lab01

October 30, 2025

[ ]:
```
%pip install -q pandas numpy scikit-learn matplotlib seaborn shap
```

```
Note: you may need to restart the kernel to use updated packages.
```

[ ]:
```
```

[ ]:
```
import os
import sys
import numpy as np
import pandas as pd
from pathlib import Path
from pandas import get_option

import matplotlib.pyplot as plt
import seaborn as sns

from sklearn.model_selection import train_test_split, KFold, cross_val_score
from sklearn.preprocessing import StandardScaler
from sklearn.pipeline import Pipeline
from sklearn.metrics import mean_squared_error, mean_absolute_error, r2_score

from sklearn.linear_model import LinearRegression
from sklearn.tree import DecisionTreeRegressor
from sklearn.ensemble import RandomForestRegressor

RANDOM_STATE = 42
np.random.seed(RANDOM_STATE)
```

[ ]:
```
IN_COLAB = "COLAB_GPU" in os.environ or "google.colab" in str(get_ipython())

if not IN_COLAB:
    ROOT = Path.cwd()
    if ROOT.name == "lab01":
        LAB_ROOT = ROOT
    elif (ROOT / "lab01").exists():
        LAB_ROOT = ROOT / "lab01"
    elif ROOT.name == "notebooks":
        LAB_ROOT = ROOT.parent
```

```
    else:
        raise FileNotFoundError("         lab01             .")

    DATA_RAW = LAB_ROOT / "data" / "raw"
    DATA_RAW.mkdir(parents=True, exist_ok=True)
    csv_path = DATA_RAW / "housing.csv"

else:
    from urllib.request import urlretrieve

    url = "https://raw.githubusercontent.com/OlegTertychnyi/ML-labs-Tert/main/
 ↪lab01/data/raw/housing.csv"
    csv_path = Path("/content/housing.csv")
    if not csv_path.exists():
        urlretrieve(url, csv_path)
```

[44]:
```
columns = [
    "CRIM",     #
    "ZN",       #                    >25k   .
    "INDUS",    #
    "CHAS",     #         (1 -    , 0 -   )
    "NOX",      #
    "RM",       #
    "AGE",      #       ,          1940  .
    "DIS",      #
    "RAD",      #
    "TAX",      #
    "PTRATIO",  #
    "B",        # 1000*(Bk - 0.63)~2,    Bk -
    "LSTAT",    # %
    "MEDV"      #                ( )
]
df = pd.read_csv(csv_path, sep=r"\s+", names=columns)
```

[24]:
```
display(df)
```

```
        CRIM    ZN  INDUS  CHAS    NOX     RM   AGE     DIS  RAD    TAX  \
0    0.00632  18.0   2.31     0  0.538  6.575  65.2  4.0900    1  296.0
1    0.02731   0.0   7.07     0  0.469  6.421  78.9  4.9671    2  242.0
2    0.02729   0.0   7.07     0  0.469  7.185  61.1  4.9671    2  242.0
3    0.03237   0.0   2.18     0  0.458  6.998  45.8  6.0622    3  222.0
4    0.06905   0.0   2.18     0  0.458  7.147  54.2  6.0622    3  222.0
..       …   …    …   …    …   …    …   …     …  …    …
501  0.06263   0.0  11.93     0  0.573  6.593  69.1  2.4786    1  273.0
502  0.04527   0.0  11.93     0  0.573  6.120  76.7  2.2875    1  273.0
503  0.06076   0.0  11.93     0  0.573  6.976  91.0  2.1675    1  273.0
504  0.10959   0.0  11.93     0  0.573  6.794  89.3  2.3889    1  273.0
```

```
505  0.04741   0.0  11.93     0  0.573  6.030  80.8  2.5050    1  273.0

     PTRATIO       B  LSTAT  MEDV
0       15.3  396.90   4.98  24.0
1       17.8  396.90   9.14  21.6
2       17.8  392.83   4.03  34.7
3       18.7  394.63   2.94  33.4
4       18.7  396.90   5.33  36.2
..       …     …    …   …
501     21.0  391.99   9.67  22.4
502     21.0  396.90   9.08  20.6
503     21.0  396.90   5.64  23.9
504     21.0  393.45   6.48  22.0
505     21.0  396.90   7.88  11.9

[506 rows x 14 columns]
```

[25]:
```
display(df.info())
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 506 entries, 0 to 505
Data columns (total 14 columns):
 #   Column   Non-Null Count  Dtype
---  ------   --------------  -----
 0   CRIM     506 non-null    float64
 1   ZN       506 non-null    float64
 2   INDUS    506 non-null    float64
 3   CHAS     506 non-null    int64
 4   NOX      506 non-null    float64
 5   RM       506 non-null    float64
 6   AGE      506 non-null    float64
 7   DIS      506 non-null    float64
 8   RAD      506 non-null    int64
 9   TAX      506 non-null    float64
 10  PTRATIO  506 non-null    float64
 11  B        506 non-null    float64
 12  LSTAT    506 non-null    float64
 13  MEDV     506 non-null    float64
dtypes: float64(12), int64(2)
memory usage: 55.5 KB

None
```

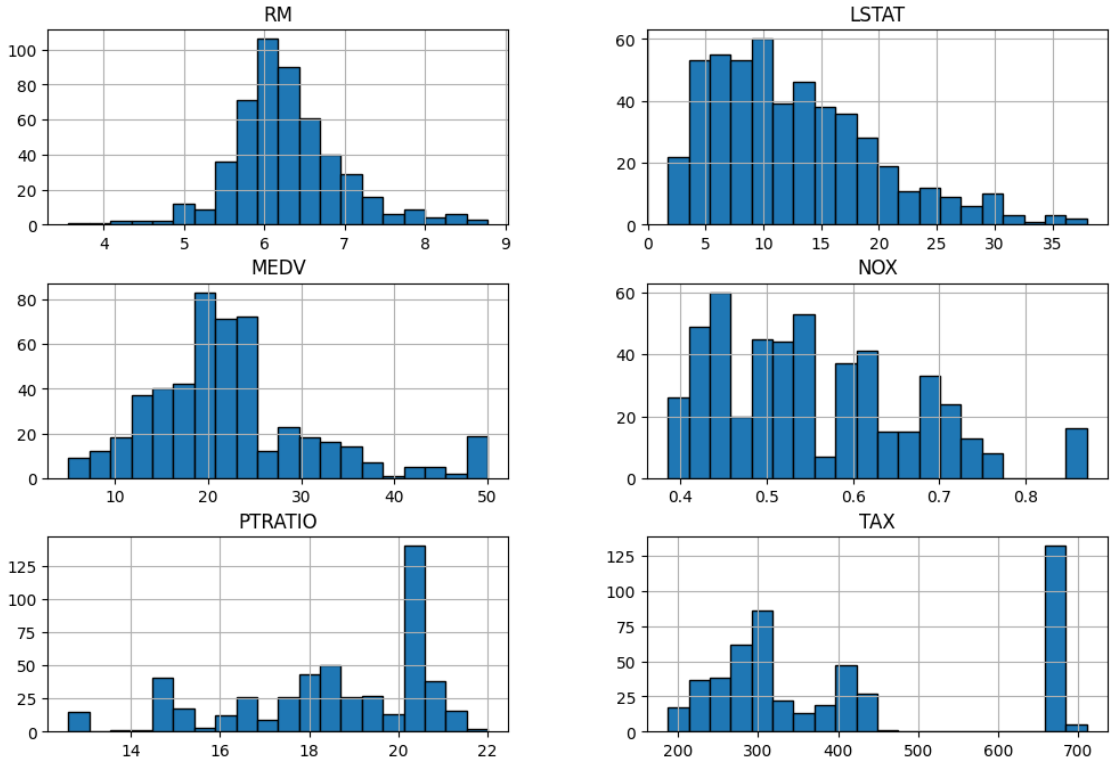
[26]:
```
display(df.describe())
```

```
             CRIM          ZN       INDUS        CHAS         NOX          RM  \
count  506.000000  506.000000  506.000000  506.000000  506.000000  506.000000
mean     3.613524   11.363636   11.136779    0.069170    0.554695    6.284634
```

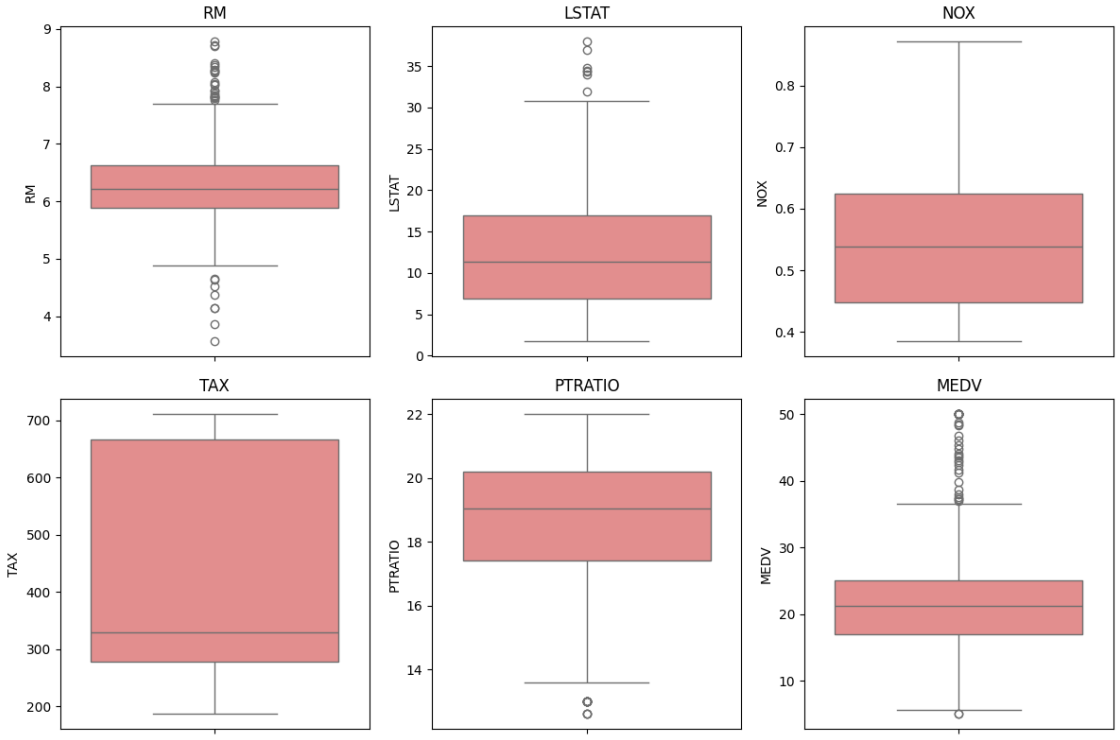
```
std       8.601545   23.322453    6.860353    0.253994    0.115878    0.702617
min       0.006320    0.000000    0.460000    0.000000    0.385000    3.561000
25%       0.082045    0.000000    5.190000    0.000000    0.449000    5.885500
50%       0.256510    0.000000    9.690000    0.000000    0.538000    6.208500
75%       3.677083   12.500000   18.100000    0.000000    0.624000    6.623500
max      88.976200  100.000000   27.740000    1.000000    0.871000    8.780000

              AGE         DIS         RAD         TAX     PTRATIO           B  \
count  506.000000  506.000000  506.000000  506.000000  506.000000  506.000000
mean    68.574901    3.795043    9.549407  408.237154   18.455534  356.674032
std     28.148861    2.105710    8.707259  168.537116    2.164946   91.294864
min      2.900000    1.129600    1.000000  187.000000   12.600000    0.320000
25%     45.025000    2.100175    4.000000  279.000000   17.400000  375.377500
50%     77.500000    3.207450    5.000000  330.000000   19.050000  391.440000
75%     94.075000    5.188425   24.000000  666.000000   20.200000  396.225000
max    100.000000   12.126500   24.000000  711.000000   22.000000  396.900000

            LSTAT        MEDV
count  506.000000  506.000000
mean    12.653063   22.532806
std      7.141062    9.197104
min      1.730000    5.000000
25%      6.950000   17.025000
50%     11.360000   21.200000
75%     16.955000   25.000000
max     37.970000   50.000000
```

[27]:
```
cols = ["RM", "LSTAT", "MEDV", "NOX", "PTRATIO", "TAX"]
df[cols].hist(bins=20, figsize=(12, 8), edgecolor='black')
plt.suptitle("                    ", fontsize=16)
plt.show()
```

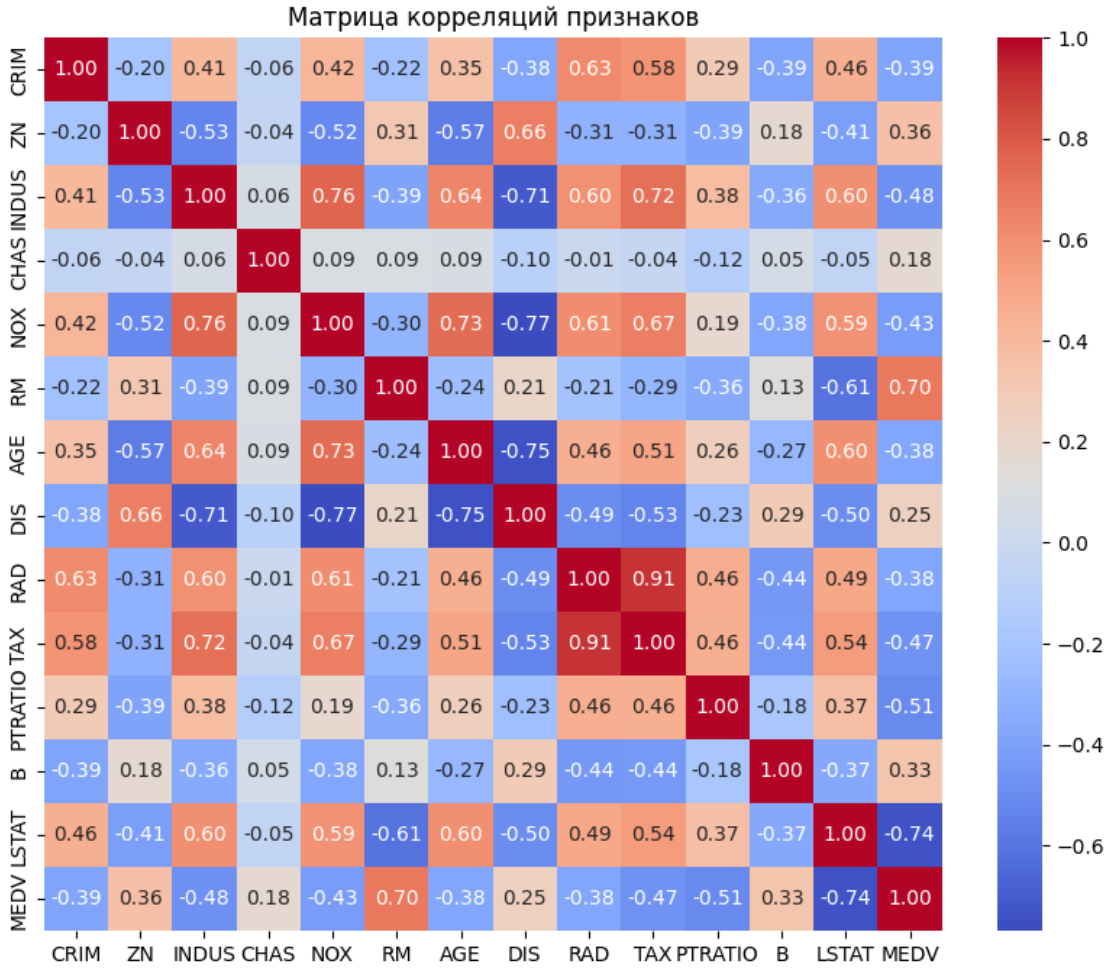
Распределения основных признаков



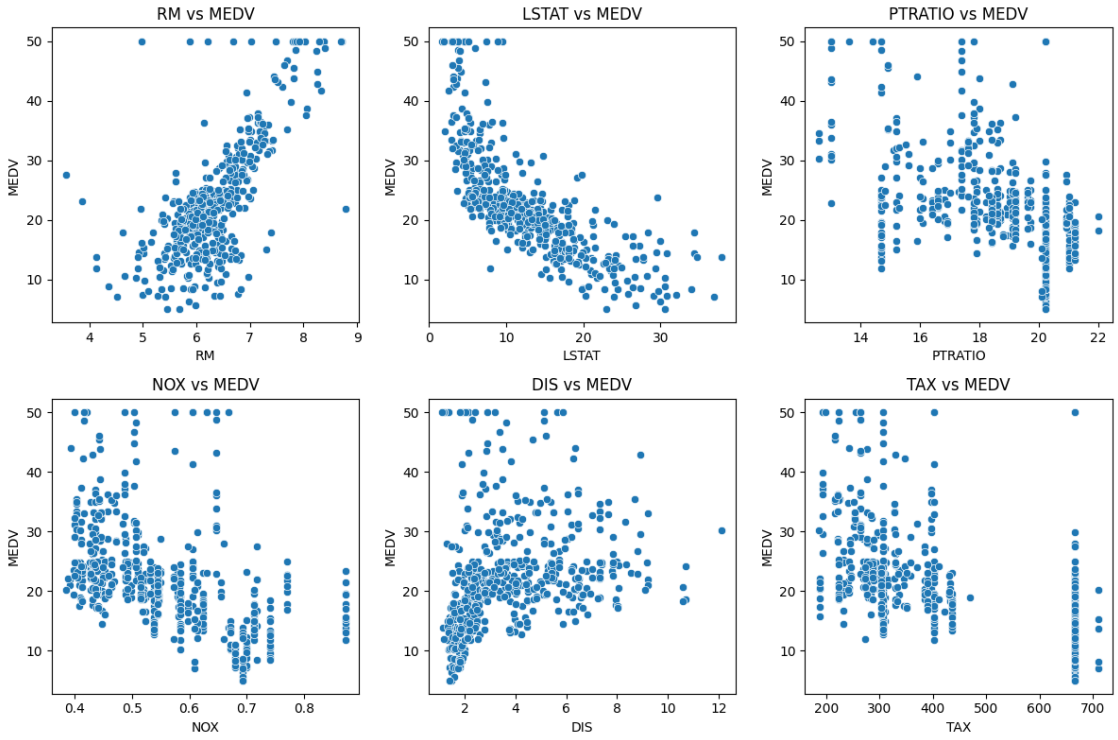
[28]:
```
cols = ["RM", "LSTAT", "NOX", "TAX", "PTRATIO", "MEDV"]
fig, axes = plt.subplots(2, 3, figsize=(12, 8))

for i, col in enumerate(cols):
    sns.boxplot(y=df[col], ax=axes[i//3, i%3], color="lightcoral")
    axes[i//3, i%3].set_title(col)

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



[29]:
```
plt.figure(figsize=(10, 8))
sns.heatmap(df.corr(), annot=True, cmap="coolwarm", fmt=".2f")
plt.title("                ")
plt.show()
```



[30]:
```
cols = ["RM", "LSTAT", "PTRATIO", "NOX", "DIS", "TAX"]
fig, axes = plt.subplots(2, 3, figsize=(12, 8))
for i, col in enumerate(cols):
    sns.scatterplot(x=df[col], y=df["MEDV"], ax=axes[i//3, i%3])
    axes[i//3, i%3].set_title(f"{col} vs MEDV")
plt.tight_layout()
plt.show()
```



[31]:
```
X = df.drop(columns=["MEDV"])
y = df["MEDV"]

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

[32]:
```
lr = Pipeline([
    ("scaler" , StandardScaler()),
    ("model", LinearRegression())
])
```

[33]:
```
cv = KFold(n_splits=5, shuffle=True, random_state=42)

cv_r2 = cross_val_score(lr, X_train, y_train, cv=cv, scoring="r2")
cv_mse = -cross_val_score(lr, X_train, y_train, cv=cv,␣
 ↪scoring="neg_mean_squared_error")

display(f"CV R^2: mean = {cv_r2.mean():.3f} ± {cv_r2.std():.3f}")
display(f"CV MSE: mean = {cv_mse.mean():.3f}")
```

```
'CV R^2: mean = 0.718 ± 0.078'
```

```
'CV MSE: mean = 24.318'
```

[34]:
```
lr.fit(X_train, y_train)
y_pred = lr.predict(X_test)
```

[35]:
```
dtr = DecisionTreeRegressor(max_depth=8, random_state=32)
dtr.fit(X_train, y_train)
y_pred = dtr.predict(X_test)
```

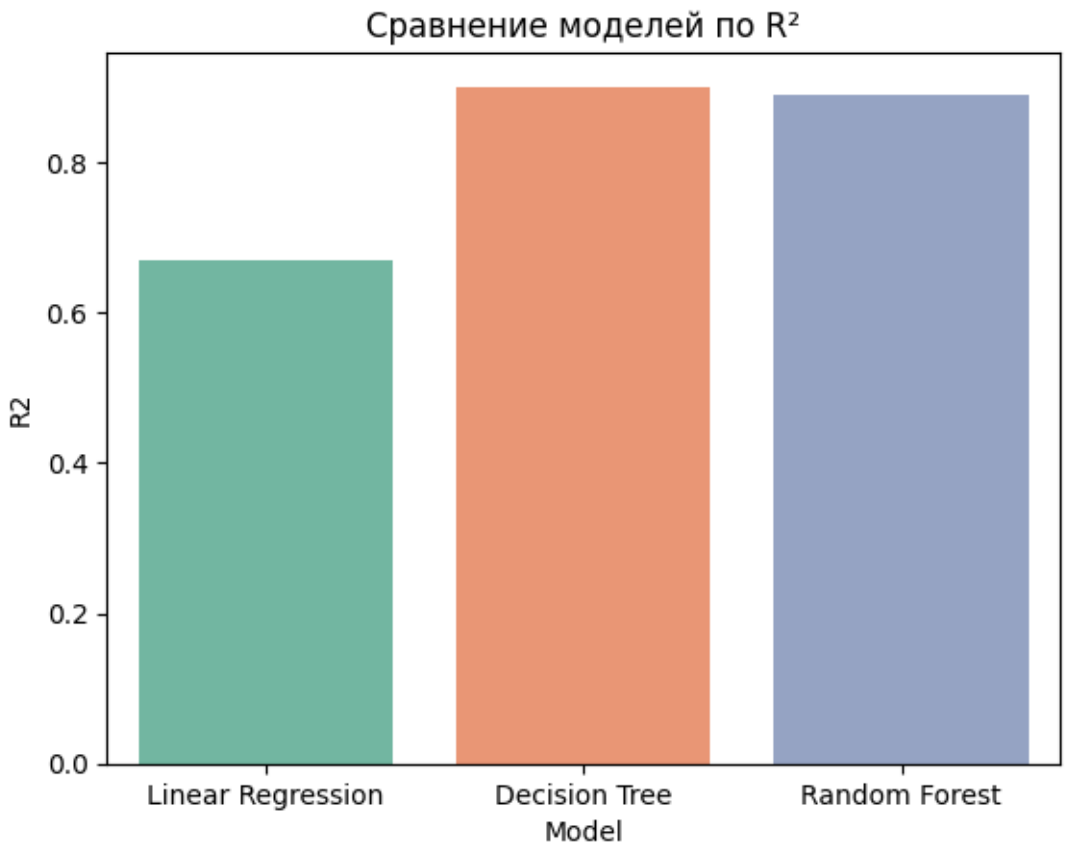
[36]:
```
rfr = RandomForestRegressor(n_estimators=100, max_depth=8, random_state=26)
rfr.fit(X_train, y_train)
y_pred = rfr.predict(X_test)
```

[37]:
```
results = {}

for name, model in {
    "Linear Regression": lr,
    "Decision Tree": dtr,
    "Random Forest": rfr
}.items():
    y_pred = model.predict(X_test)
    results[name] = {
        "R2": r2_score(y_test, y_pred),
        "MSE": mean_squared_error(y_test, y_pred),
        "MAE": mean_absolute_error(y_test, y_pred)
    }

results_df = pd.DataFrame(results).T
display(results_df.round(3))
```

	R2	MSE	MAE
Linear Regression	0.669	24.291	3.189
Decision Tree	0.900	7.300	2.045
Random Forest	0.890	8.081	2.073

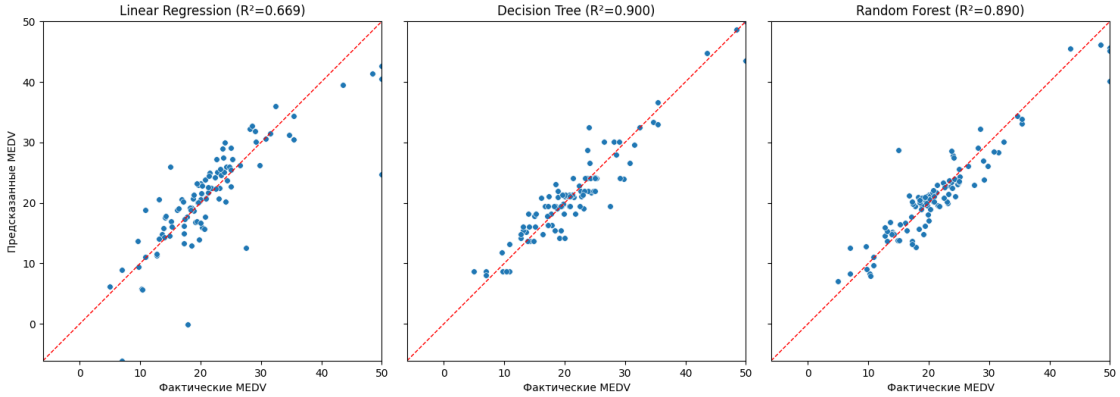
[38]:
```
results_df = results_df.reset_index().rename(columns={"index": "Model"})
sns.barplot(x="Model", y="R2", data=results_df, palette="Set2")
plt.title("            R²")
plt.show()
```

```
/tmp/ipykernel_18341/494411334.py:2: FutureWarning:

Passing `palette` without assigning `hue` is deprecated and will be removed in
v0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same
effect.

  sns.barplot(x="Model", y="R2", data=results_df, palette="Set2")
```

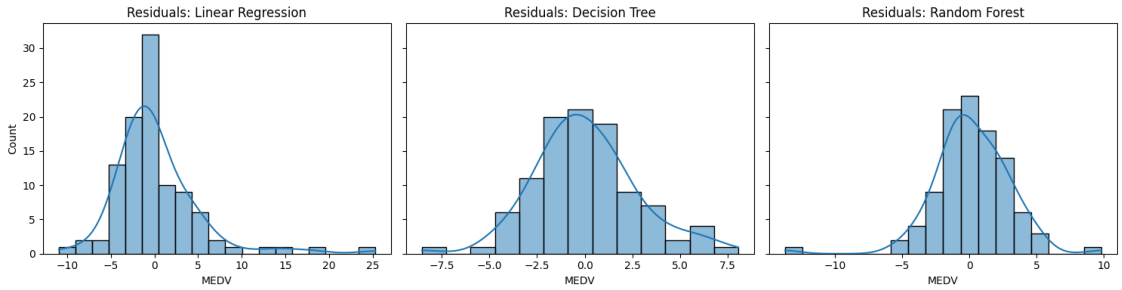


[ ]:
```python
from sklearn.metrics import r2_score

preds = {
    "Linear Regression": lr.predict(X_test),
    "Decision Tree":     dtr.predict(X_test),
    "Random Forest":     rfr.predict(X_test),
}

y_min = min(y_test.min(), *(p.min() for p in preds.values()))
y_max = max(y_test.max(), *(p.max() for p in preds.values()))

fig, axes = plt.subplots(1, 3, figsize=(15, 5), sharex=True, sharey=True)
for ax, (name, y_pred) in zip(axes, preds.items()):
    sns.scatterplot(x=y_test, y=y_pred, ax=ax, s=30)
    ax.plot([y_min, y_max], [y_min, y_max], 'r--', linewidth=1)
    ax.set_xlim(y_min, y_max)
    ax.set_ylim(y_min, y_max)
    ax.set_aspect('equal', adjustable='box')
    ax.set_title(f"{name} (R²={r2_score(y_test, y_pred):.3f})")
    ax.set_xlabel("       MEDV")
```

```
    ax.set_ylabel("        MEDV")

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

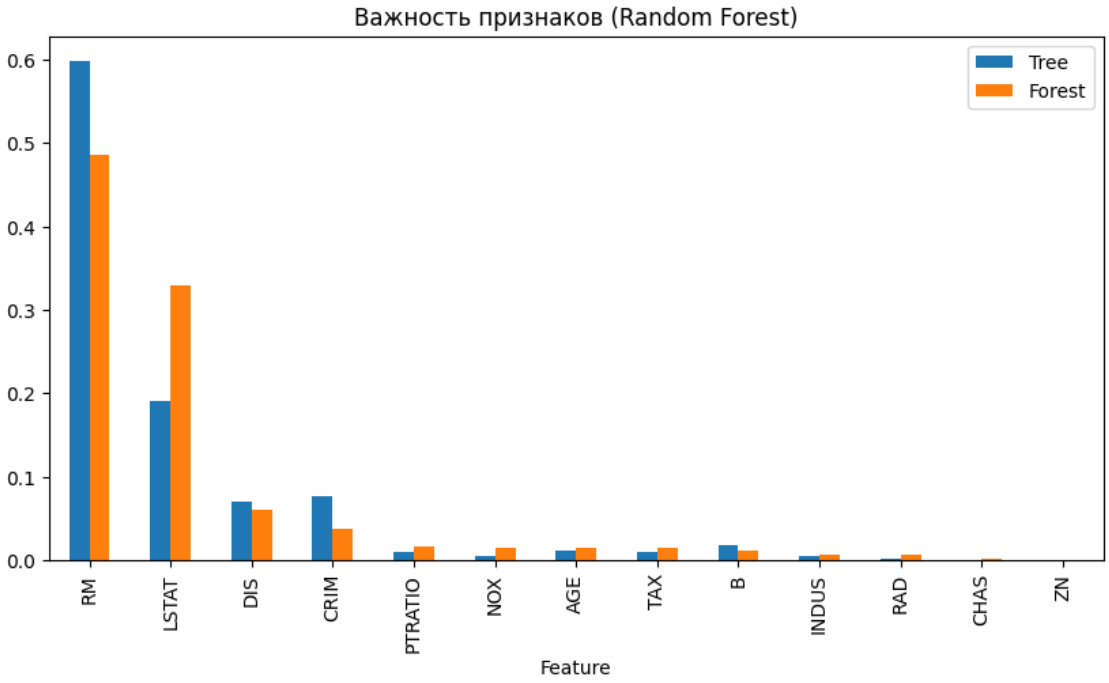


[40]:
```
fig, axes = plt.subplots(1, 3, figsize=(15, 4), sharey=True)
for ax, (name, y_pred) in zip(axes, preds.items()):
    residuals = y_test - y_pred
    sns.histplot(residuals, kde=True, ax=ax)
    ax.set_title(f"Residuals: {name}")
plt.tight_layout()
plt.show()
```

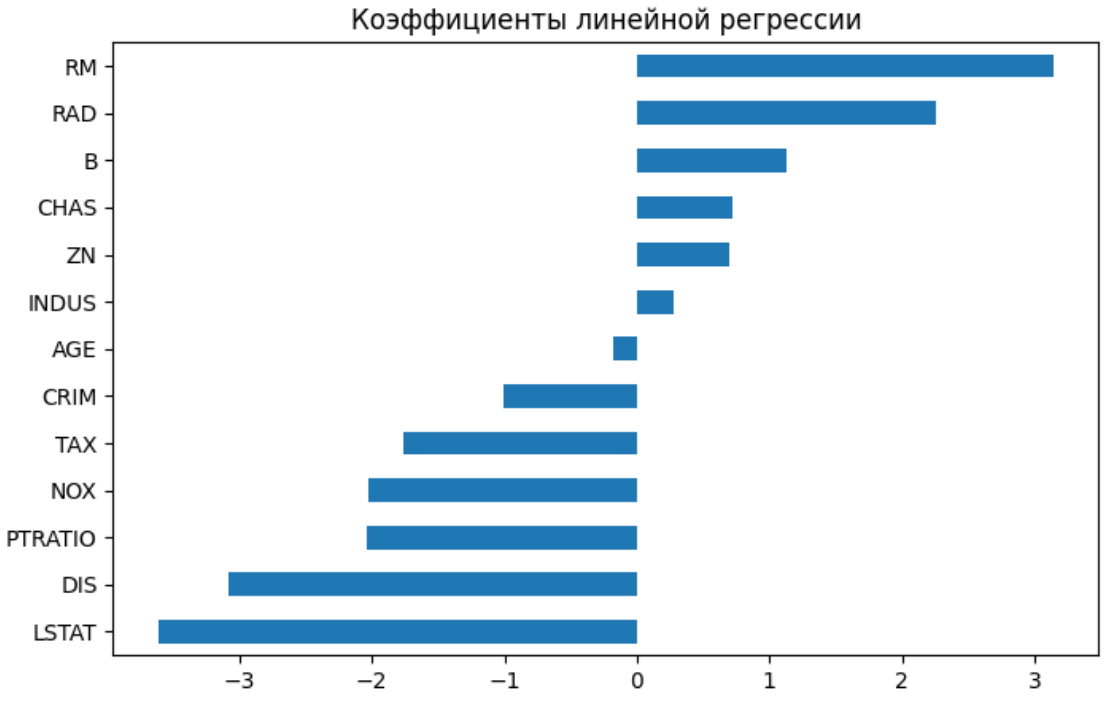


[41]:
```
feat_imp = pd.DataFrame({
    "Feature": X.columns,
    "Tree": dtr.feature_importances_,
    "Forest": rfr.feature_importances_
}).set_index("Feature")

feat_imp.sort_values("Forest", ascending=False).plot.bar(figsize=(10,5))
plt.title("           (Random Forest)")
```

```
plt.show()
```



[42]:
```
coefs = pd.Series(lr.named_steps["model"].coef_, index=X.columns)
coefs.sort_values().plot(kind="barh", figsize=(8,5))
plt.title("                    ")
plt.show()
```


Коэффициенты линейной регрессии
RM
RAD
B
CHAS
ZN
INDUS
AGE
CRIM
TAX
NOX
PTRATIO
DIS
LSTAT
−3
−2
−1
0
1
2
3