lab6

June 26, 2024

[35]:
```
import pandas as pd
from sklearn.model_selection import train_test_split
from heamy.estimator import Regressor
#     import getargspec   lib/heamy/estimator.py -     estimator
from heamy.pipeline import ModelsPipeline
from heamy.dataset import Dataset
from sklearn.metrics import mean_absolute_error
from sklearn.linear_model import LinearRegression
from sklearn.tree import DecisionTreeRegressor
from sklearn.ensemble import RandomForestRegressor
import numpy as np
import seaborn as sns
import matplotlib.pyplot as plt
%matplotlib inline
sns.set(style="ticks")
from sklearn.neural_network import MLPRegressor
```

[3]:
```
data = pd.read_csv('Mobile Price Prediction.csv', sep=",")
```

[4]:
```
data.shape
```

[4]:
```
(292, 6)
```

[5]:
```
data.head
```

[5]:
```
<bound method NDFrame.head of      Screen Size  RAM  Storage  Battery Capacity
Camera Quality  Price
0            6.2    4       64               4000             48     500
1            6.1    3      128               3110             12     800
2            6.5    6      256               4500             64     600
3            6.7    8      128               4300             48     700
4            6.4    6      128               4200             40     550
..           …  …      …               …             …    …
287          6.0    6       64               3700             12     750
288          6.3    4      128               4025             32     450
289          6.6    8      256               5000             48     700
290          6.5    6      128               4500             64     550
```

```
291            6.1    4      64               3000                16     400

[292 rows x 6 columns]>
```

```
[6]: data.dtypes
```

```
[6]: Screen Size         float64
     RAM                   int64
     Storage               int64
     Battery Capacity      int64
     Camera Quality        int64
     Price                 int64
     dtype: object
```

1 2.

```
[7]: data.isnull().sum()
```

```
[7]: Screen Size         0
     RAM                 0
     Storage             0
     Battery Capacity    0
     Camera Quality      0
     Price               0
     dtype: int64
```

2 3.

```
[8]: ins_data = data.drop(columns='Price')
     ins_X, ins_y = ins_data, data[['Price']].values
     ins_X_train, ins_X_test, ins_y_train, ins_y_test = train_test_split(
         ins_X, ins_y, test_size=0.2, random_state=1)
```

3 4.1

```
[9]: #
     def val_mae(model):
         model.fit(ins_X_train, ins_y_train)
         y_pred = model.predict(ins_X_test)
         result = mean_absolute_error(ins_y_test, y_pred)
         print(model)
         print('MAE={}'.format(result))
```

[38]:

```
#
for model in [
    LinearRegression(),
    DecisionTreeRegressor(),
    RandomForestRegressor(n_estimators=50)
]:
    val_mae(model)
    print()
```

```
LinearRegression()
MAE=91.77213251714615

DecisionTreeRegressor()
MAE=5.932203389830509

RandomForestRegressor(n_estimators=50)
MAE=10.932203389830509


c:\Users\yulia\AppData\Local\Programs\Python\Python39\lib\site-
packages\sklearn\base.py:1474: DataConversionWarning: A column-vector y was
passed when a 1d array was expected. Please change the shape of y to
(n_samples,), for example using ravel().
  return fit_method(estimator, *args, **kwargs)
```

[36]:

```
#             heamy
#

dataset = Dataset(ins_X_train, ins_y_train, ins_X_test)

#
model_tree = Regressor(dataset=dataset, estimator=DecisionTreeRegressor,␣
  ↪name='tree')
model_lr = Regressor(dataset=dataset, estimator=LinearRegression,name='lr')
model_rf = Regressor(dataset=dataset, estimator=RandomForestRegressor,␣
  ↪parameters={'n_estimators': 50},name='rf')
```

[12]:

```
#         -       :
#        :

pipeline = ModelsPipeline(model_tree, model_lr)
stack_ds = pipeline.stack(k=10, seed=1)
#
stacker = Regressor(dataset=stack_ds, estimator=LinearRegression)
results = stacker.validate(k=10,scorer=mean_absolute_error)
```

```
Metric: mean_absolute_error
Folds accuracy: [10.099482322212891, 11.079378673785781, 19.34684684227087,
30.209752520471028, 9.873620825195745, 21.754293964323068, 12.3393354483684,
24.53804227710834, 8.258690680427428, 22.413285340984103]
Mean accuracy: 16.991272889514768
Standard Deviation: 7.213334906396753
Variance: 52.03220047184185
```

[37]:

```
#          -       :    ,
#         :
pipeline = ModelsPipeline(model_tree, model_lr, model_rf)
stack_ds3 = pipeline.stack(k=10, seed=1)
#
stacker = Regressor(dataset=stack_ds3, estimator=LinearRegression)
results = stacker.validate(k=10,scorer=mean_absolute_error)
```

```
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```

```
Metric: mean_absolute_error
Folds accuracy: [13.589403717629898, 11.54047104518372, 11.851948191333255,
30.949803198842545, 8.597168913783637, 14.7265943482436, 12.32657560629455,
25.638230662453452, 11.743345265394503, 15.05109971590865]
Mean accuracy: 15.601464066506784
Standard Deviation: 6.683154509112947
Variance: 44.66455419267672
```

[39]:

```
#          -       :
#         :

pipeline = ModelsPipeline(model_tree, model_lr)
stack_ds = pipeline.stack(k=10, seed=1)
#
stacker = Regressor(dataset=stack_ds, estimator=DecisionTreeRegressor)
results = stacker.validate(k=10,scorer=mean_absolute_error)
```

```
Metric: mean_absolute_error
Folds accuracy: [16.666666666666668, 22.916666666666668, 12.5,
32.608695652173914, 4.3478260869565215, 17.391304347826086, 8.695652173913043,
19.565217391304348, 17.391304347826086, 17.391304347826086]
Mean accuracy: 16.947463768115945
Standard Deviation: 7.314719612167022
Variance: 53.50512300462087
```

[41]:

```
#           -       :    ,
#          :

pipeline = ModelsPipeline(model_tree, model_rf, model_lr)
stack_ds = pipeline.stack(k=10, seed=1)
#
stacker = Regressor(dataset=stack_ds, estimator=DecisionTreeRegressor)
results = stacker.validate(k=10,scorer=mean_absolute_error)
```

```
Metric: mean_absolute_error
Folds accuracy: [8.333333333333334, 6.25, 0.0, 28.26086956521739,
4.3478260869565215, 13.043478260869565, 15.217391304347826, 21.73913043478261,
17.391304347826086, 10.869565217391305]
Mean accuracy: 12.545289855072465
Standard Deviation: 8.044503337540489
Variance: 64.71403394770006
```

[42]:

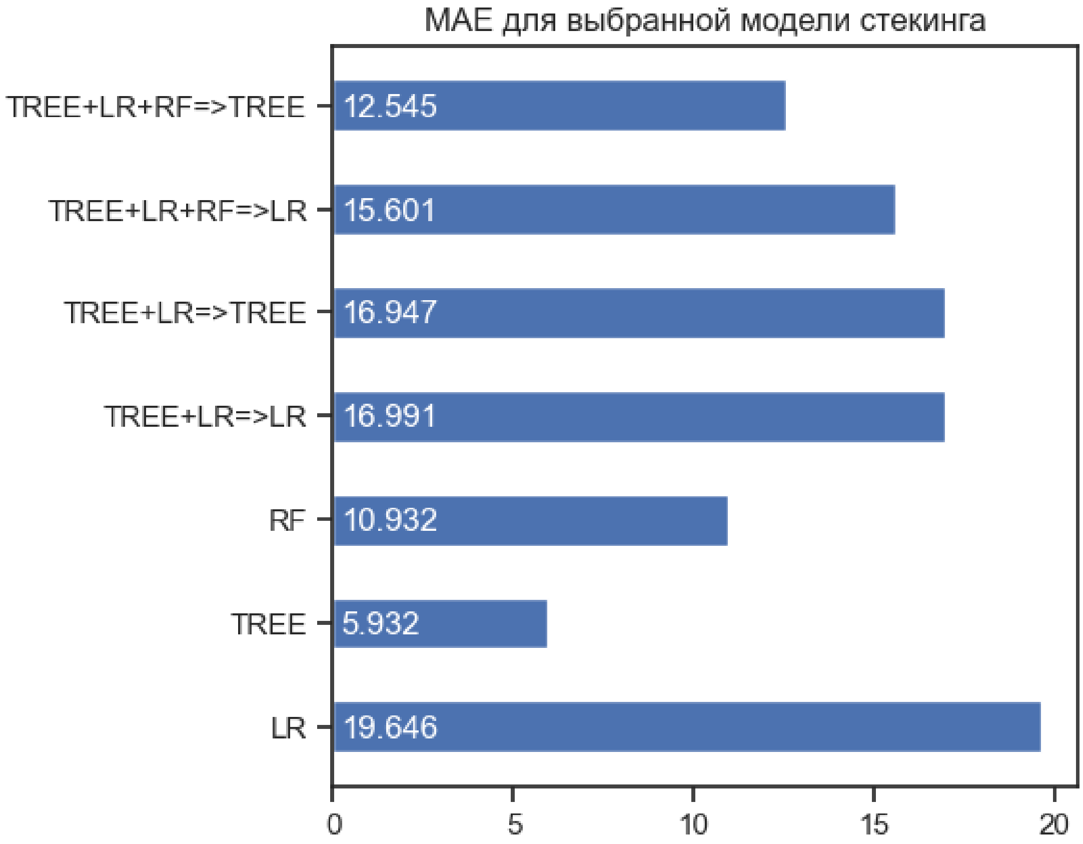
```
#
array_labels = ['LR', 'TREE', 'RF', 'TREE+LR=>LR', 'TREE+LR=>TREE',␣
 ↪'TREE+LR+RF=>LR', 'TREE+LR+RF=>TREE']
array_mae = [19.645947869043603,
             5.932203389830509,
             10.932203389830509,
             16.991272889514768,
             16.947463768115945,
             15.601464066506784,
             12.545289855072465]
```

[43]:

```
def vis_models_quality(array_metric, array_labels, str_header, figsize=(5, 5)):
    fig, ax1 = plt.subplots(figsize=figsize)
    pos = np.arange(len(array_metric))
    rects = ax1.barh(pos, array_metric,
                     align='center',
                     height=0.5,
                     tick_label=array_labels)
    ax1.set_title(str_header)
    for a,b in zip(pos, array_metric):
        plt.text(0.2, a-0.1, str(round(b,3)), color='white')
    plt.show()
```

[44]:

```
#
vis_models_quality(array_mae, array_labels, 'MAE                  ')
```



4 4.2

[16]:

```
from sklearn.preprocessing import StandardScaler

scaler = StandardScaler()

#
ins_X_train_scaled = scaler.fit_transform(ins_X_train)
ins_X_test_scaled = scaler.fit_transform(ins_X_test)
```

[17]:

```
from time import time

i = 0
df = pd.DataFrame(columns =␣
 ↪['alpha','max_iter','train_mae','test_mae','train_time'])
for a in [0.00001,0.0001,0.001,0.01, 0.1, 1, 10]:
    for mi in [10, 100, 1000, 10000]:
        st = time()
        mlp = MLPRegressor(alpha=a, max_iter=mi, random_state=1)
        mlp.fit(ins_X_train_scaled, ins_y_train)
        end = time() - st

        mae_tr = mean_absolute_error(ins_y_train, mlp.
 ↪predict(ins_X_train_scaled))
        mae = mean_absolute_error(ins_y_test, mlp.predict(ins_X_test_scaled))
        df.loc[i] = [a,mi,mae_tr,mae,end]
        i=i+1
```

```
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packages\sklearn\neural_network\_multilayer_perceptron.py:1624:
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c:\Users\yulia\AppData\Local\Programs\Python\Python39\lib\site-
packages\sklearn\neural_network\_multilayer_perceptron.py:1624:
DataConversionWarning: A column-vector y was passed when a 1d array was
expected. Please change the shape of y to (n_samples, ), for example using
ravel().
  y = column_or_1d(y, warn=True)
c:\Users\yulia\AppData\Local\Programs\Python\Python39\lib\site-
packages\sklearn\neural_network\_multilayer_perceptron.py:691:
ConvergenceWarning: Stochastic Optimizer: Maximum iterations (100) reached and
the optimization hasn't converged yet.
  warnings.warn(
c:\Users\yulia\AppData\Local\Programs\Python\Python39\lib\site-
packages\sklearn\neural_network\_multilayer_perceptron.py:1624:
DataConversionWarning: A column-vector y was passed when a 1d array was
expected. Please change the shape of y to (n_samples, ), for example using
ravel().
  y = column_or_1d(y, warn=True)
c:\Users\yulia\AppData\Local\Programs\Python\Python39\lib\site-
packages\sklearn\neural_network\_multilayer_perceptron.py:691:
ConvergenceWarning: Stochastic Optimizer: Maximum iterations (1000) reached and
the optimization hasn't converged yet.
  warnings.warn(
c:\Users\yulia\AppData\Local\Programs\Python\Python39\lib\site-
packages\sklearn\neural_network\_multilayer_perceptron.py:1624:
```

```
DataConversionWarning: A column-vector y was passed when a 1d array was
expected. Please change the shape of y to (n_samples, ), for example using
ravel().
  y = column_or_1d(y, warn=True)
c:\Users\yulia\AppData\Local\Programs\Python\Python39\lib\site-
packages\sklearn\neural_network\_multilayer_perceptron.py:1624:
DataConversionWarning: A column-vector y was passed when a 1d array was
expected. Please change the shape of y to (n_samples, ), for example using
ravel().
  y = column_or_1d(y, warn=True)
c:\Users\yulia\AppData\Local\Programs\Python\Python39\lib\site-
packages\sklearn\neural_network\_multilayer_perceptron.py:691:
ConvergenceWarning: Stochastic Optimizer: Maximum iterations (10) reached and
the optimization hasn't converged yet.
  warnings.warn(
c:\Users\yulia\AppData\Local\Programs\Python\Python39\lib\site-
packages\sklearn\neural_network\_multilayer_perceptron.py:1624:
DataConversionWarning: A column-vector y was passed when a 1d array was
expected. Please change the shape of y to (n_samples, ), for example using
ravel().
  y = column_or_1d(y, warn=True)
c:\Users\yulia\AppData\Local\Programs\Python\Python39\lib\site-
packages\sklearn\neural_network\_multilayer_perceptron.py:691:
ConvergenceWarning: Stochastic Optimizer: Maximum iterations (100) reached and
the optimization hasn't converged yet.
  warnings.warn(
c:\Users\yulia\AppData\Local\Programs\Python\Python39\lib\site-
packages\sklearn\neural_network\_multilayer_perceptron.py:1624:
DataConversionWarning: A column-vector y was passed when a 1d array was
expected. Please change the shape of y to (n_samples, ), for example using
ravel().
  y = column_or_1d(y, warn=True)
c:\Users\yulia\AppData\Local\Programs\Python\Python39\lib\site-
packages\sklearn\neural_network\_multilayer_perceptron.py:691:
ConvergenceWarning: Stochastic Optimizer: Maximum iterations (1000) reached and
the optimization hasn't converged yet.
  warnings.warn(
c:\Users\yulia\AppData\Local\Programs\Python\Python39\lib\site-
packages\sklearn\neural_network\_multilayer_perceptron.py:1624:
DataConversionWarning: A column-vector y was passed when a 1d array was
expected. Please change the shape of y to (n_samples, ), for example using
ravel().
  y = column_or_1d(y, warn=True)
```

[18]:

```
df.sort_values(by='test_mae').head(3)
#                 19: alpha = 0.1, max_iter = 10000
```

[18]:

```
       alpha  max_iter  train_mae   test_mae  train_time
19  0.10000   10000.0  44.598683  66.395082    5.492069
3   0.00001   10000.0  48.785653  68.379520    6.076551
7   0.00010   10000.0  48.781782  68.387106    6.130107
```

[19]:

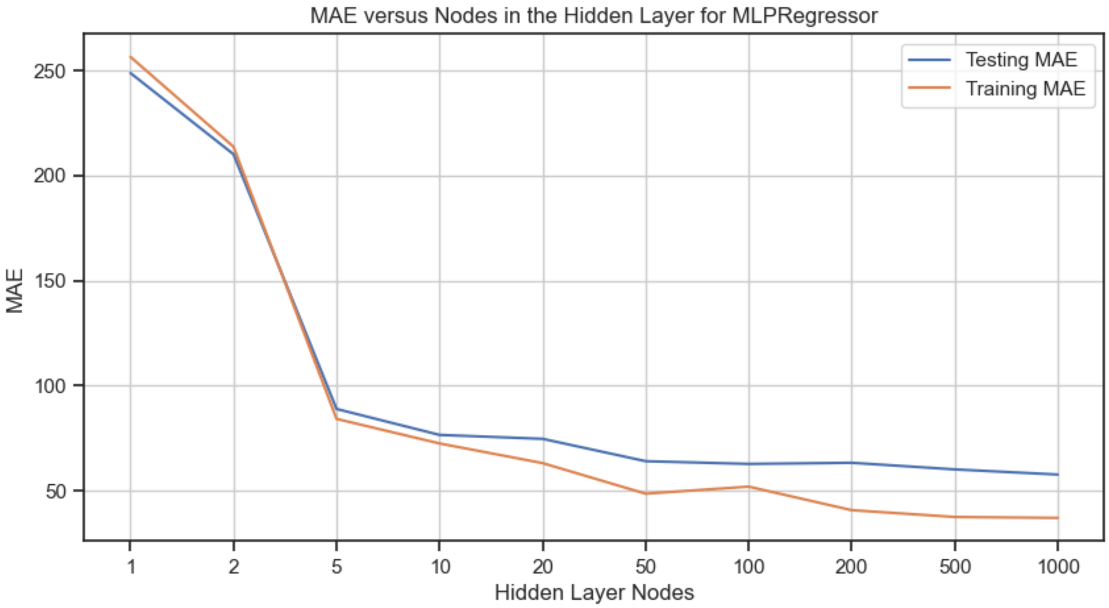
```
mae = []
mae_tr = []
timelog = []
for l in [1,2,5,10,20,50,100,200,500,1000]:
    t = time()
    mlp = MLPRegressor(alpha=0.1, max_iter=10000, hidden_layer_sizes=(l,))
    mlp.fit(ins_X_train_scaled, ins_y_train)
    endt = time() - t

    m_tr = mean_absolute_error(ins_y_train, mlp.predict(ins_X_train_scaled))
    m = mean_absolute_error(ins_y_test, mlp.predict(ins_X_test_scaled))

    mae_tr.append(m_tr)
    mae.append(m)
    timelog.append(endt)
```

```
c:\Users\yulia\AppData\Local\Programs\Python\Python39\lib\site-
packages\sklearn\neural_network\_multilayer_perceptron.py:1624:
DataConversionWarning: A column-vector y was passed when a 1d array was
expected. Please change the shape of y to (n_samples, ), for example using
ravel().
  y = column_or_1d(y, warn=True)
c:\Users\yulia\AppData\Local\Programs\Python\Python39\lib\site-
packages\sklearn\neural_network\_multilayer_perceptron.py:691:
ConvergenceWarning: Stochastic Optimizer: Maximum iterations (10000) reached and
the optimization hasn't converged yet.
  warnings.warn(
c:\Users\yulia\AppData\Local\Programs\Python\Python39\lib\site-
packages\sklearn\neural_network\_multilayer_perceptron.py:1624:
DataConversionWarning: A column-vector y was passed when a 1d array was
expected. Please change the shape of y to (n_samples, ), for example using
ravel().
  y = column_or_1d(y, warn=True)
c:\Users\yulia\AppData\Local\Programs\Python\Python39\lib\site-
packages\sklearn\neural_network\_multilayer_perceptron.py:691:
ConvergenceWarning: Stochastic Optimizer: Maximum iterations (10000) reached and
the optimization hasn't converged yet.
  warnings.warn(
c:\Users\yulia\AppData\Local\Programs\Python\Python39\lib\site-
packages\sklearn\neural_network\_multilayer_perceptron.py:1624:
DataConversionWarning: A column-vector y was passed when a 1d array was
expected. Please change the shape of y to (n_samples, ), for example using
```

```
ravel().
  y = column_or_1d(y, warn=True)
c:\Users\yulia\AppData\Local\Programs\Python\Python39\lib\site-
packages\sklearn\neural_network\_multilayer_perceptron.py:691:
ConvergenceWarning: Stochastic Optimizer: Maximum iterations (10000) reached and
the optimization hasn't converged yet.
  warnings.warn(
c:\Users\yulia\AppData\Local\Programs\Python\Python39\lib\site-
packages\sklearn\neural_network\_multilayer_perceptron.py:1624:
DataConversionWarning: A column-vector y was passed when a 1d array was
expected. Please change the shape of y to (n_samples, ), for example using
ravel().
  y = column_or_1d(y, warn=True)
c:\Users\yulia\AppData\Local\Programs\Python\Python39\lib\site-
packages\sklearn\neural_network\_multilayer_perceptron.py:691:
ConvergenceWarning: Stochastic Optimizer: Maximum iterations (10000) reached and
the optimization hasn't converged yet.
  warnings.warn(
c:\Users\yulia\AppData\Local\Programs\Python\Python39\lib\site-
packages\sklearn\neural_network\_multilayer_perceptron.py:1624:
DataConversionWarning: A column-vector y was passed when a 1d array was
expected. Please change the shape of y to (n_samples, ), for example using
ravel().
  y = column_or_1d(y, warn=True)
c:\Users\yulia\AppData\Local\Programs\Python\Python39\lib\site-
packages\sklearn\neural_network\_multilayer_perceptron.py:691:
ConvergenceWarning: Stochastic Optimizer: Maximum iterations (10000) reached and
the optimization hasn't converged yet.
  warnings.warn(
c:\Users\yulia\AppData\Local\Programs\Python\Python39\lib\site-
packages\sklearn\neural_network\_multilayer_perceptron.py:1624:
DataConversionWarning: A column-vector y was passed when a 1d array was
expected. Please change the shape of y to (n_samples, ), for example using
ravel().
  y = column_or_1d(y, warn=True)
c:\Users\yulia\AppData\Local\Programs\Python\Python39\lib\site-
packages\sklearn\neural_network\_multilayer_perceptron.py:1624:
DataConversionWarning: A column-vector y was passed when a 1d array was
expected. Please change the shape of y to (n_samples, ), for example using
ravel().
  y = column_or_1d(y, warn=True)
c:\Users\yulia\AppData\Local\Programs\Python\Python39\lib\site-
packages\sklearn\neural_network\_multilayer_perceptron.py:1624:
DataConversionWarning: A column-vector y was passed when a 1d array was
expected. Please change the shape of y to (n_samples, ), for example using
ravel().
  y = column_or_1d(y, warn=True)
c:\Users\yulia\AppData\Local\Programs\Python\Python39\lib\site-
```

```
packages\sklearn\neural_network\_multilayer_perceptron.py:1624:
DataConversionWarning: A column-vector y was passed when a 1d array was
expected. Please change the shape of y to (n_samples, ), for example using
ravel().
  y = column_or_1d(y, warn=True)
c:\Users\yulia\AppData\Local\Programs\Python\Python39\lib\site-
packages\sklearn\neural_network\_multilayer_perceptron.py:1624:
DataConversionWarning: A column-vector y was passed when a 1d array was
expected. Please change the shape of y to (n_samples, ), for example using
ravel().
  y = column_or_1d(y, warn=True)
```

[20]:
```
l = [1,2,5,10,20,50,100,200,500,1000]
N = len(l)
l2 = np.arange(N)
plt.subplots(figsize=(10, 5))
plt.plot(l2, mae, label="Testing MAE")
plt.plot(l2, mae_tr, label="Training MAE")
plt.xticks(l2,l)
plt.grid(True)
plt.xlabel("Hidden Layer Nodes")
plt.ylabel("MAE")
plt.legend()
plt.title('MAE versus Nodes in the Hidden Layer for MLPRegressor', fontsize=12)
plt.show()
```



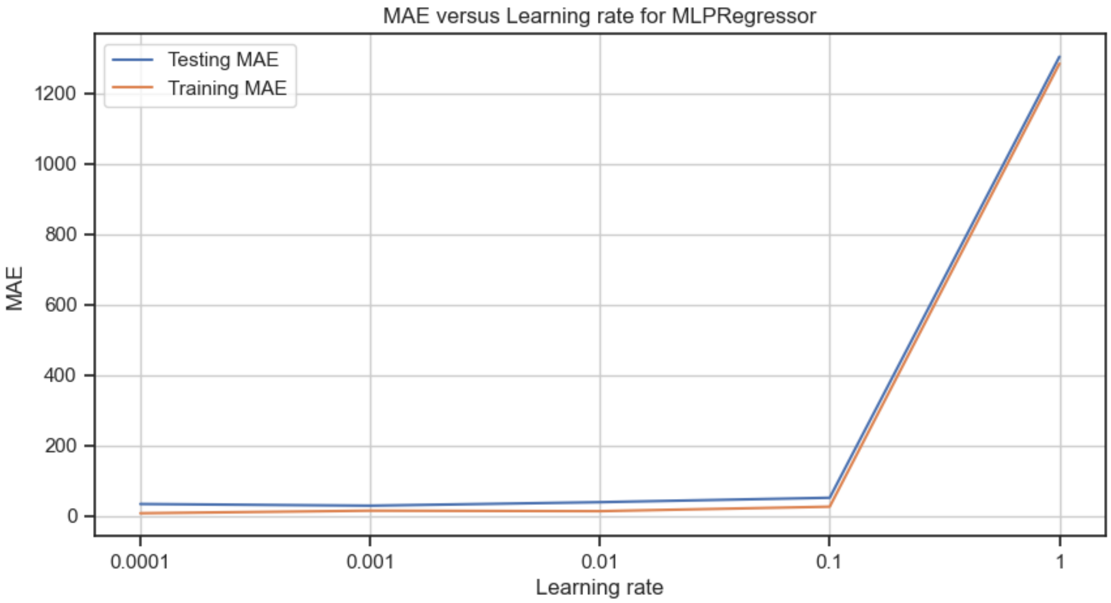
[21]:

```
mae = []
mae_tr = []
timelog = []
for l in [0.0001, 0.001, 0.01, 0.1, 1]:
    t = time()
    mlp = MLPRegressor(alpha=0.1, max_iter=10000,␣
  ↪hidden_layer_sizes=(1000,500), learning_rate_init=l)
    mlp.fit(ins_X_train_scaled, ins_y_train)
    endt = time() - t

    m_tr = mean_absolute_error(ins_y_train, mlp.predict(ins_X_train_scaled))
    m = mean_absolute_error(ins_y_test, mlp.predict(ins_X_test_scaled))

    mae_tr.append(m_tr)
    mae.append(m)
    timelog.append(endt)
```

```
c:\Users\yulia\AppData\Local\Programs\Python\Python39\lib\site-
packages\sklearn\neural_network\_multilayer_perceptron.py:1624:
DataConversionWarning: A column-vector y was passed when a 1d array was
expected. Please change the shape of y to (n_samples, ), for example using
ravel().
  y = column_or_1d(y, warn=True)
c:\Users\yulia\AppData\Local\Programs\Python\Python39\lib\site-
packages\sklearn\neural_network\_multilayer_perceptron.py:1624:
DataConversionWarning: A column-vector y was passed when a 1d array was
expected. Please change the shape of y to (n_samples, ), for example using
ravel().
  y = column_or_1d(y, warn=True)
c:\Users\yulia\AppData\Local\Programs\Python\Python39\lib\site-
packages\sklearn\neural_network\_multilayer_perceptron.py:1624:
DataConversionWarning: A column-vector y was passed when a 1d array was
expected. Please change the shape of y to (n_samples, ), for example using
ravel().
  y = column_or_1d(y, warn=True)
c:\Users\yulia\AppData\Local\Programs\Python\Python39\lib\site-
packages\sklearn\neural_network\_multilayer_perceptron.py:1624:
DataConversionWarning: A column-vector y was passed when a 1d array was
expected. Please change the shape of y to (n_samples, ), for example using
ravel().
  y = column_or_1d(y, warn=True)
c:\Users\yulia\AppData\Local\Programs\Python\Python39\lib\site-
packages\sklearn\neural_network\_multilayer_perceptron.py:1624:
DataConversionWarning: A column-vector y was passed when a 1d array was
expected. Please change the shape of y to (n_samples, ), for example using
ravel().
  y = column_or_1d(y, warn=True)
```

[22]:

```
l = [0.0001, 0.001, 0.01, 0.1, 1]
N = len(l)
l2 = np.arange(N)
plt.subplots(figsize=(10, 5))
plt.plot(l2, mae, label="Testing MAE")
plt.plot(l2, mae_tr, label="Training MAE")
plt.xticks(l2,l)
plt.grid(True)
plt.xlabel("Learning rate")
plt.ylabel("MAE")
plt.legend()
plt.title('MAE versus Learning rate for MLPRegressor', fontsize=12)
plt.show()
```



[23]:

```
mlp = MLPRegressor(hidden_layer_sizes=(1000, 500), max_iter=10000, alpha=0.1,
                   solver='adam', verbose=10, random_state=1,␣
 ↪learning_rate_init=0.001)
#     sgd        adam -        loss

mlp.fit(ins_X_train_scaled, ins_y_train)
```

```
c:\Users\yulia\AppData\Local\Programs\Python\Python39\lib\site-
packages\sklearn\neural_network\_multilayer_perceptron.py:1624:
DataConversionWarning: A column-vector y was passed when a 1d array was
expected. Please change the shape of y to (n_samples, ), for example using
ravel().
  y = column_or_1d(y, warn=True)
```

```
Iteration 1, loss = 204434.15083671
Iteration 2, loss = 203587.73005234
Iteration 3, loss = 202708.55171288
Iteration 4, loss = 201702.70549348
Iteration 5, loss = 200480.13033299
Iteration 6, loss = 199031.81753998
Iteration 7, loss = 197322.61110278
Iteration 8, loss = 195336.24980220
Iteration 9, loss = 193028.48457161
Iteration 10, loss = 190364.19311812
Iteration 11, loss = 187301.67810375
Iteration 12, loss = 183798.61161643
Iteration 13, loss = 179845.58572269
Iteration 14, loss = 175359.10704415
Iteration 15, loss = 170371.90285767
Iteration 16, loss = 164805.02148264
Iteration 17, loss = 158659.82927263
Iteration 18, loss = 151923.26699656
Iteration 19, loss = 144550.75259703
Iteration 20, loss = 136631.82318289
Iteration 21, loss = 128201.25653878
Iteration 22, loss = 119220.17775409
Iteration 23, loss = 109763.68897935
Iteration 24, loss = 100148.83179483
Iteration 25, loss = 90198.58328084
Iteration 26, loss = 80359.73616784
Iteration 27, loss = 70627.40572058
Iteration 28, loss = 61278.54471954
Iteration 29, loss = 52663.29713457
Iteration 30, loss = 44784.78271408
Iteration 31, loss = 38277.74206021
Iteration 32, loss = 32904.08174064
Iteration 33, loss = 28979.52345428
Iteration 34, loss = 26432.24364880
Iteration 35, loss = 24983.90978101
Iteration 36, loss = 24498.57049907
Iteration 37, loss = 24652.18080046
Iteration 38, loss = 24588.08223369
Iteration 39, loss = 24634.95002524
Iteration 40, loss = 24382.53014275
Iteration 41, loss = 23745.69930434
Iteration 42, loss = 22876.34894052
Iteration 43, loss = 21962.14558319
Iteration 44, loss = 20963.87191893
Iteration 45, loss = 20155.49296867
Iteration 46, loss = 19417.23302753
Iteration 47, loss = 18813.03485346
Iteration 48, loss = 18236.38712488
Iteration 49, loss = 17788.58394442
Iteration 50, loss = 17351.72035459
Iteration 51, loss = 16935.08650754
Iteration 52, loss = 16532.19828696
Iteration 53, loss = 16120.81440040
Iteration 54, loss = 15710.70425841
Iteration 55, loss = 15299.12940179
Iteration 56, loss = 14904.65815549
Iteration 57, loss = 14533.53199925
Iteration 58, loss = 14170.12994945
Iteration 59, loss = 13830.81473430
Iteration 60, loss = 13496.75471921
Iteration 61, loss = 13182.15654645
Iteration 62, loss = 12875.90284089
Iteration 63, loss = 12574.32992843
Iteration 64, loss = 12289.98093967
Iteration 65, loss = 11998.53939925
Iteration 66, loss = 11728.48678333
Iteration 67, loss = 11498.09755621
Iteration 68, loss = 11249.83125333
Iteration 69, loss = 10989.01668244
Iteration 70, loss = 10739.50643223
Iteration 71, loss = 10493.11744133
Iteration 72, loss = 10278.79260213
Iteration 73, loss = 10065.27995326
Iteration 74, loss = 9858.43708859
Iteration 75, loss = 9656.28401789
Iteration 76, loss = 9460.48844878
Iteration 77, loss = 9276.90929947
Iteration 78, loss = 9105.00853242
Iteration 79, loss = 8935.87037536
Iteration 80, loss = 8781.15919675
Iteration 81, loss = 8625.35905514
Iteration 82, loss = 8461.06749067
Iteration 83, loss = 8305.92271427
Iteration 84, loss = 8163.08871658
Iteration 85, loss = 8024.76722230
Iteration 86, loss = 7881.44435149
Iteration 87, loss = 7758.71473283
Iteration 88, loss = 7639.98101575
Iteration 89, loss = 7515.58741539
Iteration 90, loss = 7392.03048929
Iteration 91, loss = 7274.85751367
Iteration 92, loss = 7158.24396049
Iteration 93, loss = 7046.89925766
Iteration 94, loss = 6942.22136487
Iteration 95, loss = 6842.09502043
Iteration 96, loss = 6740.95422342
Iteration 97, loss = 6641.34957941
Iteration 98, loss = 6547.40828077
Iteration 99, loss = 6457.51293651
Iteration 100, loss = 6368.58162714
Iteration 101, loss = 6282.18909821
Iteration 102, loss = 6207.33259898
Iteration 103, loss = 6126.02658116
Iteration 104, loss = 6059.11605224
Iteration 105, loss = 5983.27798575
Iteration 106, loss = 5918.79110129
Iteration 107, loss = 5851.98515578
Iteration 108, loss = 5784.52842610
Iteration 109, loss = 5720.61923110
Iteration 110, loss = 5661.23827595
Iteration 111, loss = 5604.22296477
Iteration 112, loss = 5547.52859739
Iteration 113, loss = 5491.83307996
Iteration 114, loss = 5437.40687796
Iteration 115, loss = 5385.79202572
Iteration 116, loss = 5329.37496436
Iteration 117, loss = 5279.79650017
Iteration 118, loss = 5225.48801191
Iteration 119, loss = 5179.40390131
Iteration 120, loss = 5133.84203188
Iteration 121, loss = 5094.89973547
Iteration 122, loss = 5047.58829322
Iteration 123, loss = 5009.27010376
Iteration 124, loss = 4959.89874297
Iteration 125, loss = 4918.54932327
Iteration 126, loss = 4876.49650525
Iteration 127, loss = 4839.32762887
Iteration 128, loss = 4809.06511428
Iteration 129, loss = 4772.73919592
Iteration 130, loss = 4734.51597392
Iteration 131, loss = 4692.51731660
Iteration 132, loss = 4654.91124553
Iteration 133, loss = 4619.42905910
Iteration 134, loss = 4582.29836565
Iteration 135, loss = 4547.88718887
Iteration 136, loss = 4511.73171701
Iteration 137, loss = 4478.94397307
Iteration 138, loss = 4452.34907167
Iteration 139, loss = 4425.54899923
Iteration 140, loss = 4407.03480621
Iteration 141, loss = 4384.49240752
Iteration 142, loss = 4356.81928526
Iteration 143, loss = 4318.75681715
Iteration 144, loss = 4282.51527550
Iteration 145, loss = 4255.56618597
Iteration 146, loss = 4227.18616866
Iteration 147, loss = 4207.79558727
Iteration 148, loss = 4182.86909102
Iteration 149, loss = 4156.29647847
Iteration 150, loss = 4126.00432046
Iteration 151, loss = 4111.78402503
Iteration 152, loss = 4083.51570767
Iteration 153, loss = 4046.47363568
Iteration 154, loss = 4021.47247081
Iteration 155, loss = 4004.38412541
Iteration 156, loss = 3980.59782634
Iteration 157, loss = 3949.93642108
Iteration 158, loss = 3927.98665023
Iteration 159, loss = 3904.26121670
Iteration 160, loss = 3882.46912165
Iteration 161, loss = 3864.24636979
Iteration 162, loss = 3851.55879852
Iteration 163, loss = 3828.74276647
Iteration 164, loss = 3800.88511165
Iteration 165, loss = 3768.42282226
Iteration 166, loss = 3747.16556705
Iteration 167, loss = 3740.17578194
Iteration 168, loss = 3731.00614265
Iteration 169, loss = 3715.11770574
Iteration 170, loss = 3692.99172526
Iteration 171, loss = 3670.13133471
Iteration 172, loss = 3649.30298128
Iteration 173, loss = 3625.31217636
Iteration 174, loss = 3602.87304580
Iteration 175, loss = 3585.80548391
Iteration 176, loss = 3572.73626870
Iteration 177, loss = 3556.56412561
Iteration 178, loss = 3538.54085532
Iteration 179, loss = 3524.19606762
Iteration 180, loss = 3505.71401303
Iteration 181, loss = 3486.21476911
Iteration 182, loss = 3472.94021644
Iteration 183, loss = 3459.03293685
Iteration 184, loss = 3443.33477704
Iteration 185, loss = 3428.16509272
Iteration 186, loss = 3413.85709549
Iteration 187, loss = 3397.95315640
Iteration 188, loss = 3384.85422744
Iteration 189, loss = 3369.02885863
Iteration 190, loss = 3355.14118498
Iteration 191, loss = 3345.32986504
Iteration 192, loss = 3329.50666086
Iteration 193, loss = 3315.73578882
Iteration 194, loss = 3304.02288611
Iteration 195, loss = 3292.59533864
Iteration 196, loss = 3285.52764169
Iteration 197, loss = 3272.32500834
Iteration 198, loss = 3256.06229563
Iteration 199, loss = 3241.73478022
Iteration 200, loss = 3226.75950837
Iteration 201, loss = 3212.83078153
Iteration 202, loss = 3200.43282774
Iteration 203, loss = 3194.99557337
Iteration 204, loss = 3186.33838212
Iteration 205, loss = 3178.22208802
Iteration 206, loss = 3166.13598208
Iteration 207, loss = 3151.31049178
Iteration 208, loss = 3139.54600098
Iteration 209, loss = 3129.38065695
Iteration 210, loss = 3117.34025226
Iteration 211, loss = 3104.56955983
Iteration 212, loss = 3094.49564727
Iteration 213, loss = 3079.92378181
Iteration 214, loss = 3072.42997798
Iteration 215, loss = 3061.03691605
Iteration 216, loss = 3050.56662508
Iteration 217, loss = 3041.43201463
Iteration 218, loss = 3033.71399903
Iteration 219, loss = 3021.87265008
Iteration 220, loss = 3019.24468528
Iteration 221, loss = 3021.89530517
Iteration 222, loss = 3013.87055315
Iteration 223, loss = 2998.51626437
Iteration 224, loss = 2983.25447147
Iteration 225, loss = 2965.74704897
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Iteration 1156, loss = 774.59482889
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Iteration 1159, loss = 765.21044079
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Iteration 1169, loss = 758.90560439
Iteration 1170, loss = 755.92458385
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Iteration 1172, loss = 750.09989202
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Iteration 1174, loss = 772.16793265
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Iteration 1213, loss = 731.86142892
Iteration 1214, loss = 746.15937715
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Iteration 1218, loss = 718.29546013
Iteration 1219, loss = 722.51728645
Iteration 1220, loss = 748.07505630
Iteration 1221, loss = 747.81424099
Iteration 1222, loss = 722.33474529
Iteration 1223, loss = 722.01547029
Training loss did not improve more than tol=0.000100 for 10 consecutive epochs.
Stopping.
```

```
[23]: MLPRegressor(alpha=0.1, hidden_layer_sizes=(1000, 500), max_iter=10000,
                   random_state=1, verbose=10)
```

5 4.3

```
[25]: from sklearn.metrics import mean_squared_error, mean_absolute_error, r2_score

      def print_metrics(y_test, y_pred, squared=False):
          print(f"R^2: {r2_score(y_test, y_pred)}")
          crit_name = "MSE" if squared else "RMSE"
          print(f"{crit_name}: {mean_squared_error(y_test, y_pred, squared=squared)}")
          print(f"MAE: {mean_absolute_error(y_test, y_pred)}")

      def show_metric_for(y_pred, n=365):
        print_metrics(scaler.inverse_transform(ins_y_test.reshape(-1, 1)).flatten()[:
       ↪n], y_pred[:n])
```

```
[26]: import gmdh
      gmdh_combi = gmdh.Combi()
```

```
gmdh_combi.fit(ins_X_train_scaled, ins_y_train, verbose=1, n_jobs=-1,␣
 ↪test_size=0.2, limit=0,
                       criterion=gmdh.Criterion(gmdh.CriterionType.REGULARITY))
```

```
LEVEL 1  [=========================] 100% [00m:00s] (5 combinations)
error=695146.7162
LEVEL 2  [=========================] 100% [00m:00s] (10 combinations)
error=670212.555515
LEVEL 3  [=========================] 100% [00m:00s] (10 combinations)
error=648557.585664
LEVEL 4  [=========================] 100% [00m:00s] (5 combinations)
error=659882.164746
```

[26]:
```
<gmdh.gmdh.Combi at 0x1b8b220cf40>
```

[27]:
```
gmdh_mia = gmdh.Mia()
gmdh_mia.fit(ins_X_train_scaled, ins_y_train, verbose=1, n_jobs=-1, test_size=0.
 ↪2, limit=0, k_best=9,
                     criterion=gmdh.Criterion(gmdh.CriterionType.
 ↪SYM_REGULARITY),
                     polynomial_type=gmdh.PolynomialType.LINEAR)
```

```
LEVEL 1  [=========================] 100% [00m:00s] (10 combinations)
error=3.67867e+06
LEVEL 2  [=========================] 100% [00m:00s] (36 combinations)
error=3.57343e+06
LEVEL 3  [=========================] 100% [00m:00s] (36 combinations)
error=3.52661e+06
LEVEL 4  [=========================] 100% [00m:00s] (36 combinations)
error=3.52347e+06
LEVEL 5  [=========================] 100% [00m:00s] (36 combinations)
error=3.50106e+06
LEVEL 6  [=========================] 100% [00m:00s] (36 combinations)
error=3.49533e+06
LEVEL 7  [=========================] 100% [00m:00s] (36 combinations)
error=3.49154e+06
LEVEL 8  [=========================] 100% [00m:00s] (36 combinations)
error=3.4945e+06
```

[27]:
```
<gmdh.gmdh.Mia at 0x1b8b63b7c10>
```

[28]:
```
pred_mia = gmdh_mia.predict(ins_X_test_scaled)
print_metrics(ins_y_test, pred_mia)
```

```
R^2: 0.13334188124042634
RMSE: 116.98091376329361
MAE: 89.65482934967766
```

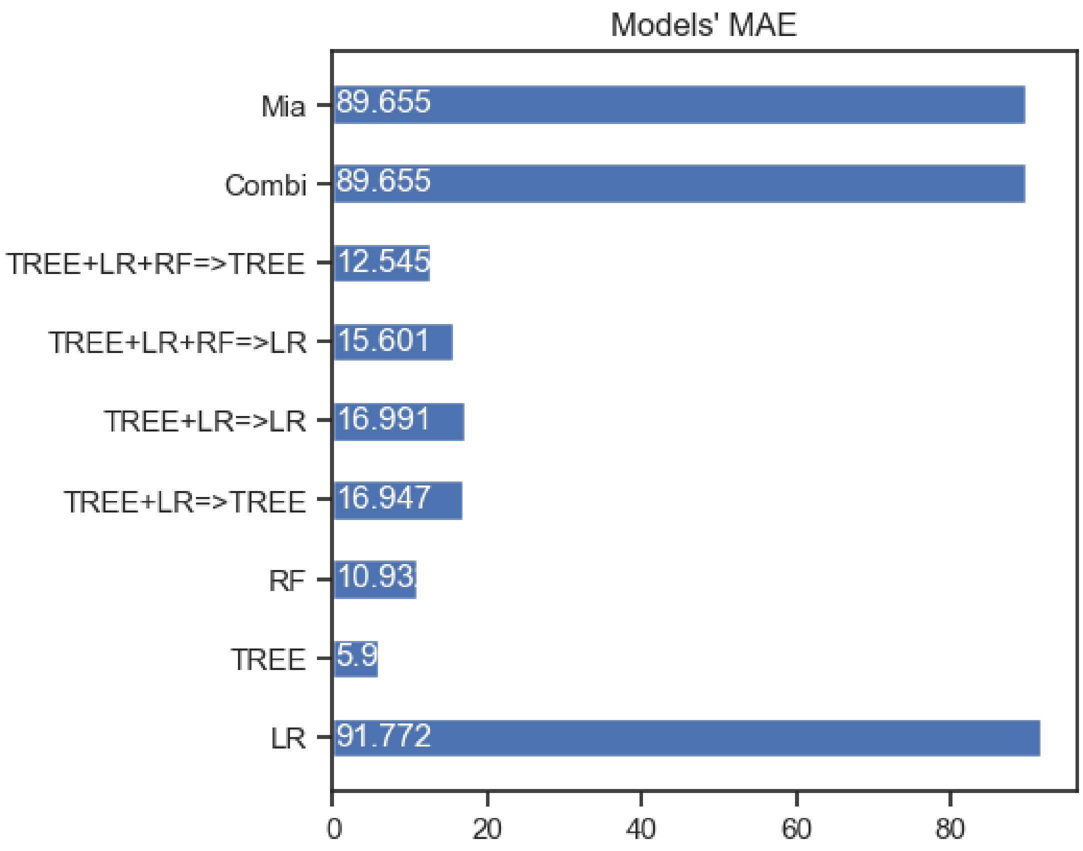
```
c:\Users\yulia\AppData\Local\Programs\Python\Python39\lib\site-
packages\sklearn\metrics\_regression.py:483: FutureWarning: 'squared' is
deprecated in version 1.4 and will be removed in 1.6. To calculate the root mean
squared error, use the function'root_mean_squared_error'.
  warnings.warn(
```

[31]:

```
def vis_models_quality(array_metric, array_labels, str_header, figsize=(8, 8)):
    fig, ax1 = plt.subplots(figsize=figsize)
    pos = np.arange(len(array_metric))
    rects = ax1.barh(pos, array_metric,
                     align='center',
                     height=0.5,
                     tick_label=array_labels)
    ax1.set_title(str_header)
    for a,b in zip(pos, array_metric):
        plt.text(0.2, a-0.1, str(round(b,3)), color='white')
    plt.show()
```

[45]:

```
dict_mae = {
            'LR': 91.77213251714615,
            'TREE': 5.932203389830509,
            'RF': 10.932203389830509,
            'TREE+LR=>TREE': 16.947463768115945,
            'TREE+LR=>LR': 16.991272889514768,
            'TREE+LR+RF=>LR': 15.601464066506784,
            'TREE+LR+RF=>TREE': 12.545289855072465,
            'Combi': 89.65482934967766,
            'Mia': 89.65482934967766,
            }
vis_models_quality(list(dict_mae.values()), list(dict_mae.keys()), 'Models\'␣
 ↪MAE')
```


Models' MAE
Mia
89.655
Combi
89.655
TREE+LR+RF=>TREE
12.545
TREE+LR+RF=>LR
15.601
TREE+LR=>LR
16.991
TREE+LR=>TREE
16.947
RF
10.93
TREE
5.9
LR
91.772
0
20
40
60
80