Деректерді өңдеу мамандарына арналған практикалық статистика (Python)

6-тарау. Статистикалық Машиналық оқыту

Import required Python packages.

In [1]:

```
import math
import os
import random
from pathlib import Path
from collections import defaultdict
from itertools import product


import pandas as pd
import numpy as np

from sklearn import preprocessing
from sklearn.neighbors import KNeighborsClassifier
from sklearn import metrics
from sklearn.model_selection import train_test_split
from sklearn.tree import DecisionTreeClassifier
from sklearn.ensemble import RandomForestClassifier

from xgboost import XGBClassifier

from dmba import plotDecisionTree, textDecisionTree

import seaborn as sns
import matplotlib.pyplot as plt
from matplotlib.patches import Ellipse

%matplotlib inline
```

```
/opt/conda/lib/python3.9/site-packages/xgboost/compat.py:36: FutureWarning: p
andas.Int64Index is deprecated and will be removed from pandas in a future ve
rsion. Use pandas.Index with the appropriate dtype instead.
  from pandas import MultiIndex, Int64Index
no display found. Using non-interactive Agg backend
```

In [2]:

```
try:
    import common
    DATA = common.dataDirectory()
except ImportError:
    DATA = Path().resolve() / 'data'
```

Define paths to data sets. If you don't keep your data in the same directory as the code, adapt the path names.

In [3]:

```
LOAN200_CSV = DATA / 'loan200.csv'
```

```
LOAN3000_CSV = DATA / 'loan3000.csv'
LOAN_DATA_CSV = DATA / 'loan_data.csv.gz'
```

Set this if the notebook crashes in the XGBoost part.

In [4]:

```
os.environ['KMP_DUPLICATE_LIB_OK'] = 'TRUE'
```

K-Nearest Neighbors

A Small Example: Predicting Loan Default

К-жақын көршілер

Шағын мысал: несие бойынша дефолтты болжау

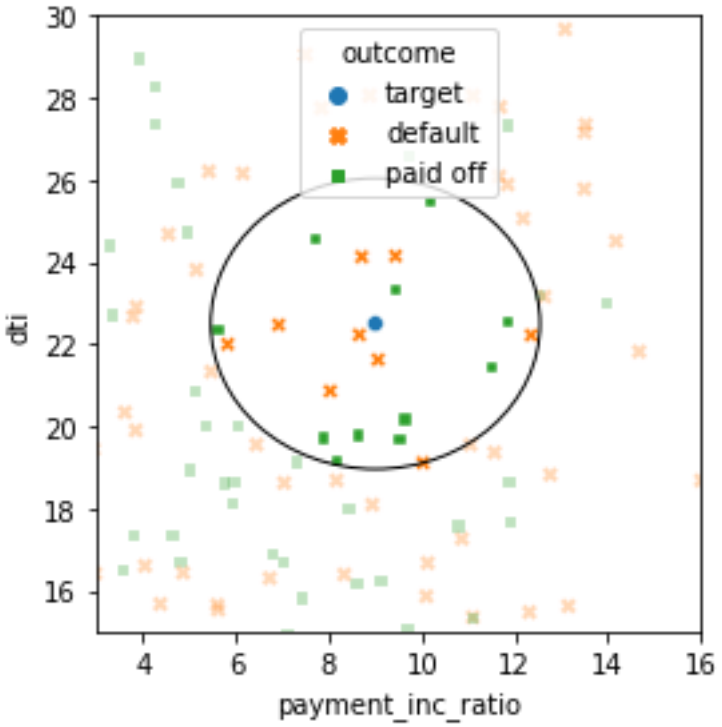
In [5]:

```
loan200 = pd.read_csv(LOAN200_CSV)

predictors = ['payment_inc_ratio', 'dti']
outcome = 'outcome'


newloan = loan200.loc[0:0, predictors]
X = loan200.loc[1:, predictors]
y = loan200.loc[1:, outcome]

knn = KNeighborsClassifier(n_neighbors=20)
knn.fit(X, y)
knn.predict(newloan)
print(knn.predict_proba(newloan))
```

```
[[0.45 0.55]]
```

In [6]:

```
nbrs = knn.kneighbors(newloan)
maxDistance = np.max(nbrs[0][0])

fig, ax = plt.subplots(figsize=(4, 4))
sns.scatterplot(x='payment_inc_ratio', y='dti', style='outcome',
                hue='outcome', data=loan200, alpha=0.3, ax=ax)
sns.scatterplot(x='payment_inc_ratio', y='dti', style='outcome',
                hue='outcome',
                data=pd.concat([loan200.loc[0:0, :], loan200.loc[nbrs[1][0] +
1,:]]),
                ax=ax, legend=False)
ellipse = Ellipse(xy=newloan.values[0],
                  width=2 * maxDistance, height=2 * maxDistance,
                  edgecolor='black', fc='None', lw=1)
ax.add_patch(ellipse)
ax.set_xlim(3, 16)
ax.set_ylim(15, 30)

plt.tight_layout()
plt.show()
```



Standardization (Normalization, Z-Scores)

Стандарттау (қалыпқа келтіру, Z-ұпайлар)

In [7]:

```
loan_data = pd.read_csv(LOAN_DATA_CSV)
loan_data = loan_data.drop(columns=['Unnamed: 0', 'status'])
loan_data['outcome'] = pd.Categorical(loan_data['outcome'],
                                      categories=['paid off', 'default'],
                                      ordered=True)


predictors = ['payment_inc_ratio', 'dti', 'revol_bal', 'revol_util']
outcome = 'outcome'

newloan = loan_data.loc[0:0, predictors]
print(newloan)
X = loan_data.loc[1:, predictors]
y = loan_data.loc[1:, outcome]

knn = KNeighborsClassifier(n_neighbors=5)
knn.fit(X, y)

nbrs = knn.kneighbors(newloan)
print(X.iloc[nbrs[1][0], :])
```

```
   payment_inc_ratio  dti  revol_bal  revol_util
0             2.3932  1.0       1687         9.4
       payment_inc_ratio   dti  revol_bal  revol_util
35536            1.47212  1.46       1686        10.0
33651            3.38178  6.37       1688         8.4
25863            2.36303  1.39       1691         3.5
42953            1.28160  7.14       1684         3.9
43599            4.12244  8.98       1684         7.2
```

In [8]:

```
newloan = loan_data.loc[0:0, predictors]
X = loan_data.loc[1:, predictors]
y = loan_data.loc[1:, outcome]

scaler = preprocessing.StandardScaler()
scaler.fit(X * 1.0)

X_std = scaler.transform(X * 1.0)
newloan_std = scaler.transform(newloan * 1.0)

knn = KNeighborsClassifier(n_neighbors=5)
knn.fit(X_std, y)

nbrs = knn.kneighbors(newloan_std)
print(X.iloc[nbrs[1][0], :])
```

```
       payment_inc_ratio   dti  revol_bal  revol_util
2080             2.61091  1.03       1218         9.7
1438             2.34343  0.51        278         9.9
30215            2.71200  1.34       1075         8.5
28542            2.39760  0.74       2917         7.4
44737            2.34309  1.37        488         7.2
```

KNN as a Feature Engine

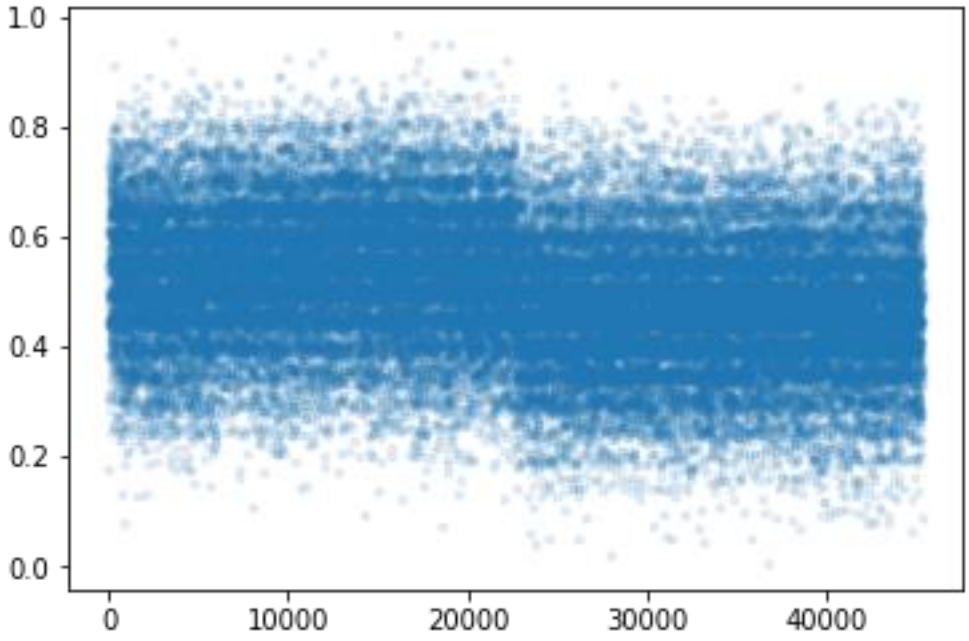
Функция қозғалтқышы ретінде белгілі

In [9]:

```
loan_data = pd.read_csv(LOAN_DATA_CSV)
loan_data = loan_data.drop(columns=['Unnamed: 0', 'status'])
loan_data['outcome'] = pd.Categorical(loan_data['outcome'],
                                      categories=['paid off', 'default'],
                                      ordered=True)

predictors = ['dti', 'revol_bal', 'revol_util', 'open_acc',
              'delinq_2yrs_zero', 'pub_rec_zero']
outcome = 'outcome'

X = loan_data[predictors]
y = loan_data[outcome]

knn = KNeighborsClassifier(n_neighbors=20)
knn.fit(X, y)
plt.scatter(range(len(X)), [bs + random.gauss(0, 0.015) for bs in
knn.predict_proba(X)[:,0]],
            alpha=0.1, marker='.')
knn.predict_proba(X)[:, 0]

loan_data['borrower_score'] = knn.predict_proba(X)[:, 0]
print(loan_data['borrower_score'].describe())
```

```
count    45342.000000
mean         0.501098
std          0.128736
min          0.000000
25%          0.400000
50%          0.500000
```

```
75%          0.600000
max          0.950000
Name: borrower_score, dtype: float64
```



Tree Models

A Simple Example

Үш модель

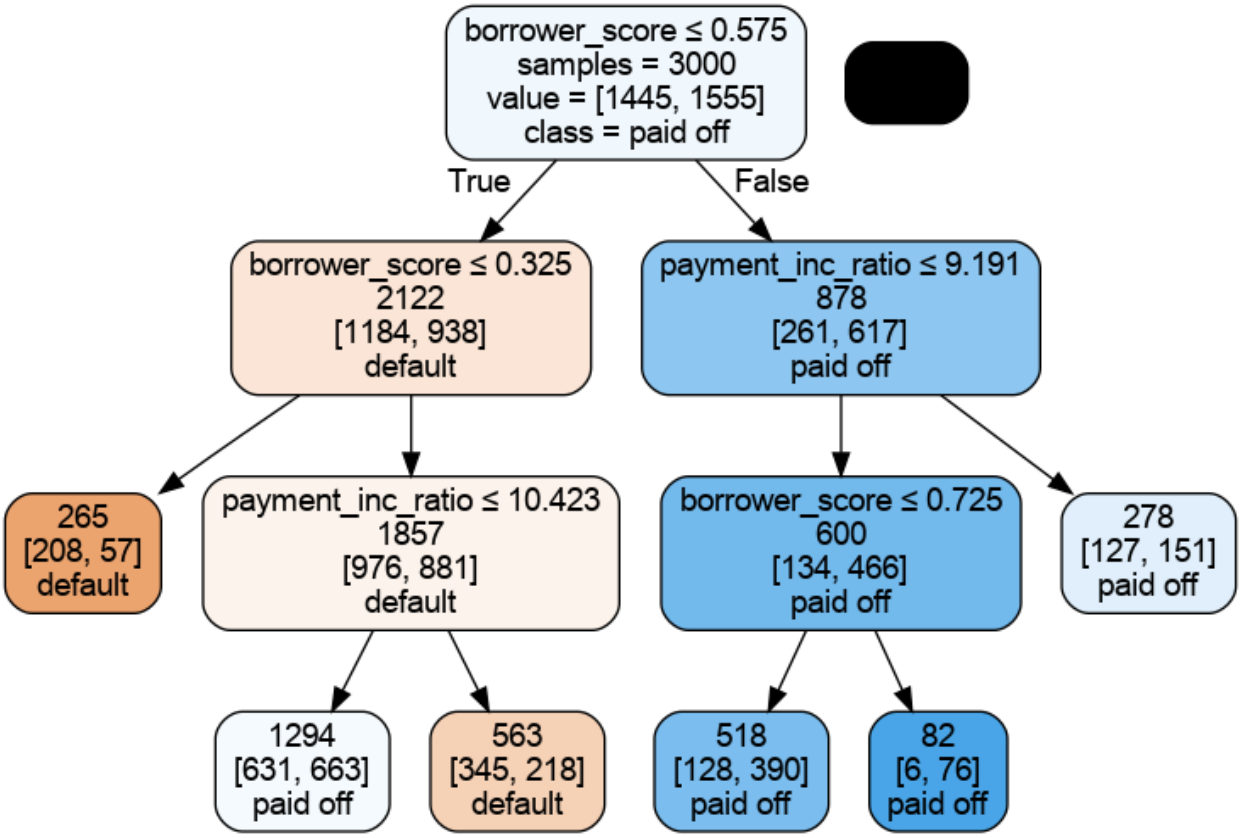
Қарапайым мысал

The package *scikit-learn* has the class DecisionTreeClassifier to build a decision tree model. The function plotDecisionTree from the *dmba* package can be used to visualize the tree.

In [10]:

```
loan3000 = pd.read_csv(LOAN3000_CSV)

predictors = ['borrower_score', 'payment_inc_ratio']
outcome = 'outcome'

X = loan3000[predictors]
y = loan3000[outcome]

loan_tree = DecisionTreeClassifier(random_state=1, criterion='entropy',
                                   min_impurity_decrease=0.003)
loan_tree.fit(X, y)
plotDecisionTree(loan_tree, feature_names=predictors,
class_names=loan_tree.classes_)
```

Out[10]:



In [11]:

```
print(textDecisionTree(loan_tree))
```

```
node=0 test node: go to node 1 if 0 <= 0.5750000178813934 else to node 6
  node=1 test node: go to node 2 if 0 <= 0.32500000298023224 else to node 3
    node=2 leaf node: [[0.785, 0.215]]
    node=3 test node: go to node 4 if 1 <= 10.42264986038208 else to node 5
      node=4 leaf node: [[0.488, 0.512]]
      node=5 leaf node: [[0.613, 0.387]]
  node=6 test node: go to node 7 if 1 <= 9.19082498550415 else to node 10
    node=7 test node: go to node 8 if 0 <= 0.7249999940395355 else to node 9
      node=8 leaf node: [[0.247, 0.753]]
      node=9 leaf node: [[0.073, 0.927]]
    node=10 leaf node: [[0.457, 0.543]]
```

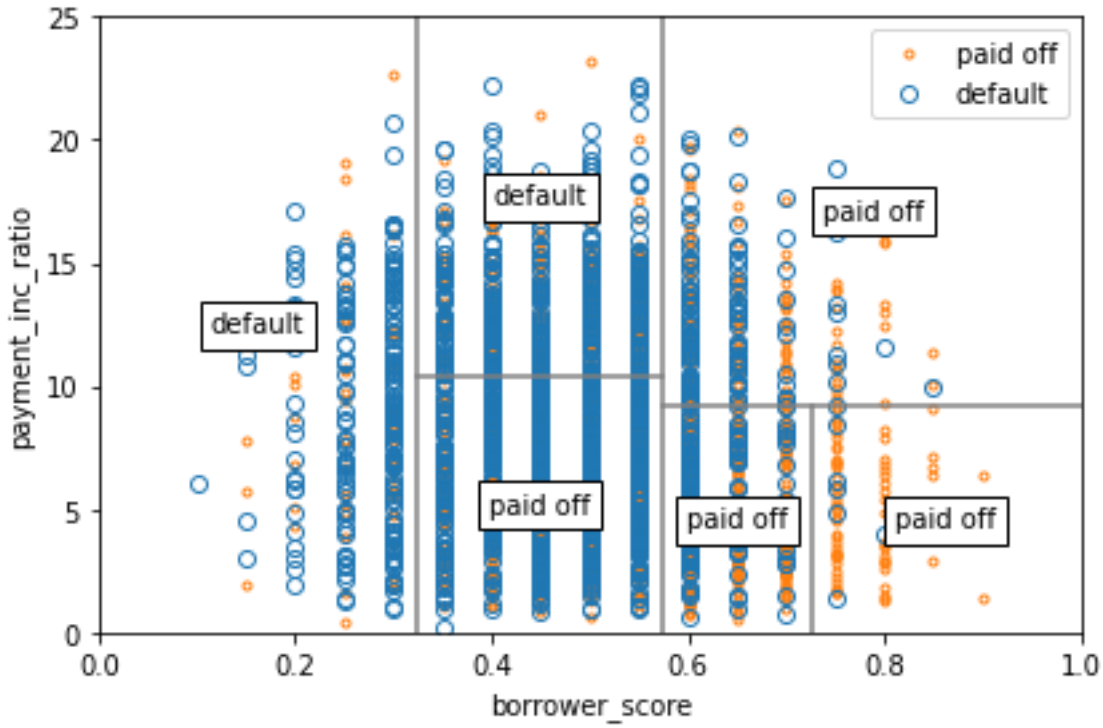
The Recursive Partitioning Algorithm

Рекурсивті бөлу алгоритмі

In [12]:

```
fig, ax = plt.subplots(figsize=(6, 4))

loan3000.loc[loan3000.outcome=='paid off'].plot(
    x='borrower_score', y='payment_inc_ratio', style='.',
    markerfacecolor='none', markeredgecolor='C1', ax=ax)
loan3000.loc[loan3000.outcome=='default'].plot(
    x='borrower_score', y='payment_inc_ratio', style='o',
    markerfacecolor='none', markeredgecolor='C0', ax=ax)
ax.legend(['paid off', 'default']);
ax.set_xlim(0, 1)
ax.set_ylim(0, 25)
ax.set_xlabel('borrower_score')
```

```
ax.set_ylabel('payment_inc_ratio')

x0 = 0.575
x1a = 0.325; y1b = 9.191
y2a = 10.423; x2b = 0.725
ax.plot((x0, x0), (0, 25), color='grey')
ax.plot((x1a, x1a), (0, 25), color='grey')
ax.plot((x0, 1), (y1b, y1b), color='grey')
ax.plot((x1a, x0), (y2a, y2a), color='grey')
ax.plot((x2b, x2b), (0, y1b), color='grey')

labels = [('default', (x1a / 2, 25 / 2)),
          ('default', ((x0 + x1a) / 2, (25 + y2a) / 2)),
          ('paid off', ((x0 + x1a) / 2, y2a / 2)),
          ('paid off', ((1 + x0) / 2, (y1b + 25) / 2)),
          ('paid off', ((1 + x2b) / 2, (y1b + 0) / 2)),
          ('paid off', ((x0 + x2b) / 2, (y1b + 0) / 2)),
         ]
for label, (x, y) in labels:
    ax.text(x, y, label, bbox={'facecolor':'white'},
            verticalalignment='center', horizontalalignment='center')

plt.tight_layout()
plt.show()
```



Measuring Homogeneity or Impurity

Біртектілікті немесе қоспаны өлшеу

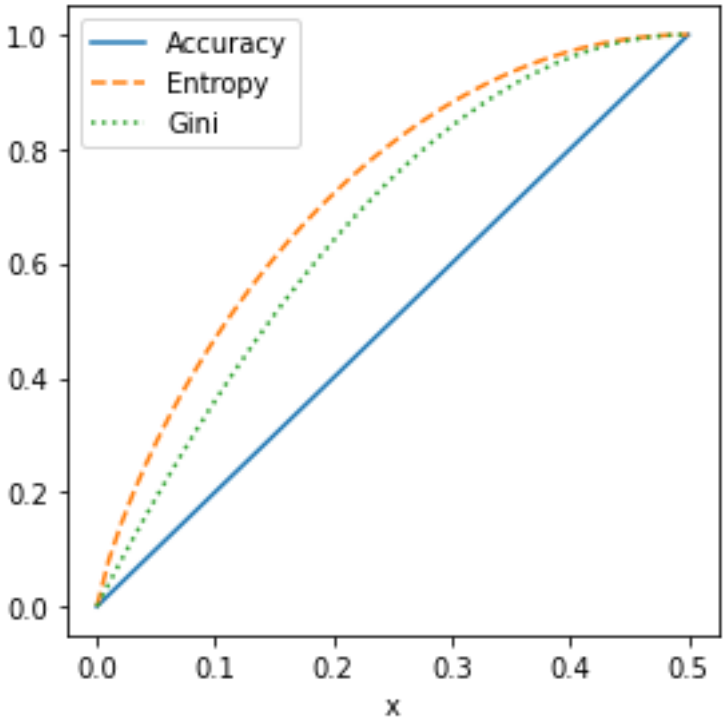
In [13]:

```
def entropyFunction(x):
    if x == 0: return 0
    return -x * math.log(x, 2) - (1 - x) * math.log(1 - x, 2)
```

```
def giniFunction(x):
    return x * (1 - x)
```

In [14]:

```
x = np.linspace(0, 0.5, 50)
impure = pd.DataFrame({
    'x': x,
    'Accuracy': 2 * x,
    'Gini': [giniFunction(xi) / giniFunction(.5) for xi in x],
    'Entropy': [entropyFunction(xi) for xi in x],
})

fig, ax = plt.subplots(figsize=(4, 4))

impure.plot(x='x', y='Accuracy', ax=ax, linestyle='solid')
impure.plot(x='x', y='Entropy', ax=ax, linestyle='--')
impure.plot(x='x', y='Gini', ax=ax, linestyle=':')

plt.tight_layout()
plt.show()
```



Bagging and the Random Forest

Random Forest

Bagging және кездейсоқ орман

Кездейсоқ орман

In [15]:

```
predictors = ['borrower_score', 'payment_inc_ratio']
```

```
outcome = 'outcome'

X = loan3000[predictors]
y = loan3000[outcome]

rf = RandomForestClassifier(n_estimators=500, random_state=1,
                            oob_score=True)
rf.fit(X, y)
print(rf.oob_decision_function_)
```

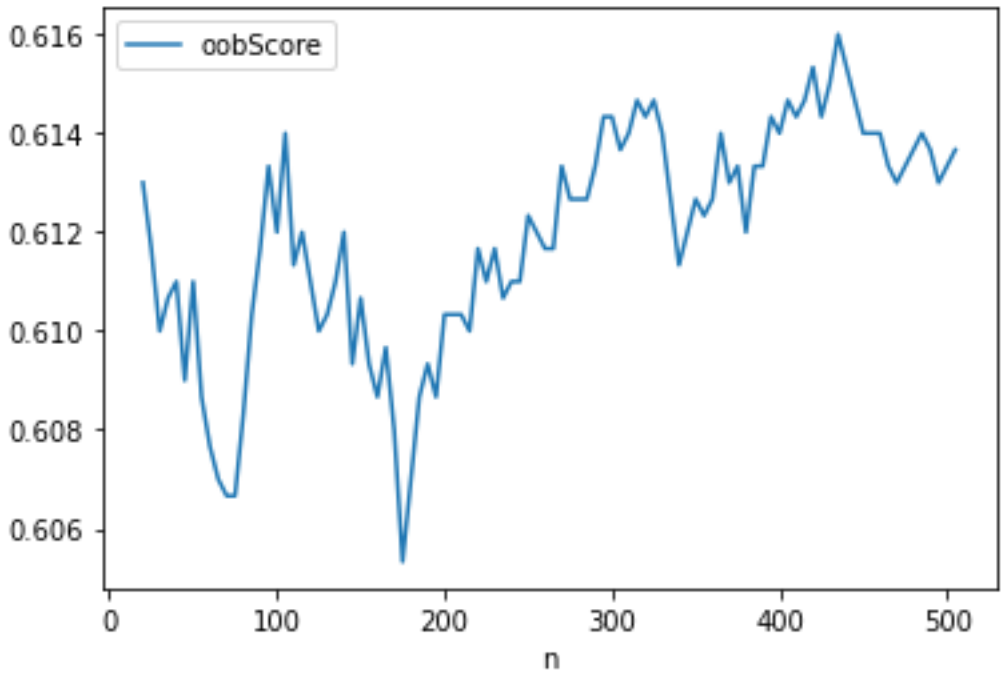
```
[[0.18131868 0.81868132]
 [0.26704545 0.73295455]
 [0.93333333 0.06666667]
 ...
 [1.         0.        ]
 [0.73157895 0.26842105]
 [0.68085106 0.31914894]]
```

In [16]:

```
n_estimator = list(range(20, 510, 5))
oobScores = []
for n in n_estimator:
    rf = RandomForestClassifier(n_estimators=n,
                                criterion='entropy', max_depth=5,
                                random_state=1, oob_score=True)
    rf.fit(X, y)
    oobScores.append(rf.oob_score_)
```

In [17]:

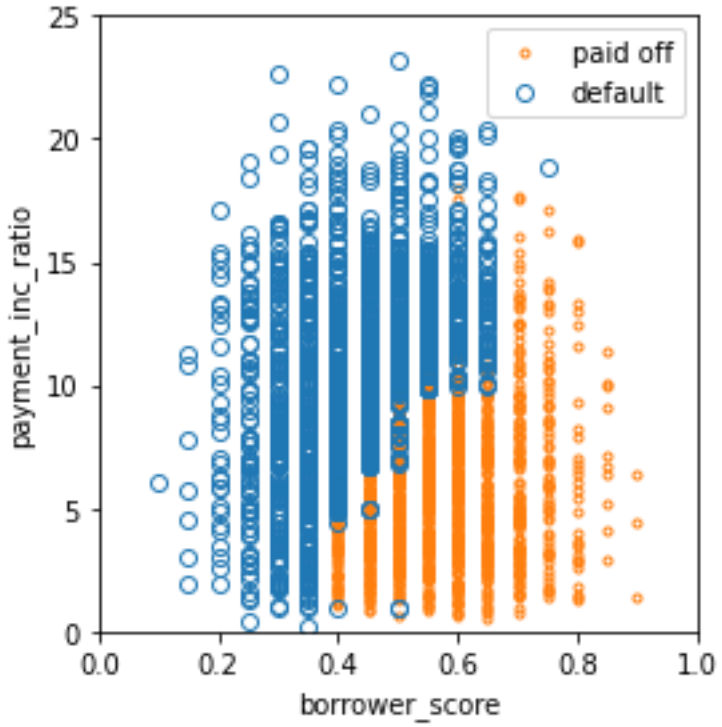
```
pd.DataFrame({
    'n': n_estimator,
    'oobScore': oobScores
}).plot(x='n', y='oobScore')
plt.show()
```



In [18]:

```
predictions = X.copy()
predictions['prediction'] = rf.predict(X)
predictions.head()
```

```
fig, ax = plt.subplots(figsize=(4, 4))

predictions.loc[predictions.prediction=='paid off'].plot(
    x='borrower_score', y='payment_inc_ratio', style='.',
    markerfacecolor='none', markeredgecolor='C1', ax=ax)
predictions.loc[predictions.prediction=='default'].plot(
    x='borrower_score', y='payment_inc_ratio', style='o',
    markerfacecolor='none', markeredgecolor='C0', ax=ax)
ax.legend(['paid off', 'default']);
ax.set_xlim(0, 1)
ax.set_ylim(0, 25)
ax.set_xlabel('borrower_score')
ax.set_ylabel('payment_inc_ratio')

plt.tight_layout()
plt.show()
```



Variable importance

Айнымалы маңыздылығы

This is different to R. The accuracy decrease is not available out of the box.

In [19]:

```
predictors = ['loan_amnt', 'term', 'annual_inc', 'dti',
              'payment_inc_ratio', 'revol_bal', 'revol_util',
              'purpose', 'delinq_2yrs_zero', 'pub_rec_zero',
              'open_acc', 'grade', 'emp_length', 'purpose_',
              'home_', 'emp_len_', 'borrower_score']
outcome = 'outcome'

X = pd.get_dummies(loan_data[predictors], drop_first=True)
y = loan_data[outcome]
```

```
rf_all = RandomForestClassifier(n_estimators=500, random_state=1)
rf_all.fit(X, y)

rf_all_entropy = RandomForestClassifier(n_estimators=500, random_state=1,
                                        criterion='entropy')
print(rf_all_entropy.fit(X, y))
```

```
RandomForestClassifier(criterion='entropy', n_estimators=500, random_state=1)
```

In [20]:

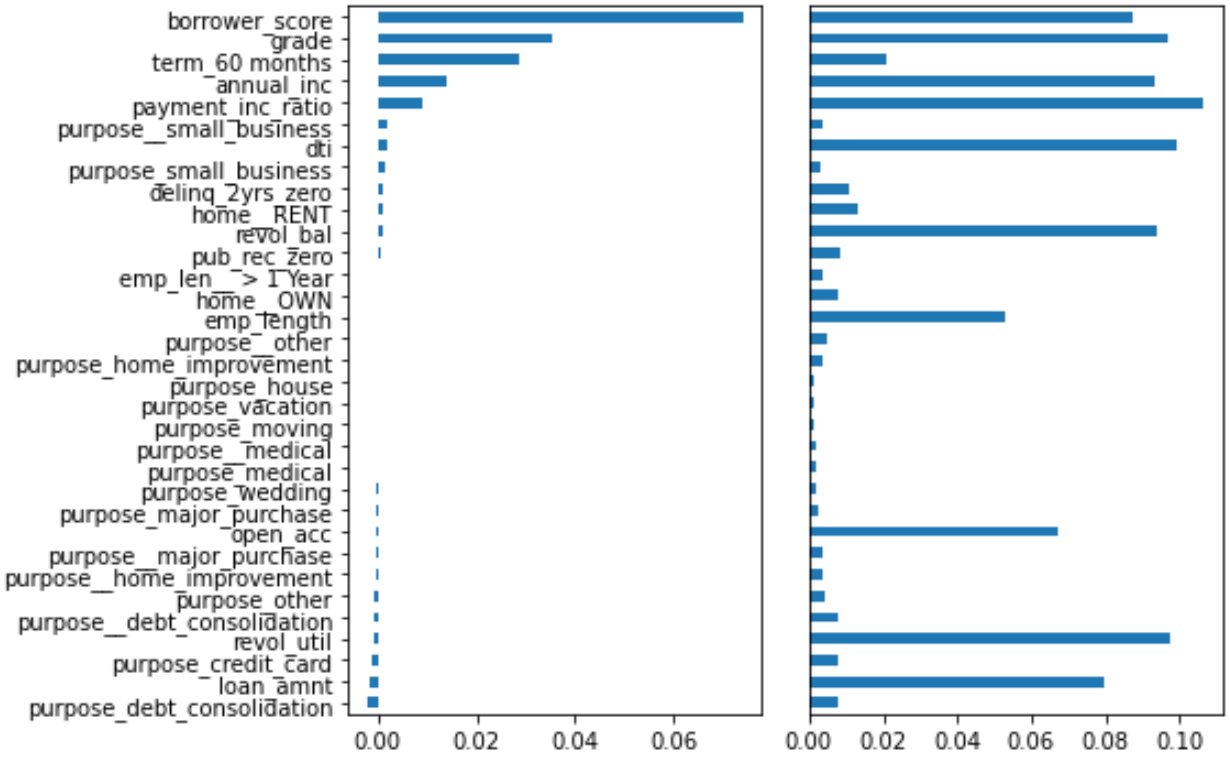
```
rf = RandomForestClassifier(n_estimators=500)
scores = defaultdict(list)

# crossvalidate the scores on a number of different random splits of the data
for _ in range(3):
    train_X, valid_X, train_y, valid_y = train_test_split(X, y,
                                                          test_size=0.3)
    rf.fit(train_X, train_y)
    acc = metrics.accuracy_score(valid_y, rf.predict(valid_X))
    for column in X.columns:
        X_t = valid_X.copy()
        X_t[column] = np.random.permutation(X_t[column].values)
        shuff_acc = metrics.accuracy_score(valid_y, rf.predict(X_t))
        scores[column].append((acc-shuff_acc)/acc)
print('Features sorted by their score:')
print(sorted([(round(np.mean(score), 4), feat) for
              feat, score in scores.items()], reverse=True))
```

```
Features sorted by their score:
[(0.0739, 'borrower_score'), (0.0352, 'grade'), (0.0286, 'term_60 months'), (
0.0137, 'annual_inc'), (0.009, 'payment_inc_ratio'), (0.0021, 'purpose__small
_business'), (0.002, 'dti'), (0.0016, 'purpose_small_business'), (0.0011, 'ho
me__RENT'), (0.0011, 'delinq_2yrs_zero'), (0.001, 'revol_bal'), (0.0004, 'pub
_rec_zero'), (0.0003, 'home__OWN'), (0.0003, 'emp_len__ > 1 Year'), (0.0002,
'purpose__other'), (0.0002, 'emp_length'), (0.0001, 'purpose_vacation'), (0.0
001, 'purpose_house'), (0.0001, 'purpose_home_improvement'), (-0.0, 'purpose_
moving'), (-0.0001, 'purpose_medical'), (-0.0001, 'purpose__medical'), (-0.00
02, 'purpose_wedding'), (-0.0004, 'purpose_major_purchase'), (-0.0004, 'open_
acc'), (-0.0005, 'purpose__major_purchase'), (-0.0006, 'purpose__home_improve
ment'), (-0.0007, 'purpose_other'), (-0.0007, 'purpose__debt_consolidation'),
(-0.0008, 'revol_util'), (-0.0013, 'purpose_credit_card'), (-0.0019, 'loan_am
nt'), (-0.0022, 'purpose_debt_consolidation')]
```

In [21]:

```
importances = rf_all.feature_importances_

df = pd.DataFrame({
    'feature': X.columns,
    'Accuracy decrease': [np.mean(scores[column]) for column in
                          X.columns],
    'Gini decrease': rf_all.feature_importances_,
    'Entropy decrease': rf_all_entropy.feature_importances_,
})
df = df.sort_values('Accuracy decrease')

fig, axes = plt.subplots(ncols=2, figsize=(8, 5))
ax = df.plot(kind='barh', x='feature', y='Accuracy decrease',
             legend=False, ax=axes[0])
ax.set_ylabel('')

ax = df.plot(kind='barh', x='feature', y='Gini decrease',
             legend=False, ax=axes[1])
```

```
ax.set_ylabel('')
ax.get_yaxis().set_visible(False)

plt.tight_layout()
plt.show()
```



Boosting

XGBoost

In [22]:

```
predictors = ['borrower_score', 'payment_inc_ratio']
outcome = 'outcome'

X = loan3000[predictors]
y = pd.Series([1 if o == 'default' else 0 for o in loan3000[outcome]])

xgb = XGBClassifier(objective='binary:logistic', subsample=.63,
                    use_label_encoder=False, eval_metric='error')
print(xgb.fit(X, y))
```

```
XGBClassifier(base_score=0.5, booster='gbtree', colsample_bylevel=1,
              colsample_bynode=1, colsample_bytree=1, enable_categorical=Fals
e,
              eval_metric='error', gamma=0, gpu_id=-1, importance_type=None,
              interaction_constraints='', learning_rate=0.300000012,
              max_delta_step=0, max_depth=6, min_child_weight=1, missing=nan,
              monotone_constraints='()', n_estimators=100, n_jobs=8,
              num_parallel_tree=1, predictor='auto', random_state=0,
              reg_alpha=0, reg_lambda=1, scale_pos_weight=1, subsample=0.63,
              tree_method='exact', use_label_encoder=False,
              validate_parameters=1, verbosity=None)
```

```
/opt/conda/lib/python3.9/site-packages/xgboost/data.py:262: FutureWarning: pa
ndas.Int64Index is deprecated and will be removed from pandas in a future ver
sion. Use pandas.Index with the appropriate dtype instead.
  elif isinstance(data.columns, (pd.Int64Index, pd.RangeIndex)):
```

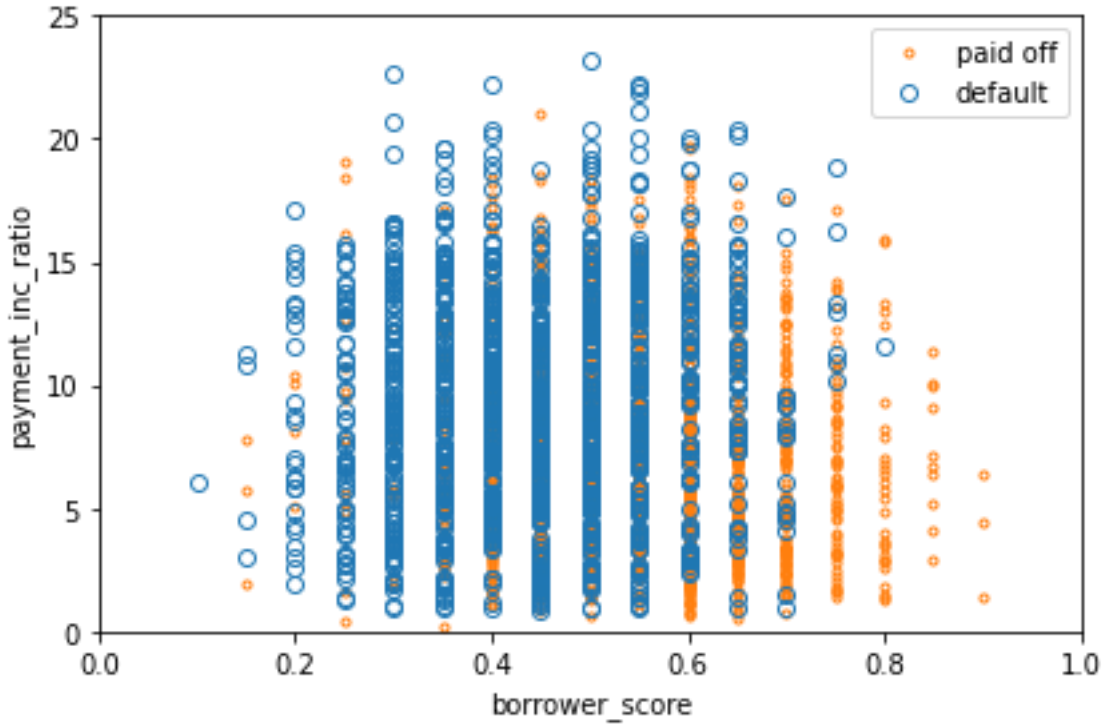
In [23]:

```
xgb_df = X.copy()
xgb_df['prediction'] = ['default' if p == 1 else 'paid off' for p in
xgb.predict(X)]
xgb_df['prob_default'] = xgb.predict_proba(X)[:, 0]
print(xgb_df.head())
```

```
   borrower_score  payment_inc_ratio prediction  prob_default
0            0.40            5.11135   paid off      0.828856
1            0.40            5.43165    default      0.260156
2            0.70            9.23003    default      0.320805
3            0.40            2.33482   paid off      0.678005
4            0.45           12.10320    default      0.140204
/opt/conda/lib/python3.9/site-packages/xgboost/data.py:262: FutureWarning: pa
ndas.Int64Index is deprecated and will be removed from pandas in a future ver
sion. Use pandas.Index with the appropriate dtype instead.
  elif isinstance(data.columns, (pd.Int64Index, pd.RangeIndex)):
```

In [24]:

```
fig, ax = plt.subplots(figsize=(6, 4))

xgb_df.loc[xgb_df.prediction=='paid off'].plot(
    x='borrower_score', y='payment_inc_ratio', style='.',
    markerfacecolor='none', markeredgecolor='C1', ax=ax)
xgb_df.loc[xgb_df.prediction=='default'].plot(
    x='borrower_score', y='payment_inc_ratio', style='o',
    markerfacecolor='none', markeredgecolor='C0', ax=ax)
ax.legend(['paid off', 'default']);
ax.set_xlim(0, 1)
ax.set_ylim(0, 25)
ax.set_xlabel('borrower_score')
ax.set_ylabel('payment_inc_ratio')

plt.tight_layout()
plt.show()
```



Regularization: Avoiding Overfitting

Реттеу: қайта оқытудан аулақ болу

In [25]:

```
predictors = ['loan_amnt', 'term', 'annual_inc', 'dti',
              'payment_inc_ratio', 'revol_bal', 'revol_util',
              'purpose', 'delinq_2yrs_zero', 'pub_rec_zero',
              'open_acc', 'grade', 'emp_length', 'purpose_',
              'home_', 'emp_len_', 'borrower_score']
outcome = 'outcome'

X = pd.get_dummies(loan_data[predictors], drop_first=True)
y = pd.Series([1 if o == 'default' else 0 for o in loan_data[outcome]])

train_X, valid_X, train_y, valid_y = train_test_split(X, y, test_size=10000)

xgb_default = XGBClassifier(objective='binary:logistic', n_estimators=250,
max_depth=6,
                            reg_lambda=0, learning_rate=0.3, subsample=1,
                            use_label_encoder=False, eval_metric='error')
xgb_default.fit(train_X, train_y)

xgb_penalty = XGBClassifier(objective='binary:logistic', n_estimators=250,
max_depth=6,
                            reg_lambda=1000, learning_rate=0.1,
subsample=0.63,
                            use_label_encoder=False, eval_metric='error')
print(xgb_penalty.fit(train_X, train_y))
```

```
/opt/conda/lib/python3.9/site-packages/xgboost/data.py:262: FutureWarning: pa
ndas.Int64Index is deprecated and will be removed from pandas in a future ver
sion. Use pandas.Index with the appropriate dtype instead.
  elif isinstance(data.columns, (pd.Int64Index, pd.RangeIndex)):
```

```
XGBClassifier(base_score=0.5, booster='gbtree', colsample_bylevel=1,
              colsample_bynode=1, colsample_bytree=1, enable_categorical=Fals
e,
              eval_metric='error', gamma=0, gpu_id=-1, importance_type=None,
              interaction_constraints='', learning_rate=0.1, max_delta_step=0
,
              max_depth=6, min_child_weight=1, missing=nan,
              monotone_constraints='()', n_estimators=250, n_jobs=8,
              num_parallel_tree=1, predictor='auto', random_state=0,
              reg_alpha=0, reg_lambda=1000, scale_pos_weight=1, subsample=0.6
3,
              tree_method='exact', use_label_encoder=False,
              validate_parameters=1, verbosity=None)
```

In [26]:

```
pred_default = xgb_default.predict_proba(train_X)[:, 1]
error_default = abs(train_y - pred_default) > 0.5
print('default (train): ', np.mean(error_default))

pred_default = xgb_default.predict_proba(valid_X)[:, 1]
error_default = abs(valid_y - pred_default) > 0.5
print('default: ', np.mean(error_default))

pred_penalty = xgb_penalty.predict_proba(valid_X)[:, 1]
error_penalty = abs(valid_y - pred_penalty) > 0.5
print('penalty: ', np.mean(error_penalty))
```

```
default (train):  0.12678965536755135
default:  0.3553
penalty:  0.3311
```

In [27]:

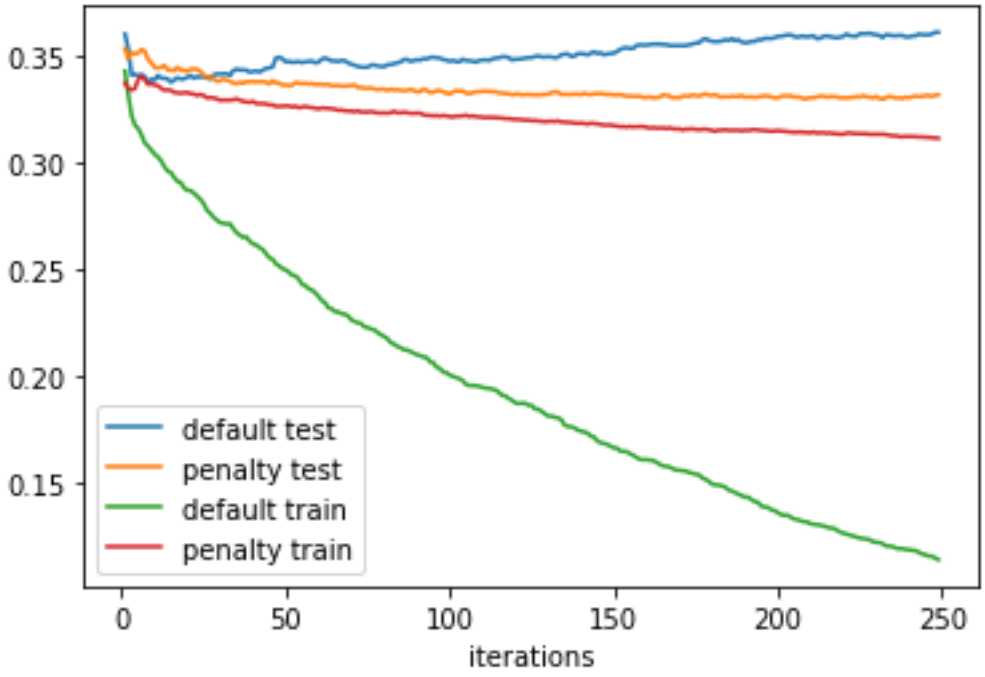
```
results = []
for ntree_limit in range(1, 250):
    iteration_range = [1, ntree_limit + 1]
    train_default = xgb_default.predict_proba(train_X,
iteration_range=iteration_range)[:, 1]
    train_penalty = xgb_penalty.predict_proba(train_X,
iteration_range=iteration_range)[:, 1]
    pred_default = xgb_default.predict_proba(valid_X,
iteration_range=iteration_range)[:, 1]
    pred_penalty = xgb_penalty.predict_proba(valid_X,
iteration_range=iteration_range)[:, 1]
    results.append({
        'iterations': ntree_limit,
        'default train': np.mean(abs(train_y - train_default) > 0.5),
        'penalty train': np.mean(abs(train_y - train_penalty) > 0.5),
        'default test': np.mean(abs(valid_y - pred_default) > 0.5),
        'penalty test': np.mean(abs(valid_y - pred_penalty) > 0.5),
    })

results = pd.DataFrame(results)
print(results.head())
```

```
   iterations  default train  penalty train  default test  penalty test
0           1       0.342680       0.337021        0.3600        0.3532
1           2       0.331419       0.334559        0.3530        0.3483
2           3       0.321883       0.333795        0.3407        0.3511
3           4       0.317300       0.334446        0.3412        0.3508
4           5       0.315772       0.338662        0.3404        0.3510
```

In [28]:

```
ax = results.plot(x='iterations', y='default test')
```

```
results.plot(x='iterations', y='penalty test', ax=ax)
results.plot(x='iterations', y='default train', ax=ax)
results.plot(x='iterations', y='penalty train', ax=ax)
plt.show()
```



Hyperparameters and Cross-Validation

Гиперпараметрлер және Кросс-тексеру

In [29]:

```
idx = np.random.choice(range(5), size=len(X), replace=True)
error = []
for eta, max_depth in product([0.1, 0.5, 0.9], [3, 6, 9]):
    xgb = XGBClassifier(objective='binary:logistic', n_estimators=250,
                        max_depth=max_depth, learning_rate=eta,
                        use_label_encoder=False, eval_metric='error')
    cv_error = []
    for k in range(5):
        fold_idx = idx == k
        train_X = X.loc[~fold_idx]; train_y = y[~fold_idx]
        valid_X = X.loc[fold_idx]; valid_y = y[fold_idx]

        xgb.fit(train_X, train_y)
        pred = xgb.predict_proba(valid_X)[:, 1]
        cv_error.append(np.mean(abs(valid_y - pred) > 0.5))
    error.append({
        'eta': eta,
        'max_depth': max_depth,
        'avg_error': np.mean(cv_error)
    })
    print(error[-1])
errors = pd.DataFrame(error)
print(errors)
```

```
/opt/conda/lib/python3.9/site-packages/xgboost/data.py:262: FutureWarning: pa
ndas.Int64Index is deprecated and will be removed from pandas in a future ver
sion. Use pandas.Index with the appropriate dtype instead.
  elif isinstance(data.columns, (pd.Int64Index, pd.RangeIndex)):
{'eta': 0.1, 'max_depth': 3, 'avg_error': 0.32895002759265257}
{'eta': 0.1, 'max_depth': 6, 'avg_error': 0.3360983351965724}
{'eta': 0.1, 'max_depth': 9, 'avg_error': 0.3461055248368196}
{'eta': 0.5, 'max_depth': 3, 'avg_error': 0.3425077028439957}
{'eta': 0.5, 'max_depth': 6, 'avg_error': 0.3694194098086156}
{'eta': 0.5, 'max_depth': 9, 'avg_error': 0.3764740475715814}
{'eta': 0.9, 'max_depth': 3, 'avg_error': 0.3519677896500327}
{'eta': 0.9, 'max_depth': 6, 'avg_error': 0.3871414745778243}
{'eta': 0.9, 'max_depth': 9, 'avg_error': 0.38706390437335264}
```

	eta	max_depth	avg_error
0	0.1	3	0.328950
1	0.1	6	0.336098
2	0.1	9	0.346106
3	0.5	3	0.342508
4	0.5	6	0.369419
5	0.5	9	0.376474
6	0.9	3	0.351968
7	0.9	6	0.387141
8	0.9	9	0.387064

In [30]:

```
print(errors.pivot_table(index='eta', columns='max_depth',
values='avg_error') * 100)
```

max_depth	3	6	9
eta			
0.1	32.895003	33.609834	34.610552
0.5	34.250770	36.941941	37.647405
0.9	35.196779	38.714147	38.706390