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Факультет «Информатика и системы управления»

Кафедра ИУ5 «Системы обработки информации и управления»

Курс «Технологии машинного обучения»

Лабораторная работа №5-6

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Выберите набор данных (датасет) для решения задачи классификации или регресии.

В случае необходимости проведите удаление или заполнение пропусков и кодирование категориальных признаков. С использованием метода train_test_split разделите выборку на обучающую и тестовую. Обучите следующие ансамблевые модели:

- две модели группы бэггинга (бэггинг или случайный лес или сверхслучайные деревья);
- AdaBoost;
- градиентный бустинг.
- одну из моделей группы стекинга.
- модель многослойного персептрона. По желанию, вместо библиотеки scikit-learn возможно использование библиотек TensorFlow, PyTorch или других аналогичных библиотек.
- двумя методами на выбор из семейства МГУА (один из линейных методов COMBI / MULTI + один из нелинейных методов MIA / RIA) с использованием библиотеки gmdh.

Оцените качество моделей с помощью одной из подходящих для задачи метрик. Сравните качество полученных моделей.

Ход работы:

```
#!pip install heamy
!pip install gmdh
```

```
Collecting gmdh
  Downloading gmdh-1.0.3-cp310-cp310-manylinux1_x86_64.whl (875 kB)
━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━
875.3/875.3 kB 10.1 MB/s eta 0:00:00
 gmdh)
  Downloading docstring_inheritance-2.2.0-py3-none-any.whl (24 kB)
Requirement already satisfied: numpy in
/usr/local/lib/python3.10/dist-packages (from gmdh) (1.25.2)
Installing collected packages: docstring-inheritance, gmdh
Successfully installed docstring-inheritance-2.2.0 gmdh-1.0.3
```

```
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns
import gmdh
from sklearn.ensemble import RandomForestRegressor
from sklearn.model_selection import train_test_split
from sklearn.metrics import mean_absolute_error
from sklearn.datasets import *
from heamy.dataset import Dataset
from heamy.estimator import Regressor, Classifier
from heamy.pipeline import ModelsPipeline
from sklearn.linear_model import LinearRegression
from sklearn.preprocessing import StandardScaler
```

```
from sklearn.ensemble import RandomForestClassifier, StackingClassifier,
GradientBoostingClassifier
from sklearn.tree import DecisionTreeRegressor
from sklearn.metrics import mean_squared_error, r2_score

import warnings
warnings.filterwarnings('ignore')
```

```
/usr/local/lib/python3.10/dist-packages/ipykernel/ipkernel.py:283:
DeprecationWarning: `should_run_async` will not call `transform_cell`
automatically in the future. Please pass the result to `transformed_cell`
argument and any exception that happen during thetransform in
`preprocessing_exc_tuple` in IPython 7.17 and above.
  and should_run_async(code)
```

```
df = pd.read_csv('sample_data/cleaned_all_phones.csv')
```

```
df.head()
```

```
{"type":"dataframe","variable_name":"df"}
```

```
df.tail()
```

```
{"type":"dataframe"}
```

```
df.shape
```

```
(1512, 22)
```

```
df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 1512 entries, 0 to 1511
Data columns (total 22 columns):
 #   Column             Non-Null Count  Dtype
---  ------             --------------  -----
 0   phone_name         1512 non-null   object
 1   brand              1512 non-null   object
 2   os                 1512 non-null   object
 3   inches             1512 non-null   float64
 4   resolution         1512 non-null   object
 5   battery            1512 non-null   int64
 6   battery_type       1512 non-null   object
 7   ram(GB)            1512 non-null   int64
 8   announcement_date  1512 non-null   object
 9   weight(g)          1512 non-null   float64
 10  storage(GB)        1512 non-null   int64
 11  video_720p         1512 non-null   bool
 12  video_1080p        1512 non-null   bool
 13  video_4K           1512 non-null   bool
 14  video_8K           1512 non-null   bool
 15  video_30fps        1512 non-null   bool
 16  video_60fps        1512 non-null   bool
 17  video_120fps       1512 non-null   bool
 18  video_240fps       1512 non-null   bool
 19  video_480fps       1512 non-null   bool
```

```
 20  video_960fps       1512 non-null   bool
 21  price(USD)         1512 non-null   float64
dtypes: bool(10), float64(3), int64(3), object(6)
memory usage: 156.6+ KB
```

```
df.describe()
```


```
{"summary":"{\n  \"name\": \"df\",\n  \"rows\": 8,\n  \"fields\": [\n
{\n      \"column\": \"inches\",\n      \"properties\": {\n
\"dtype\": \"number\",\n        \"std\": 532.5310851556795,\n
\"min\": 0.4770430982109062,\n        \"max\": 1512.0,\n
\"num_unique_values\": 8,\n        \"samples\": [\n
6.4224603174603185,\n          6.5,\n          1512.0\n        ],\n
\"semantic_type\": \"\",\n        \"description\": \"\"\n      }\n    },\n
{\n      \"column\": \"battery\",\n      \"properties\": {\n
\"dtype\": \"number\",\n        \"std\": 2148.127173043608,\n
\"min\": 784.6070221906537,\n        \"max\": 7250.0,\n
\"num_unique_values\": 8,\n        \"samples\": [\n
4389.798941798942,\n          4500.0,\n          1512.0\n        ],\n
\"semantic_type\": \"\",\n        \"description\": \"\"\n      }\n    },\n
{\n      \"column\": \"ram(GB)\",\n      \"properties\": {\n
\"dtype\": \"number\",\n        \"std\": 531.8729184957466,\n
\"min\": 1.0,\n        \"max\": 1512.0,\n        \"num_unique_values\":
7,\n        \"samples\": [\n          1512.0,\n
6.6838624338624335,\n          8.0\n        ],\n        \"semantic_type\":
\"\",\n        \"description\": \"\"\n      }\n    },\n    {\n
\"column\": \"weight(g)\",\n      \"properties\": {\n        \"dtype\":
\"number\",\n        \"std\": 482.7337788722055,\n        \"min\":
26.20011485546831,\n        \"max\": 1512.0,\n
\"num_unique_values\": 8,\n        \"samples\": [\n
187.6362433862434,\n          187.0,\n          1512.0\n        ],\n
\"semantic_type\": \"\",\n        \"description\": \"\"\n      }\n    },\n
{\n      \"column\": \"storage(GB)\",\n      \"properties\": {\n
\"dtype\": \"number\",\n        \"std\": 507.5688180604079,\n
\"min\": 1.0,\n        \"max\": 1512.0,\n        \"num_unique_values\":
7,\n        \"samples\": [\n          1512.0,\n
109.16468253968254,\n          128.0\n        ],\n
\"semantic_type\": \"\",\n        \"description\": \"\"\n      }\n    },\n
{\n      \"column\": \"price(USD)\",\n      \"properties\": {\n
\"dtype\": \"number\",\n        \"std\": 803.235184359574,\n
\"min\": 40.0,\n        \"max\": 2300.0,\n        \"num_unique_values\":
8,\n        \"samples\": [\n          337.8470357142857,\n
260.0,\n          1512.0\n        ],\n        \"semantic_type\": \"\",\n
\"description\": \"\"\n      }\n    }\n  ]\n}","type":"dataframe"}
```


```
df.duplicated().sum()
```

```
0
```

```
df.isna().sum()
```

```
phone_name          0
brand               0
os                  0
inches              0
```

```
resolution           0
battery              0
battery_type         0
ram(GB)              0
announcement_date    0
weight(g)            0
storage(GB)          0
video_720p           0
video_1080p          0
video_4K             0
video_8K             0
video_30fps          0
video_60fps          0
video_120fps         0
video_240fps         0
video_480fps         0
video_960fps         0
price(USD)           0
dtype: int64
```

```
df.columns
```

```
Index(['phone_name', 'brand', 'os', 'inches', 'resolution', 'battery',
       'battery_type', 'ram(GB)', 'announcement_date', 'weight(g)',
       'storage(GB)', 'video_720p', 'video_1080p', 'video_4K', 'video_8K',
       'video_30fps', 'video_60fps', 'video_120fps', 'video_240fps',
       'video_480fps', 'video_960fps', 'price(USD)'],
      dtype='object')
```

Преобразование данных

```
df['width'] = [int(i.split('x')[0] )for i in df['resolution']]
df['height'] = [int(i.split('x')[1] )for i in df['resolution']]
```

```
from sklearn.preprocessing import LabelEncoder
le = LabelEncoder()
df['brand'] = le.fit_transform(df['brand'])
df['battery_type'] = le.fit_transform(df['battery_type'])
df['os'] = le.fit_transform(df['os'])
```

```
bool_col = [col for col in df.columns if df[col].dtype == 'bool']
df[bool_col] = df[bool_col].astype(int)
```

```
df['announcement_date'] = pd.to_datetime(df['announcement_date'])
df['year'] = df['announcement_date'].dt.year
```

```
camera = [ x for x in df.columns if 'video' in x]
df['camera_score'] = df[camera].sum(axis=1)
```

```
df.drop(bool_col, axis = 1, inplace=True)
```

```
df.columns
```

```
Index(['phone_name', 'brand', 'os', 'inches', 'resolution', 'battery',
       'battery_type', 'ram(GB)', 'announcement_date', 'weight(g)',
       'storage(GB)', 'price(USD)', 'width', 'height', 'year',
```

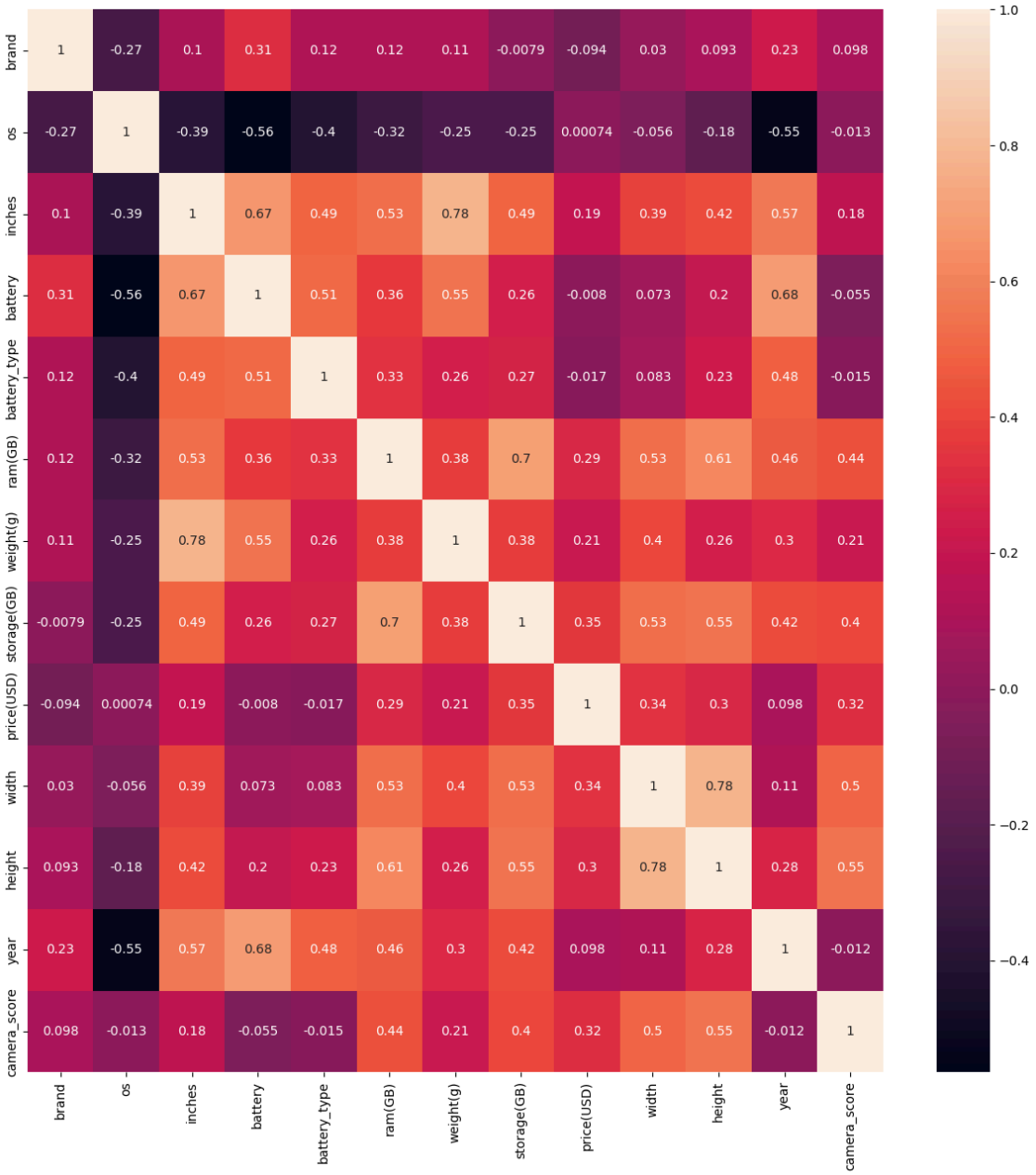
```
'camera_score'],
      dtype='object')
```

```
df = df.drop(['phone_name','announcement_date','resolution'], axis = 1)
```

```
df.info()
```

```
plt.figure(figsize = (15,15))
sns.heatmap(df.corr(), annot = True)
```

```
<Axes: >
```



Масштабирование данных

```
from sklearn.preprocessing import MinMaxScaler
```

```
scaler = MinMaxScaler()
```

```
scaled_data = scaler.fit_transform(df)
df = pd.DataFrame(scaled_data, columns=df.columns)

X = df.drop(['price(USD)'], axis = 1)
y = df['price(USD)']
```

Разделение выборки на обучающую и тестовую

```
from sklearn.model_selection import train_test_split

X_train, X_test, y_train, y_test = train_test_split(X, y, test_size = 0.2,
random_state = 42)

X_train.shape, y_train.shape, X_test.shape, y_test.shape
```

```
((1209, 12), (1209,), (303, 12), (303,))
```

Обучение ансамблевых моделей

Модель *бэггинга*

```
from sklearn.ensemble import BaggingRegressor

bagging_model = BaggingRegressor(n_estimators=5, oob_score=True,
random_state=10)
bagging_model.fit(X_train, y_train)
```

```
/usr/local/lib/python3.10/dist-packages/ipykernel/ipkernel.py:283:
DeprecationWarning: `should_run_async` will not call `transform_cell`
automatically in the future. Please pass the result to `transformed_cell`
argument and any exception that happen during thetransform in
`preprocessing_exc_tuple` in IPython 7.17 and above.
  and should_run_async(code)

---------------------------------------------------------------------------
-
ValueError                                Traceback (most recent call
last)
<ipython-input-152-d3af98c2e679> in <cell line: 2>()
      1 bagging_model = BaggingRegressor(n_estimators=5, oob_score=True,
random_state=10)
----> 2 bagging_model.fit(X_train, y_train)

/usr/local/lib/python3.10/dist-packages/sklearn/ensemble/_bagging.py in
fit(self, X, y, sample_weight)
    327
    328         # Convert data (X is required to be 2d and indexable)
--> 329         X, y = self._validate_data(
    330             X,
    331             y,

/usr/local/lib/python3.10/dist-packages/sklearn/base.py in
_validate_data(self, X, y, reset, validate_separately, **check_params)
    582                 y = check_array(y, input_name="y",
**check_y_params)
    583             else:
--> 584                 X, y = check_X_y(X, y, **check_params)
```

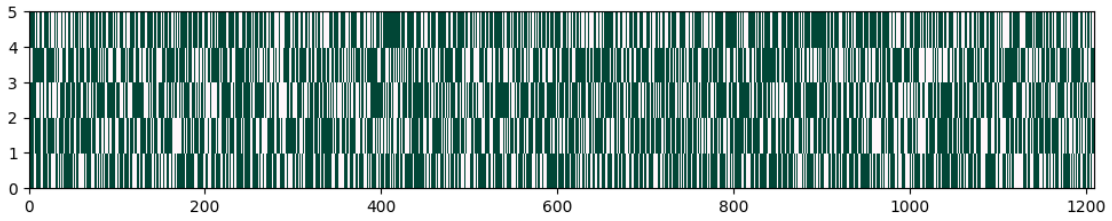
```
    585             out = X, y
    586
```

```
/usr/local/lib/python3.10/dist-packages/sklearn/utils/validation.py in
check_X_y(X, y, accept_sparse, accept_large_sparse, dtype, order, copy,
force_all_finite, ensure_2d, allow_nd, multi_output, ensure_min_samples,
ensure_min_features, y_numeric, estimator)
   1122     y = _check_y(y, multi_output=multi_output,
y_numeric=y_numeric, estimator=estimator)
   1123
-> 1124     check_consistent_length(X, y)
   1125
   1126     return X, y

/usr/local/lib/python3.10/dist-packages/sklearn/utils/validation.py in
check_consistent_length(*arrays)
    395     uniques = np.unique(lengths)
    396     if len(uniques) > 1:
--> 397         raise ValueError(
    398             "Found input variables with inconsistent numbers of
samples: %r"
    399             % [int(l) for l in lengths]

ValueError: Found input variables with inconsistent numbers of samples:
[1209, 1013]
```

```
bin_array = np.zeros((5, X_train.shape[0]))
for i in range(5):
    for j in bagging_model.estimators_samples_[i]:
        bin_array[i][j] = 1
bin_array
```

```
array([[0., 0., 0., ..., 1., 1., 0.],
       [0., 1., 0., ..., 0., 1., 1.],
       [1., 1., 1., ..., 1., 0., 0.],
       [1., 0., 1., ..., 1., 1., 1.],
       [1., 1., 1., ..., 1., 1., 0.]])
```

```
fig, ax = plt.subplots(figsize=(12,2))
ax.pcolor(bin_array, cmap='PuBuGn')
plt.show()
```




```
for i in range(5):
    cur_data = bin_array[i]
    len_cur_data = len(cur_data)
    sum_cur_data = sum(cur_data)
    (len(bin_array[0]) - sum(bin_array[0])) / len(bin_array[0])
```

```
    oob_i = (len_cur_data - sum_cur_data) / len_cur_data
    print('Для модели {} размер OOB составляет {}%'.format(i+1,
round(oob_i, 4)*100.0))
```

```
Для модели 1 размер OOB составляет 36.15%
Для модели 2 размер OOB составляет 36.059999999999995%
Для модели 3 размер OOB составляет 36.89%
Для модели 4 размер OOB составляет 37.8%
Для модели 5 размер OOB составляет 37.3%
```

Случайный лес

```
tree = RandomForestRegressor(n_estimators=10, random_state=12)
tree.fit(X_train, y_train)
tree_y = tree.predict(X_test)
```

```
tree_y
```

```
array([0.10176991, 0.2591085 , 0.05561593, 0.19871504, 0.14159292,
       0.08080177, 0.10339233, 0.35619469, 0.09459646, 0.17923319,
       0.11712035, 0.19685841, 0.21578761, 0.14050885, 0.09756637,
       0.08584071, 0.11147566, 0.08453142, 0.26202389, 0.08601062,
       0.04324726, 0.10297699, 0.23807788, 0.0880531 , 0.38230088,
       0.30313009, 0.08893805, 0.02763274, 0.14610566, 0.09175522,
       0.15221239, 0.09159292, 0.12538301, 0.10486726, 0.10474336,
       0.18858354, 0.18650442, 0.14779159, 0.1135469 , 0.15115472,
       0.15588407, 0.11712035, 0.17208053, 0.06548673, 0.11451372,
       0.04061947, 0.32364779, 0.28821504, 0.30353982, 0.08038348,
       0.12141593, 0.08893805, 0.22787611, 0.26150442, 0.16497788,
       0.14291549, 0.09140118, 0.09335752, 0.07710575, 0.06016947,
       0.17787611, 0.09557522, 0.18858354, 0.36411504, 0.14773894,
       0.27396903, 0.12131814, 0.17377301, 0.27402655, 0.06769912,
       0.16566394, 0.02827743, 0.33141593, 0.05584071, 0.10375133,
       0.13185841, 0.12365652, 0.19110619, 0.15324867, 0.12256637,
       0.22581106, 0.07163274, 0.09132743, 0.06769912, 0.09026549,
       0.04469027, 0.11688053, 0.05973451, 0.11283186, 0.19513274,
       0.15      , 0.50176991, 0.07250619, 0.02857699, 0.2000385 ,
       0.17310841, 0.14233053, 0.13244653, 0.12616504, 0.13853783,
       0.14032212, 0.08119469, 0.12166991, 0.05641745, 0.20012788,
       0.05320531, 0.20112832, 0.0857194 , 0.14469027, 0.04955752,
       0.10499749, 0.2000385 , 0.10575221, 0.06371681, 0.09047699,
       0.38761062, 0.23008805, 0.20229513, 0.06530973, 0.18225664,
       0.07655605, 0.12220743, 0.07345133, 0.05978451, 0.04930389,
       0.3854351 , 0.34245442, 0.08938053, 0.09380531, 0.11747788,
       0.10336168, 0.09911504, 0.15767982, 0.08561947, 0.06039823,
       0.04895499, 0.19557522, 0.06412248, 0.14115044, 0.16575208,
       0.15457788, 0.26349558, 0.05728496, 0.37234513, 0.20707965,
       0.02876106, 0.08849558, 0.15562965, 0.01700619, 0.17699115,
       0.12079646, 0.1659292 , 0.1141141 , 0.0941146 , 0.10022736,
       0.33592867, 0.06279808, 0.10349558, 0.14115044, 0.10929204,
       0.14836667, 0.08982257, 0.50486726, 0.0960177 , 0.03802313,
       0.09229504, 0.06761805, 0.04055434, 0.12079646, 0.14292035,
       0.16163717, 0.07710575, 0.16401858, 0.14376106, 0.13850084,
       0.16057367, 0.1       , 0.12131814, 0.20707965, 0.08205611,
       0.12345133, 0.15728168, 0.04729833, 0.02337876, 0.27145708,
```

```
       0.18440133, 0.11495115, 0.08761062, 0.0829154 , 0.12644735,
       0.10987739, 0.19915487, 0.02119602, 0.06457876, 0.17437788,
       0.10416681, 0.08390466, 0.20256549, 0.08400531, 0.11946903,
       0.11844425, 0.05796407, 0.03973451, 0.03802313, 0.18903973,
       0.11353938, 0.09690265, 0.08938584, 0.11599558, 0.16327434,
       0.21725664, 0.16007876, 0.1874073 , 0.27181361, 0.19043274,
       0.08663009, 0.17989947, 0.14970487, 0.04079189, 0.2610177 ,
       0.14911504, 0.08837522, 0.1135469 , 0.05097345, 0.06906062,
       0.1168385 , 0.12300885, 0.13565324, 0.15940265, 0.13424912,
       0.06398894, 0.13053097, 0.26884558, 0.16222071, 0.1473885 ,
       0.09675708, 0.12920354, 0.08061858, 0.04709265, 0.10176991,
       0.0877985 , 0.34645442, 0.07035398, 0.1948177 , 0.29527434,
       0.23118221, 0.17890855, 0.07431416, 0.13274115, 0.37871681,
       0.03753673, 0.15      , 0.0804615 , 0.10336168, 0.23265398,
       0.13353929, 0.20676991, 0.07816018, 0.18262071, 0.5079646 ,
       0.05708496, 0.2102208 , 0.08128628, 0.10708451, 0.04469027,
       0.09867212, 0.19263805, 0.18150301, 0.12743363, 0.10268982,
       0.1380531 , 0.19424779, 0.03035398, 0.09778761, 0.09574867,
       0.26957655, 0.12973451, 0.07875389, 0.05740301, 0.12075168,
       0.05740301, 0.28404867, 0.05522124, 0.09593186, 0.08717115,
       0.1311782 , 0.26442434, 0.19238938, 0.17566372, 0.08980885,
       0.24279292, 0.13730973, 0.05884956, 0.16824757, 0.03159292,
       0.09596372, 0.04513274, 0.01871549, 0.59004381, 0.11190487,
       0.16769912, 0.26363186, 0.02878398])
```

Ada boosting

```
from sklearn.ensemble import AdaBoostRegressor
ada_boost_model = AdaBoostRegressor(random_state=42)
ada_boost_model.fit(X_train, y_train)
predictions = ada_boost_model.predict(X_test)
predictions
```

```
array([0.16756232, 0.1859162 , 0.14925959, 0.26920256, 0.14478193,
       0.17883235, 0.14478193, 0.47063134, 0.17883235, 0.17883235,
       0.17883235, 0.17883235, 0.17883235, 0.17883235, 0.14392564,
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       0.14925959, 0.15760683, 0.18824637, 0.13246773, 0.25469012,
       0.33385408, 0.13521878, 0.13521878, 0.18824637, 0.17883235,
       0.2616506 , 0.14478193, 0.16756232, 0.13061342, 0.17883235,
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       0.14478193, 0.18824637, 0.26920256, 0.26240248, 0.11645297,
       0.14925959, 0.14478193, 0.14478193, 0.17883235, 0.2616506 ,
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       0.14925959, 0.17883235, 0.18824637, 0.17883235, 0.14869284,
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       0.17883235, 0.39222966, 0.16756232, 0.14925959, 0.33385408,
       0.16756232, 0.17883235, 0.17883235, 0.17883235, 0.17883235,
       0.1859162 , 0.14392564, 0.16756232, 0.14925959, 0.17883235,
       0.14925959, 0.26920256, 0.14925959, 0.099378  , 0.099378  ,
```

```
0.16756232, 0.33385408, 0.12097364, 0.099378  , 0.17883235,
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0.54160177, 0.34432782, 0.14478193, 0.25469012, 0.14925959,
0.17883235, 0.17883235, 0.17883235, 0.16946697, 0.16234584,
0.14925959, 0.17883235, 0.14925959, 0.13246773, 0.17883235,
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0.13521878, 0.14478193, 0.16756232, 0.14925959, 0.1859162 ,
0.14869284, 0.17395657, 0.14925959, 0.17883235, 0.17883235,
0.1859162 , 0.14925959, 0.14478193, 0.14478193, 0.14478193,
0.16756232, 0.16756232, 0.54160177, 0.14869284, 0.14478193,
0.12097364, 0.14869284, 0.14925959, 0.14869284, 0.14869284,
0.16756232, 0.14925959, 0.17883235, 0.16756232, 0.14925959,
0.17883235, 0.17883235, 0.17883235, 0.14869284, 0.14925959,
0.14478193, 0.17883235, 0.14925959, 0.14925959, 0.17395657,
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0.17883235, 0.17883235, 0.16756232, 0.14925959, 0.2616506 ,
0.17395657, 0.14925959, 0.22073009, 0.14478193, 0.14925959,
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0.14925959, 0.13521878, 0.14925959, 0.14925959, 0.16756232,
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0.18824637, 0.1859162 , 0.099378  , 0.17883235, 0.25469012,
0.14925959, 0.17883235, 0.14925959, 0.17883235, 0.17395657,
0.17883235, 0.17883235, 0.14925959, 0.17883235, 0.54160177,
0.14925959, 0.34159646, 0.14925959, 0.16756232, 0.13521878,
0.16946697, 0.1859162 , 0.18824637, 0.17883235, 0.17883235,
0.14478193, 0.2616506 , 0.12097364, 0.14925959, 0.13061342,
0.19191669, 0.16234584, 0.14925959, 0.14925959, 0.17883235,
0.14925959, 0.26920256, 0.14478193, 0.16756232, 0.14925959,
0.17883235, 0.18824637, 0.17883235, 0.2616506 , 0.16756232,
0.14478193, 0.14925959, 0.099378  , 0.16234584, 0.14478193,
0.16756232, 0.099378  , 0.14925959, 0.41668782, 0.17883235,
0.14478193, 0.17883235, 0.14925959])
```

Модель градиентного бустинга

```
from sklearn.ensemble import GradientBoostingRegressor

gradient_model = GradientBoostingRegressor(n_estimators=5)
gradient_model.fit(X_train, y_train)

GradientBoostingRegressor(n_estimators=5)
```

Стекинг

```
dataset = Dataset(X_train, y_train, X_test)

model_rf = Regressor(dataset=dataset, estimator=RandomForestRegressor,
parameters={'n_estimators': 10},name='rf')
model_lr = Regressor(dataset=dataset, estimator=LinearRegression,
```

```
parameters={},name='lr')

pipeline = ModelsPipeline(model_rf, model_lr)
stack_ds = pipeline.stack(k=15, seed=111)

stacker = Regressor(dataset=stack_ds, estimator=DecisionTreeRegressor)
stacker_y = stacker.predict()
results = stacker.validate(k=15, scorer=mean_squared_error)
```

```
Metric: mean_squared_error
Folds accuracy: [0.0227087972470267, 0.02150157678143149,
0.011089838427018462, 0.016406638441760477, 0.019717242025683826,
0.017153566026681128, 0.01989910946050862, 0.03447653616425389,
0.017792527498262097, 0.02524013829306328, 0.01955321142321247,
0.011264577201425327, 0.012080472966540056, 0.02966041993706438,
0.028175594111059986]
Mean accuracy: 0.02044801640033281
Standard Deviation: 0.0065745436073302455
Variance: 4.3224623644687e-05
```

Модель многослойного персептрона

```
from sklearn.neural_network import MLPRegressor

mlp = MLPRegressor(hidden_layer_sizes=(100, 50),  # Структура скрытых
слоев
                   activation='relu',             # Функция активации
                   solver='adam',                 # Оптимизатор
                   max_iter=1000,                 # Максимальное число
итераций
                   random_state=42)

# Обучение модели
mlp.fit(X_train, y_train)

nn_y = mlp.predict(X_test)
nn_y
```

```
array([0.11538884, 0.1475732 , 0.09323403, 0.22812901, 0.10920988,
       0.13014394, 0.08178939, 0.11760709, 0.10610423, 0.11396791,
       0.13423277, 0.16312752, 0.12729333, 0.12887886, 0.07471095,
       0.0960732 , 0.10433174, 0.08557473, 0.15507126, 0.10988527,
       0.06104875, 0.10879311, 0.24910293, 0.10433499, 0.28092765,
       0.23801488, 0.04902827, 0.06365788, 0.16587253, 0.09987761,
       0.12508277, 0.05000829, 0.10445032, 0.09697995, 0.10331713,
       0.05920072, 0.07695417, 0.11933005, 0.1128849 , 0.09731224,
       0.07838016, 0.13423277, 0.21531335, 0.08918128, 0.10878526,
       0.05755499, 0.426858  , 0.15757394, 0.26443565, 0.09275872,
       0.11582431, 0.11065747, 0.10539497, 0.09496359, 0.15870614,
       0.18636052, 0.09057254, 0.11070021, 0.09295011, 0.05394476,
       0.11573772, 0.08166461, 0.05920072, 0.11768173, 0.11024979,
       0.38750266, 0.07822764, 0.11128127, 0.24819281, 0.09657004,
       0.11785008, 0.06577801, 0.20268041, 0.0654479 , 0.10149517,
       0.0748529 , 0.09161444, 0.22952322, 0.20660413, 0.15227305,
       0.16650595, 0.09842326, 0.10815743, 0.09657004, 0.05843818,
```

```
       0.07857027, 0.16035054, 0.08934942, 0.08197133, 0.11695724,
       0.1499057 , 0.27365063, 0.09579997, 0.05489506, 0.22235218,
       0.10428457, 0.14893687, 0.12184264, 0.12823993, 0.12148396,
       0.12133107, 0.08038515, 0.11647827, 0.08508838, 0.20314722,
       0.06488663, 0.15596037, 0.09180963, 0.08795227, 0.07458806,
       0.11532824, 0.22235218, 0.08483764, 0.0663059 , 0.09709347,
       0.17997262, 0.17822098, 0.14430179, 0.09157508, 0.14861832,
       0.11597013, 0.07500735, 0.09293246, 0.09486835, 0.05200361,
       0.12717025, 0.21678705, 0.11396098, 0.1217402 , 0.05218756,
       0.09204128, 0.1251515 , 0.17177759, 0.03124266, 0.08636616,
       0.09969585, 0.1564211 , 0.07343659, 0.08114427, 0.11951358,
       0.09939511, 0.21067611, 0.09008146, 0.35425679, 0.12179877,
       0.04827865, 0.10349031, 0.12395861, 0.04498454, 0.12854828,
       0.13708183, 0.11929649, 0.04565419, 0.11000646, 0.10592178,
       0.10058381, 0.08051355, 0.04612547, 0.08741956, 0.11507196,
       0.08094913, 0.11448191, 0.19029131, 0.13929413, 0.05250748,
       0.06689683, 0.08145896, 0.0409143 , 0.12124261, 0.10242368,
       0.11621705, 0.09295011, 0.12686604, 0.10350314, 0.05857901,
       0.12482037, 0.09412937, 0.07822764, 0.110147  , 0.07602304,
       0.10634102, 0.16626857, 0.08492951, 0.05710912, 0.10972523,
       0.18069666, 0.11418766, 0.06399392, 0.09958021, 0.12273068,
       0.111828  , 0.11066595, 0.04494416, 0.09107661, 0.04948704,
       0.10773866, 0.10147352, 0.16933085, 0.08453812, 0.09651596,
       0.09716796, 0.0923456 , 0.06067951, 0.05250748, 0.13565747,
       0.14196901, 0.14378271, 0.11339027, 0.09044682, 0.12121381,
       0.13192427, 0.12687243, 0.12229883, 0.22281299, 0.10515386,
       0.12448383, 0.13118761, 0.11602733, 0.07547219, 0.18167834,
       0.15204711, 0.09183976, 0.1128849 , 0.07556754, 0.08525186,
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       0.03242133, 0.06967397, 0.10409459, 0.08052159, 0.10291004,
       0.1044202 , 0.12336455, 0.05937816, 0.08541059, 0.11610394,
       0.1077498 , 0.24210172, 0.10620578, 0.21862241, 0.2507288 ,
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       0.1094373 , 0.22946625, 0.06345325, 0.08912573, 0.18433933,
       0.0971331 , 0.22367556, 0.07646124, 0.10870699, 0.1121786 ,
       0.1406179 , 0.18282943, 0.23367718, 0.15461364, 0.0706927 ,
       0.08988797, 0.07706828, 0.06979774, 0.10217188, 0.10503668,
       0.17257081, 0.11849973, 0.08354512, 0.07193773, 0.10282381,
       0.07193773, 0.16796394, 0.0690563 , 0.11343235, 0.09616962,
       0.08981784, 0.1504968 , 0.18185462, 0.13083517, 0.09121092,
       0.1066607 , 0.05741587, 0.04584818, 0.05661788, 0.07907463,
       0.09908896, 0.08527696, 0.04637529, 0.25207331, 0.11235321,
       0.1212677 , 0.14604879, 0.04990143])
```

```
from gmdh import Multi, split_data
```

```
/usr/local/lib/python3.10/dist-packages/ipykernel/ipkernel.py:283:
DeprecationWarning: `should_run_async` will not call `transform_cell`
automatically in the future. Please pass the result to `transformed_cell`
argument and any exception that happen during thetransform in
`preprocessing_exc_tuple` in IPython 7.17 and above.
  and should_run_async(code)
```

```
model = Multi()
x_train, x_test, y_train, y_test = split_data(X, y, test_size=0.33)

model.fit(x_train, y_train, k_best=2, test_size=0.3)

y_predicted = model.predict(X_test)
y_predicted
```

```
/usr/local/lib/python3.10/dist-packages/ipykernel/ipkernel.py:283:
DeprecationWarning: `should_run_async` will not call `transform_cell`
automatically in the future. Please pass the result to `transformed_cell`
argument and any exception that happen during thetransform in
`preprocessing_exc_tuple` in IPython 7.17 and above.
  and should_run_async(code)
```

```
array([0.14208213, 0.15213179, 0.11057812, 0.21294061, 0.11326468,
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       0.14500974, 0.15271739, 0.15417166, 0.14575538, 0.08192499,
       0.1245362 , 0.13336794, 0.12275594, 0.17018991, 0.14239416,
       0.07194184, 0.11098339, 0.2083537 , 0.11256565, 0.22848628,
       0.22135126, 0.07678513, 0.07882243, 0.18729172, 0.13011019,
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       0.06352499, 0.18404729, 0.08452408, 0.11264963, 0.12707816,
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       0.14387621, 0.07194184, 0.09467171, 0.0998361 , 0.07489993,
       0.1375897 , 0.1738458 , 0.11710169, 0.16456454, 0.0746844 ,
       0.12427652, 0.14452877, 0.16431892, 0.13868911, 0.11116841,
       0.11052441, 0.18430581, 0.08909712, 0.12619687, 0.14011519,
       0.13145518, 0.2016658 , 0.10961697, 0.29093672, 0.13938798,
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       0.16268885, 0.14909951, 0.0656449 , 0.13429598, 0.1333161 ,
       0.13311695, 0.10202025, 0.07647928, 0.09395893, 0.10867471,
       0.10364631, 0.14715229, 0.16283633, 0.15173557, 0.06123221,
       0.06867783, 0.10146645, 0.06659009, 0.17503878, 0.13606144,
       0.14603511, 0.10409659, 0.14185536, 0.13308272, 0.08374318,
       0.15220061, 0.12242666, 0.11453216, 0.14739629, 0.07194184,
       0.11352265, 0.19127154, 0.10410614, 0.07081199, 0.13914318,
       0.18434555, 0.13737064, 0.1153479 , 0.13051237, 0.14395289,
       0.13393115, 0.16285892, 0.06382274, 0.12562947, 0.07431957,
```

```
       0.08140247, 0.13067076, 0.1824877 , 0.12204499, 0.10628779,
       0.11524497, 0.12524675, 0.05514081, 0.06123221, 0.16106344,
       0.15690347, 0.15075592, 0.12175454, 0.1392487 , 0.14743406,
       0.13767877, 0.14076144, 0.14142916, 0.17805237, 0.17123057,
       0.14290333, 0.19793271, 0.14798086, 0.08289172, 0.23978828,
       0.14939564, 0.11724043, 0.14036831, 0.08341685, 0.08557243,
       0.18273966, 0.15110703, 0.14545713, 0.07893899, 0.15017948,
       0.04619133, 0.07565283, 0.1349623 , 0.12970905, 0.13404103,
       0.12392815, 0.13248939, 0.07991521, 0.10452242, 0.14387621,
       0.1266652 , 0.17555931, 0.14068454, 0.21233257, 0.21966616,
       0.20937512, 0.13469787, 0.08833144, 0.17341741, 0.24639154,
       0.07951672, 0.14971526, 0.10335795, 0.12427652, 0.13877835,
       0.14159287, 0.19514062, 0.07262211, 0.14828798, 0.16283633,
       0.11127771, 0.19021998, 0.10335795, 0.14370967, 0.08960123,
       0.13087995, 0.19144505, 0.20441554, 0.18518863, 0.11407599,
       0.13670735, 0.0660013 , 0.06851634, 0.11971725, 0.11892017,
       0.17755042, 0.12297064, 0.10311474, 0.10179335, 0.1332015 ,
       0.10179335, 0.17026461, 0.06496807, 0.14788194, 0.11102069,
       0.12437241, 0.16225009, 0.15908724, 0.16757692, 0.11388648,
       0.1236344 , 0.07598693, 0.05096993, 0.09519557, 0.06785663,
       0.13349247, 0.08640543, 0.06382274, 0.19191123, 0.14563377,
       0.12979036, 0.17402281, 0.07405024])
```

```
from gmdh import Mia

mia_model = Mia()
mia_model.fit(x_train, y_train, k_best=5, p_average=3)

y_mia = mia_model.predict(X_test)
y_mia
```

```
/usr/local/lib/python3.10/dist-packages/ipykernel/ipkernel.py:283:
DeprecationWarning: `should_run_async` will not call `transform_cell`
automatically in the future. Please pass the result to `transformed_cell`
argument and any exception that happen during thetransform in
`preprocessing_exc_tuple` in IPython 7.17 and above.
  and should_run_async(code)
```

```
array([ 0.15913822,  0.16092086,  0.1170128 ,  0.2896894 ,  0.12014218,
        0.12538191,  0.09444396,  0.1406753 ,  0.166097  ,  0.15999851,
        0.16482614,  0.16017894,  0.16988662,  0.17092471,  0.08577415,
        0.12126872,  0.15739188,  0.12138252,  0.21974952,  0.1437926 ,
        0.08574617,  0.11747657,  0.19723418,  0.11587192,  0.25088256,
        0.33463973,  0.08562167,  0.08562167,  0.18896404,  0.14152684,
        0.16035437,  0.1122179 ,  0.14376598,  0.13219958,  0.16105563,
        0.1040853 ,  0.12064946,  0.16299098,  0.1437812 ,  0.14102891,
        0.13976987,  0.16482614,  0.21688645,  0.12041645,  0.15501119,
        0.08574844,  0.18442375,  0.17798824,  0.21632034,  0.08527284,
        0.1209401 ,  0.11589481,  0.13302232,  0.11006675,  0.17463837,
        0.13497775,  0.10411045,  0.15675786,  0.11702471,  0.1041211 ,
        0.14494979,  0.12484199,  0.1040853 ,  0.12078691,  0.11926819,
        0.16523433,  0.11052362,  0.15999851,  0.30774505,  0.09443733,
        0.16616816,  0.08578454,  0.21877254,  0.08579442,  0.14071088,
        0.12019544,  0.1423262 ,  0.18310614,  0.1643798 ,  0.13882163,
```

```
0.17223735,  0.0852821 ,  0.14416395,  0.09443733,  0.11142644,
0.09050934,  0.16429734,  0.09444354,  0.10999438,  0.12800016,
0.15793793,  0.206068  ,  0.11618405,  0.0857764 ,  0.3091745 ,
0.15899454,  0.16317722,  0.15930468,  0.16153994,  0.16402871,
0.15533822,  0.104105  ,  0.16131944,  0.11696712,  0.16316234,
0.08580834,  0.18175991,  0.1205268 ,  0.06209487,  0.08570927,
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0.2185989 ,  0.18165209,  0.21689169,  0.14336573, -0.00995588,
0.15881371,  0.08574617,  0.10080561,  0.08497152,  0.10412437,
0.14140111,  0.19227421,  0.12462393,  0.10482502,  0.10409951,
0.14191762,  0.15155549,  0.17245061,  0.11143697,  0.12763639,
0.11650635,  0.17013729,  0.10413118,  0.13263546,  0.16616816,
0.14071088,  0.18090494,  0.11628954,  0.23266555,  0.13297006,
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0.10831974,  0.12946173,  0.08578454,  0.16011512,  0.14481241,
0.15877801,  0.11626195,  0.0857189 ,  0.11044878,  0.08527948,
0.11037388,  0.16437037,  0.17034547,  0.09403452,  0.08576517,
0.08570112,  0.11639525,  0.0858133 ,  0.12701052,  0.1543229 ,
0.15897456,  0.11702471,  0.16904991,  0.14336573,  0.10411067,
0.16320008,  0.13968547,  0.11052362,  0.13764917,  0.08574617,
0.12078143,  0.17340889,  0.11693489,  0.08576683,  0.16271117,
0.17790221,  0.16277849,  0.124524  ,  0.14222955,  0.16234439,
0.15943525,  0.12506827,  0.08578812,  0.14698252,  0.10409402,
0.10080747,  0.14376598,  0.17751175,  0.14204973,  0.08520939,
0.11650635,  0.14389082,  0.07162622,  0.08576517,  0.18528137,
0.16849024,  0.15817123,  0.11657985,  0.16500657,  0.16035437,
0.16283607,  0.15694775,  0.16151908,  0.16692319,  0.13637818,
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0.15381497,  0.11642423,  0.1437812 ,  0.09444396,  0.10411045,
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0.12196942,  0.1900474 ,  0.18045658,  0.18060813,  0.11042095,
0.13248446,  0.08571955,  0.08570751,  0.11657985,  0.13400469,
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0.11664712,  0.22269831,  0.08571252,  0.16584771,  0.11647279,
0.14222955,  0.17197698,  0.16938725,  0.16139417,  0.11046053,
0.11891289,  0.10411637,  0.07129832,  0.11034979,  0.08573522,
0.14071088,  0.09444005,  0.08578812,  0.19695382,  0.17067102,
0.11938378,  0.16315762,  0.1041211 ])
```

Оценка моделей

```
results_metrics = [mean_squared_error(y_test, tree_y),
mean_squared_error(y_test, tree_y), mean_squared_error(y_test, reg_y),
mean_squared_error(y_test, stacker_y), mean_squared_error(y_test, nn_y),
mean_squared_error(y_test, gmdh_y)]
model_list = ['bagging', 'random_forest', 'boosting', 'stacker', 'nn',
'gmdh']
```

```
sorted_el = list(sorted(list(zip(model_list, results_metrics)), key=lambda
x: -x[1]))
results_metrics = list(map(lambda x: x[1], sorted_el))
model_list = list(map(lambda x: x[0], sorted_el))

fig, ax = plt.subplots(figsize=(20,20))
pos = np.arange(len(model_list))
rects = ax.barh(pos, results_metrics,
             align='center',
             height=0.5,
             tick_label=model_list)
ax.set_title('mean_squared')
for a, b in zip(pos, results_metrics):
    plt.text(max(results_metrics)/2, a-0.05, str(round(b,6)),
color='black')
plt.show()
```