 32 finished with value: 2.232301798921591 and parameters: {'lambda': 8.464206072394669, 'alpha': 5.396398387423498, 'colsample\_bytree': 0.7, 'subsample': 0.5, 'learning\_rate': 0.008, 'max\_depth': 5, 'random\_state': 2020, 'min\_child\_weight': 167}. Best is trial 29 with value: 2.2308354083599675.

[I 2024-02-19 14:32:35,221] Trial 33 finished with value: 2.2317281202612915 and parameters: {'lambda': 8.580605198716023, 'alpha': 5.436403916666777, 'colsample\_bytree': 0.7, 'subsample': 0.5, 'learning\_rate': 0.008, 'max\_depth': 5, 'random\_state': 2020, 'min\_child\_weight': 178}. Best is trial 29 with value: 2.2308354083599675.

[I 2024-02-19 14:33:25,509] Trial 34 finished with value: 2.2483695507648993 and parameters: {'lambda': 9.732237770953093, 'alpha': 6.810541175275475, 'colsample\_bytree': 0.7, 'subsample': 0.5, 'learning\_rate': 0.016, 'max\_depth': 9, 'random\_state': 2020, 'min\_child\_weight': 190}. Best is trial 29 with value: 2.2308354083599675.

[I 2024-02-19 14:34:01,659] Trial 35 finished with value: 2.2339091929055304 and parameters: {'lambda': 8.976378162058221, 'alpha': 4.243203595643355, 'colsample\_bytree': 0.8, 'subsample': 0.5, 'learning\_rate': 0.008, 'max\_depth': 5, 'random\_state': 2020, 'min\_child\_weight': 296}. Best is trial 29 with value: 2.2308354083599675.

[I 2024-02-19 14:35:10,681] Trial 36 finished with value: 2.2616734224683976 and parameters: {'lambda': 7.187014926563883, 'alpha': 5.143400206014303, 'colsample\_bytree': 0.7, 'subsample': 0.5, 'learning\_rate': 0.02, 'max\_depth': 15, 'random\_state': 2020, 'min\_child\_weight': 183}. Best is trial 29 with value: 2.2308354083599675.

[I 2024-02-19 14:36:13,050] Trial 37 finished with value: 2.252802668232195 and parameters: {'lambda': 8.192435116134469, 'alpha': 6.913872412381166, 'colsample\_bytree': 0.9, 'subsample': 0.5, 'learning\_rate': 0.008, 'max\_depth': 11, 'random\_state': 2020, 'min\_child\_weight': 233}. Best is trial 29 with value: 2.2308354083599675.

[I 2024-02-19 14:37:04,124] Trial 38 finished with value: 2.250030966464017 and parameters: {'lambda': 2.5342238739228256, 'alpha': 4.801548304610598, 'colsample\_bytree': 0.4, 'subsample': 0.5, 'learning\_rate': 0.016, 'max\_depth': 17, 'random\_state': 2020, 'min\_child\_weight': 276}. Best is trial 29 with value: 2.2308354083599675.

[I 2024-02-19 14:37:46,063] Trial 39 finished with value: 2.2380883724146288 and parameters: {'lambda': 4.124470716604636, 'alpha': 5.950063871304157, 'colsample\_bytree': 0.5, 'subsample': 0.6, 'learning\_rate': 0.01, 'max\_depth': 7, 'random\_state': 2020, 'min\_child\_weight': 250}. Best is trial 29 with value: 2.2308354083599675.

[I 2024-02-19 14:38:22,501] Trial 40 finished with value: 2.2357473605647584 and parameters: {'lambda': 3.2723439445042732, 'alpha': 3.7499821097205523, 'colsample\_bytree': 0.7, 'subsample': 0.5, 'learning\_rate': 0.014, 'max\_depth': 5, 'random\_state': 2020, 'min\_child\_weight': 166}. Best is trial 29 with value: 2.2308354083599675.

[I 2024-02-19 14:38:57,569] Trial 41 finished with value: 2.2315826366806912 and parameters: {'lambda': 8.623706579941345, 'alpha': 5.333719681724232,

'colsample\_bytree': 0.7, 'subsample': 0.5, 'learning\_rate': 0.008, 'max\_depth': 5, 'random\_state': 2020, 'min\_child\_weight': 181}. Best is trial 29 with value: 2.2308354083599675.

[I 2024-02-19 14:39:31,956] Trial 42 finished with value: 2.2319050350898424 and parameters: {'lambda': 9.502891023893246, 'alpha': 4.606371821414966, 'colsample\_bytree': 0.7, 'subsample': 0.5, 'learning\_rate': 0.008, 'max\_depth': 5, 'random\_state': 2020, 'min\_child\_weight': 206}. Best is trial 29 with value: 2.2308354083599675.

[I 2024-02-19 14:40:06,966] Trial 43 finished with value: 2.232646412882698 and parameters: {'lambda': 9.496330302734322, 'alpha': 4.54747828588099, 'colsample\_bytree': 0.7, 'subsample': 0.8, 'learning\_rate': 0.008, 'max\_depth': 5, 'random\_state': 2020, 'min\_child\_weight': 207}. Best is trial 29 with value: 2.2308354083599675.

[I 2024-02-19 14:40:42,576] Trial 44 finished with value: 2.231114981105639 and parameters: {'lambda': 9.360281232039322, 'alpha': 6.617574302583474, 'colsample\_bytree': 0.7, 'subsample': 0.4, 'learning\_rate': 0.008, 'max\_depth': 5, 'random\_state': 2020, 'min\_child\_weight': 222}. Best is trial 29 with value: 2.2308354083599675.

[I 2024-02-19 14:41:17,782] Trial 45 finished with value: 2.236398528222862 and parameters: {'lambda': 7.71510541190886, 'alpha': 7.52212234629492, 'colsample\_bytree': 0.8, 'subsample': 0.4, 'learning\_rate': 0.012, 'max\_depth': 5, 'random\_state': 2020, 'min\_child\_weight': 275}. Best is trial 29 with value: 2.2308354083599675.

[I 2024-02-19 14:42:40,769] Trial 46 finished with value: 2.2628258693558387 and parameters: {'lambda': 8.686029634663779, 'alpha': 6.606209447216889, 'colsample\_bytree': 1.0, 'subsample': 0.4, 'learning\_rate': 0.008, 'max\_depth': 17, 'random\_state': 2020, 'min\_child\_weight': 221}. Best is trial 29 with value: 2.2308354083599675.

[I 2024-02-19 14:43:36,663] Trial 47 finished with value: 2.2464047687420523 and parameters: {'lambda': 8.03827955341762, 'alpha': 7.452084417667172, 'colsample\_bytree': 0.7, 'subsample': 1.0, 'learning\_rate': 0.01, 'max\_depth': 13, 'random\_state': 2020, 'min\_child\_weight': 245}. Best is trial 29 with value: 2.2308354083599675.

[I 2024-02-19 14:44:07,532] Trial 48 finished with value: 2.2485828869978848 and parameters: {'lambda': 9.319793309479033, 'alpha': 5.730169362782144, 'colsample\_bytree': 0.4, 'subsample': 0.4, 'learning\_rate': 0.008, 'max\_depth': 5, 'random\_state': 2020, 'min\_child\_weight': 192}. Best is trial 29 with value: 2.2308354083599675.

[I 2024-02-19 14:44:43,335] Trial 49 finished with value: 2.2380340426731657 and parameters: {'lambda': 9.947133875890087, 'alpha': 8.42740933306834, 'colsample\_bytree': 0.5, 'subsample': 0.6, 'learning\_rate': 0.02, 'max\_depth': 5, 'random\_state': 2020, 'min\_child\_weight': 180}. Best is trial 29 with value: 2.2308354083599675.

Number of finished trials: 50

Best trial: {'lambda': 8.58600777460456, 'alpha': 5.322150421377522, 'colsample\_bytree': 0.7, 'subsample': 0.5, 'learning\_rate': 0.008, 'max\_depth': 5, 'random\_state': 2020, 'min\_child\_weight': 296}

```
[ ]: # visualize optimization history
optuna.visualization.plot_optimization_history(study)
```

```
[ ]: # final model
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.3)
final_model = xgb.XGBRegressor(**study.best_trial.params)
final_model.fit(
    X_train,
    y_train,
    eval_set=[(X_test, y_test)],
    verbose=0,
)
y_pred = final_model.predict(X_test)
rmse = root_mean_squared_error(y_test, y_pred)
print(f"the rmse of the final model is {rmse}")
```

the rmse of the final model is 2.492829116048651

```
[ ]: # saving final model
final_model.save_model("../models/model.json")
```

sources:

- <https://forecastegy.com/posts/xgboost-hyperparameter-tuning-with-optuna/>
- <https://medium.com/optuna/using-optuna-to-optimize-xgboost-hyperparameters-63bfcd3407>
- <https://www.kaggle.com/code/hamzaghanmi/xgboost-catboost-using-optuna?scriptVersionId=94510532>