МОСКОВСКИЙ ГОСУДАРСТВЕННЫЙ ТЕХНИЧЕСКИЙ УНИВЕРСИТЕТ
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ОТЧЕТ

Домашнее задание
по дисциплине «Методы машинного обучения»

ИСПОЛНИТЕЛЬ: Макаров Д.А.
ФИО
группа ИУ5-21М _____
подпись
"__"_____2020 г.

ПРЕПОДАВАТЕЛЬ: _____
ФИО
_____
подпись
"__"_____2020 г.

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Задание

Домашнее задание по дисциплине направлено на решение комплексной задачи машинного обучения. Домашнее задание включает выполнение следующих шагов:

1. Поиск и выбор набора данных для построения моделей машинного обучения. На основе выбранного набора данных студент должен построить модели машинного обучения для решения или задачи классификации, или задачи регрессии.
2. Проведение разведочного анализа данных. Построение графиков, необходимых для понимания структуры данных. Анализ и заполнение пропусков в данных.
3. Выбор признаков, подходящих для построения моделей. Кодирование категориальных признаков. Масштабирование данных. Формирование вспомогательных признаков, улучшающих качество моделей.
4. Проведение корреляционного анализа данных. Формирование промежуточных выводов о возможности построения моделей машинного обучения. В зависимости от набора данных, порядок выполнения пунктов 2, 3, 4 может быть изменен.
5. Выбор метрик для последующей оценки качества моделей. Необходимо выбрать не менее двух метрик и обосновать выбор.
6. Выбор наиболее подходящих моделей для решения задачи классификации или регрессии. Необходимо использовать не менее трех моделей, хотя бы одна из которых должна быть ансамблевой.
7. Формирование обучающей и тестовой выборок на основе исходного набора данных.
8. Построение базового решения (baseline) для выбранных моделей без подбора гиперпараметров. Производится обучение моделей на основе обучающей выборки и оценка качества моделей на основе тестовой выборки.
9. Подбор гиперпараметров для выбранных моделей. Рекомендуется подбирать не более 1-2 гиперпараметров. Рекомендуется использовать методы кросс-валидации. В зависимости от используемой библиотеки можно применять функцию GridSearchCV, использовать перебор параметров в цикле, или использовать другие методы.
10. Повторение пункта 8 для найденных оптимальных значений гиперпараметров. Сравнение качества полученных моделей с качеством baseline-моделей.
11. Формирование выводов о качестве построенных моделей на основе выбранных метрик.

Решение

In [1]:

```
import numpy as np
import pandas as pd
import seaborn as sns
import matplotlib.pyplot as plt
from sklearn.preprocessing import MinMaxScaler
from sklearn.linear_model import LinearRegression, LogisticRegression
from sklearn.model_selection import train_test_split
from sklearn.neighbors import KNeighborsRegressor, KNeighborsClassifier
from sklearn.metrics import accuracy_score, balanced_accuracy_score
from sklearn.metrics import precision_score, recall_score, f1_score, classification_report
from sklearn.metrics import confusion_matrix
from sklearn.metrics import plot_confusion_matrix
from sklearn.model_selection import GridSearchCV
from sklearn.metrics import mean_absolute_error, mean_squared_error, mean_squared_log_error,
median_absolute_error, r2_score
from sklearn.metrics import roc_curve, roc_auc_score
from sklearn.svm import SVC, NuSVC, LinearSVC, OneClassSVM, SVR, NuSVR, LinearSVR
from sklearn.tree import DecisionTreeClassifier, DecisionTreeRegressor, export_graphviz
from sklearn.ensemble import RandomForestClassifier, RandomForestRegressor
from sklearn.ensemble import ExtraTreesClassifier, ExtraTreesRegressor
from sklearn.ensemble import GradientBoostingClassifier, GradientBoostingRegressor
from sklearn.utils import shuffle
# !pip install gmdhpy
from gmdhpy import gmdh
%matplotlib inline
sns.set(style="ticks")
```

1. Поиск и выбор набора данных для построения моделей машинного обучения. На основе выбранного набора данных построение модели машинного обучения для решения или задачи регрессии.

В качестве набора данных возьмем набор с данными о фильмах и их характеристиках. title year lifetime_gross ratingInteger ratingCount duration nrOfWins nrOfNominations nrOfPhotos nrOfNewsArticles nrOfUserReviews nrOfGenre Набор содержит такие

ratingCount duration nrOfWins nrOfNominations nrOfPhotos nrOfNewsArticles nrOfUserReviews nrOfGenre Набор содержит такие колонки как:

- title - название
- year - год выхода
- lifetime_gross - сборы
- ratingInteger - рейтинг
- ratingCount - количество оценок
- duration - продолжительность
- nrOfWins - количество побед
- nrOfNominations - количество номинаций
- nrOfPhotos - количество фотографий
- nrOfNewsArticles - количество статей
- nrOfUserReviews - количество отзывов
- nrOfGenre - количество жанров

Поставим задачу предсказания количества оценок фильма по данным характеристикам. Построим модель машинного обучения для данного набора и решим задачу регрессии.

2. Проведение разведочного анализа данных. Построение графиков, необходимых для понимания структуры данных. Анализ и заполнение пропусков в данных.

In [2]:

```
data = pd.read_csv('MACHINE_LEARNING_FINAL.csv', sep=',')
data.head()
```

Out[2]:

	title	year	lifetime_gross	ratingInteger	ratingCount	duration	nrOfWins	nrOfNominations	nrOfPhotos	nrOfNewsArticles
0	METROPOLIS	1927	1236166	8	81007	9180	3	4	67	428
1	CITY LIGHTS	1931	19181	9	70057	5220	2	0	38	187
2	MODERN TIMES	1936	163577	9	90847	5220	3	1	44	27
3	GONE WITH THE WIND	1939	198676459	8	160414	14280	10	6	143	1263
4	THE WIZARD OF OZ	1939	22342633	8	209506	6120	6	12	126	2363

In [3]:

```
data.shape
```

Out[3]:

```
(3747, 12)
```

In [4]:

```
data.columns
```

Out[4]:

```
Index(['title', 'year', 'lifetime_gross', 'ratingInteger', 'ratingCount',
       'duration', 'nrOfWins', 'nrOfNominations', 'nrOfPhotos',
       'nrOfNewsArticles', 'nrOfUserReviews', 'nrOfGenre'],
      dtype='object')
```

In [5]:

```
data.isnull().sum()
```

Out[5]:

```
title               0
year                0
```

```
lifetime_gross       0
ratingInteger        0
ratingCount          0
duration             0
nrOfWins             0
nrOfNominations      0
nrOfPhotos           0
nrOfNewsArticles     0
nrOfUserReviews      0
nrOfGenre            0
dtype: int64
```

In [6]:

```
data.dtypes
```

Out[6]:

```
title                object
year                  int64
lifetime_gross        int64
ratingInteger         int64
ratingCount           int64
duration              int64
nrOfWins              int64
nrOfNominations       int64
nrOfPhotos            int64
nrOfNewsArticles      int64
nrOfUserReviews       int64
nrOfGenre             int64
dtype: object
```

In [7]:

```
data.describe()
```

Out[7]:

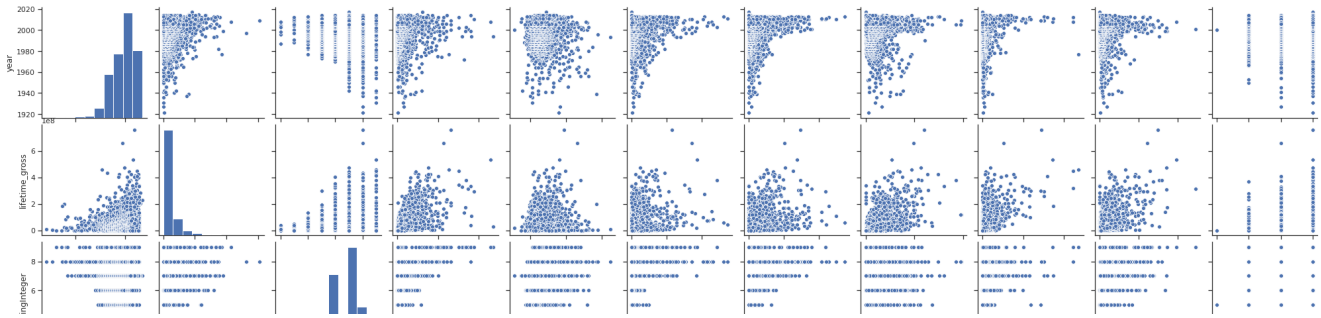
	year	lifetime_gross	ratingInteger	ratingCount	duration	nrOfWins	nrOfNominations	nrOfPhotos	nrOfNewsAr
count	3747.000000	3.747000e+03	3747.000000	3.747000e+03	3747.000000	3747.000000	3747.000000	3747.000000	3747.0(
mean	1998.083800	4.846733e+07	6.631972	7.094831e+04	6624.579664	5.405391	7.549239	45.380838	595.8(
std	11.544566	6.397511e+07	1.030435	1.016571e+05	1294.655800	11.616207	13.175695	39.408302	1436.9(
min	1921.000000	4.230000e+02	2.000000	5.300000e+01	2760.000000	0.000000	0.000000	0.000000	0.0(
25%	1991.000000	8.402959e+06	6.000000	1.308850e+04	5760.000000	0.000000	0.000000	20.000000	42.0(
50%	2000.000000	2.783841e+07	7.000000	3.584800e+04	6360.000000	1.000000	3.000000	35.000000	154.0(
75%	2007.000000	6.144441e+07	7.000000	8.576500e+04	7200.000000	5.000000	9.000000	59.500000	547.0(
max	2017.000000	7.605076e+08	9.000000	1.183395e+06	16260.000000	137.000000	137.000000	394.000000	23660.0(

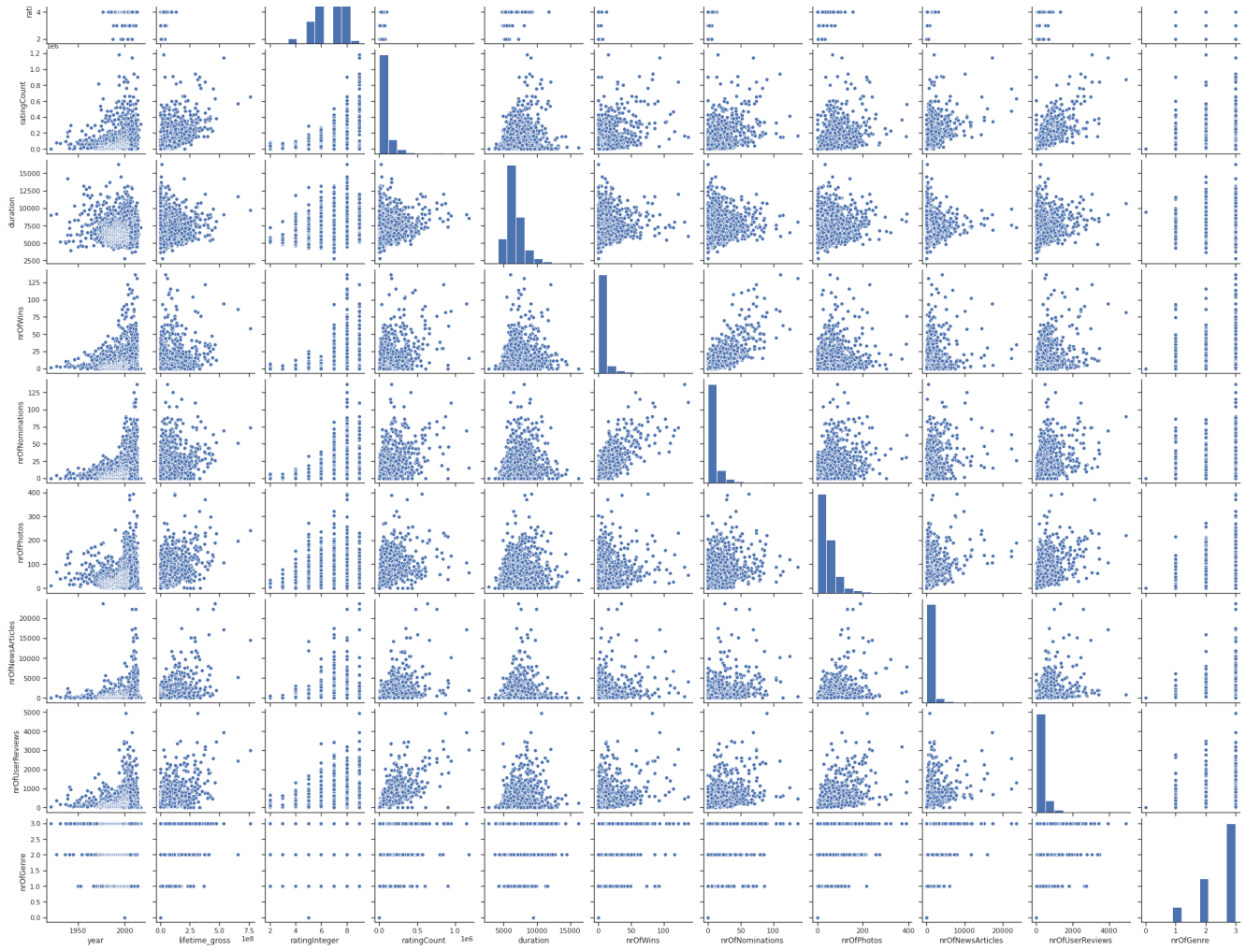
In [8]:

```
sns.pairplot(data)
```

Out[8]:

```
<seaborn.axisgrid.PairGrid at 0x7f548068e128>
```





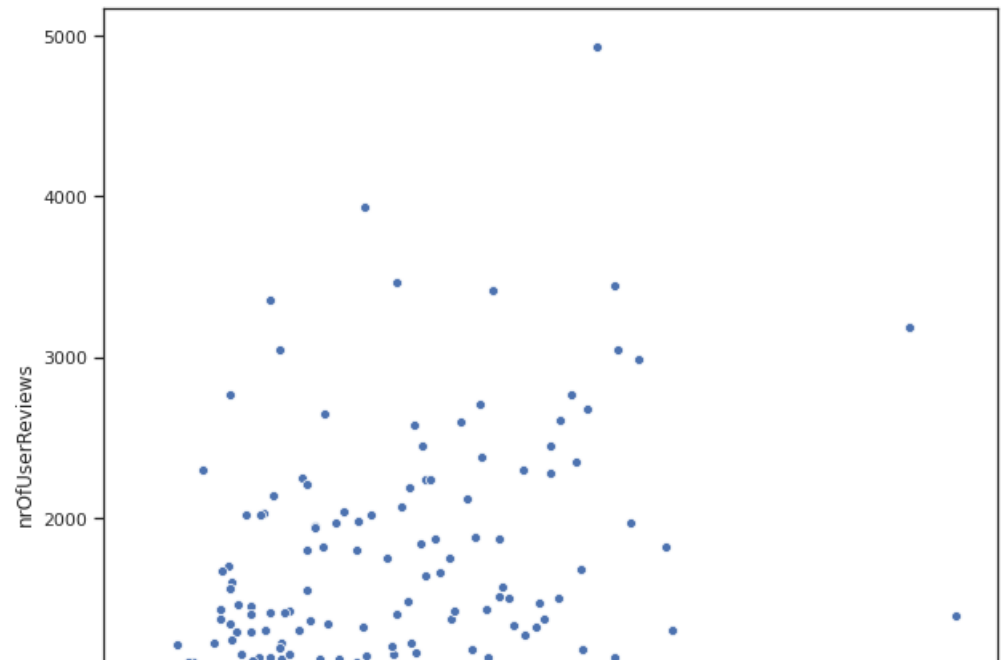
Видим, что заметна корреляция таких характеристик как количество фото и количество отзывов. В остальных случаях зависимости не такие очевидные.

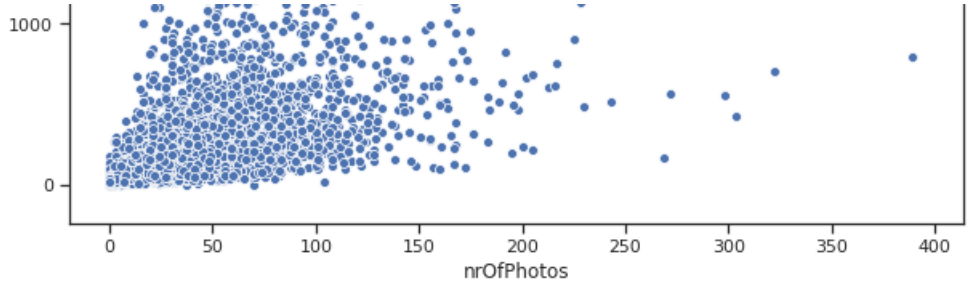
In [9]:

```
fig, ax = plt.subplots(figsize=(10,10))
sns.scatterplot(ax=ax, x='nrOfPhotos', y='nrOfUserReviews', data=data)
```

Out[9]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x7f547a751a20>
```



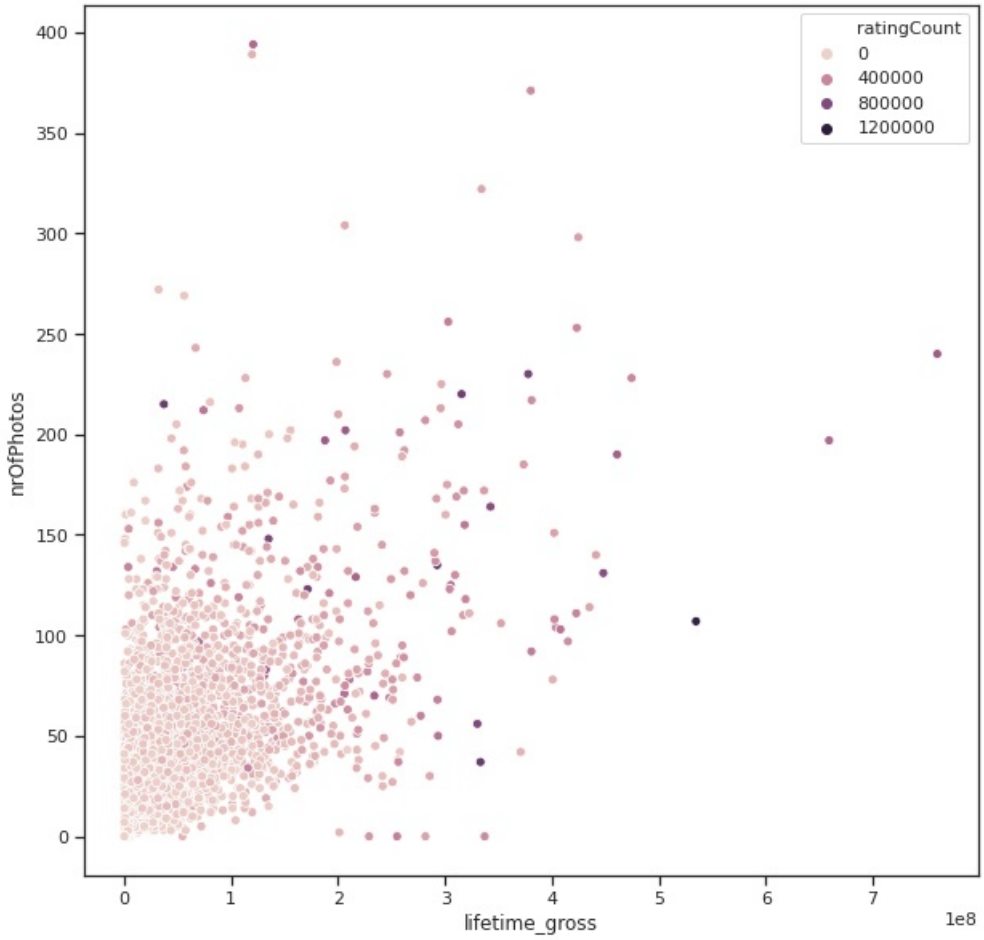


In [10]:

```
fig, ax = plt.subplots(figsize=(10,10))
sns.scatterplot(ax=ax, x='lifetime_gross', y='nrOfPhotos', data=data, hue='ratingCount')
```

Out[10]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x7f547b640f98>
```

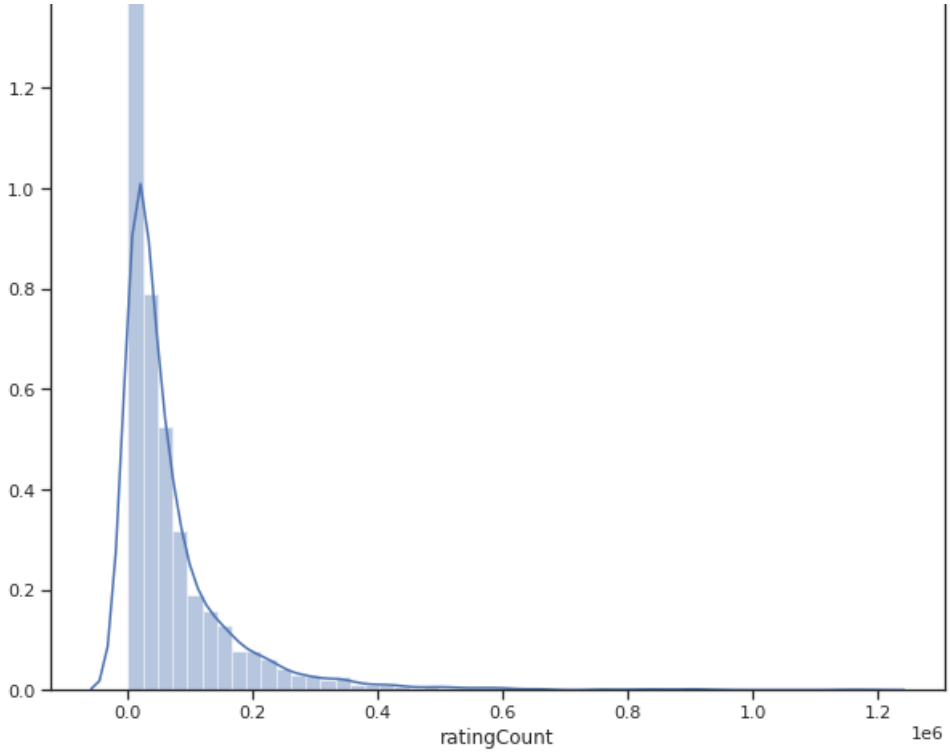


In [11]:

```
fig, ax = plt.subplots(figsize=(10,10))
sns.distplot(data['ratingCount'])
```

Out[11]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x7f547871abe0>
```



In [12]:

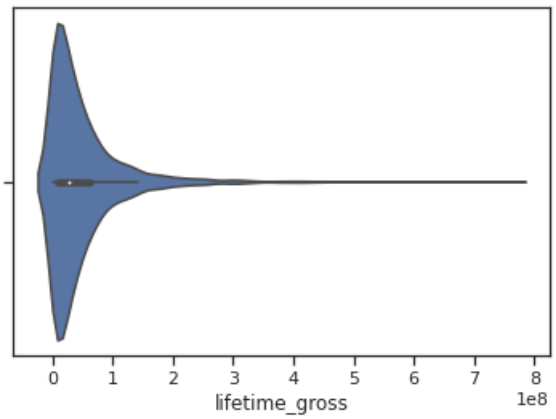
```
data.columns
```

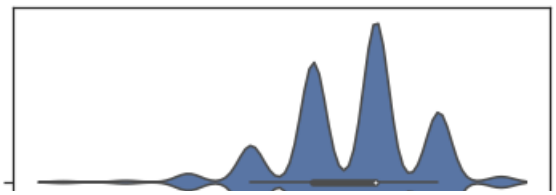
Out[12]:

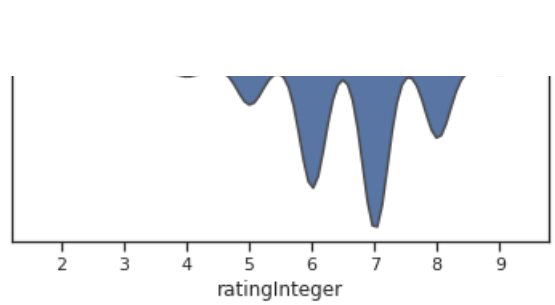
```
Index(['title', 'year', 'lifetime_gross', 'ratingInteger', 'ratingCount',
       'duration', 'nrOfWins', 'nrOfNominations', 'nrOfPhotos',
       'nrOfNewsArticles', 'nrOfUserReviews', 'nrOfGenre'],
      dtype='object')
```

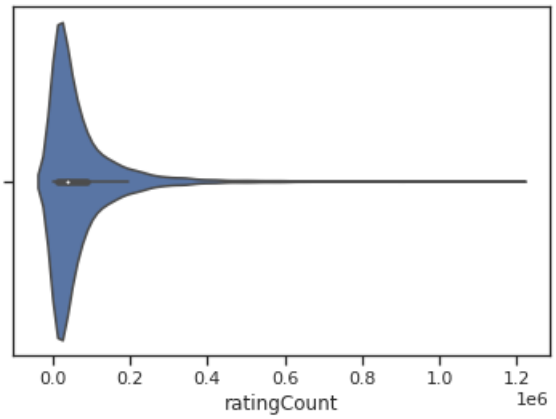
In [13]:

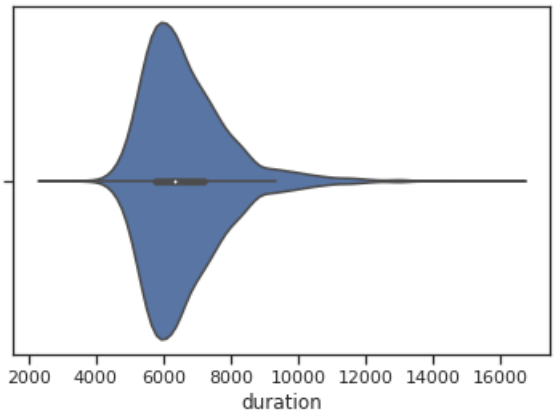
```
# Скрипичные диаграммы для числовых колонок
for col in [ 'lifetime_gross', 'ratingInteger', 'ratingCount',
       'duration', 'nrOfWins', 'nrOfNominations', 'nrOfPhotos',
       'nrOfNewsArticles', 'nrOfUserReviews', 'nrOfGenre']:

    sns.violinplot(x=data[col])
    plt.show()
```

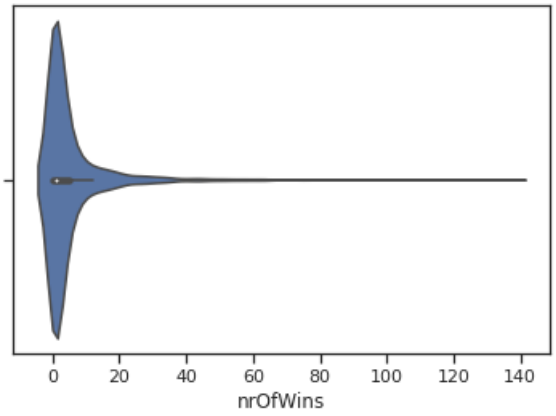


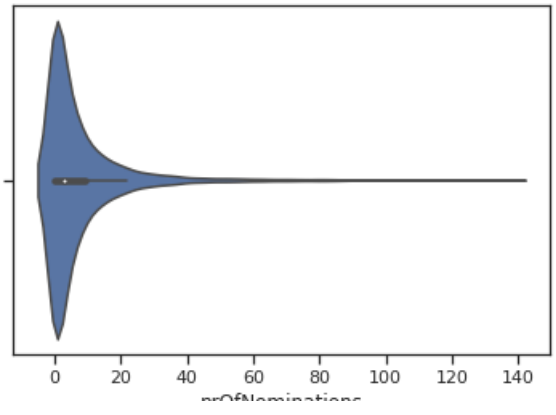


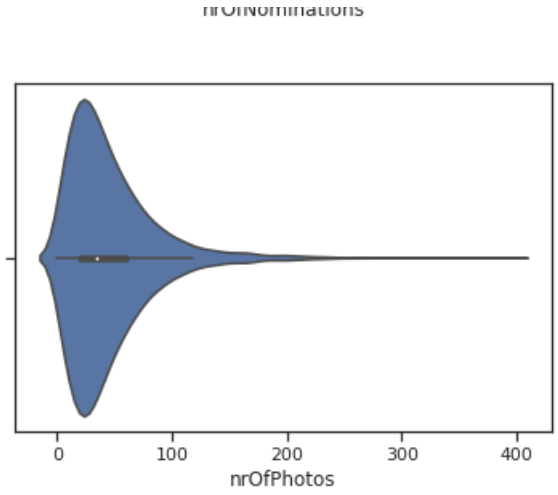

2
3
4
5
6
7
8
9
ratingInteger

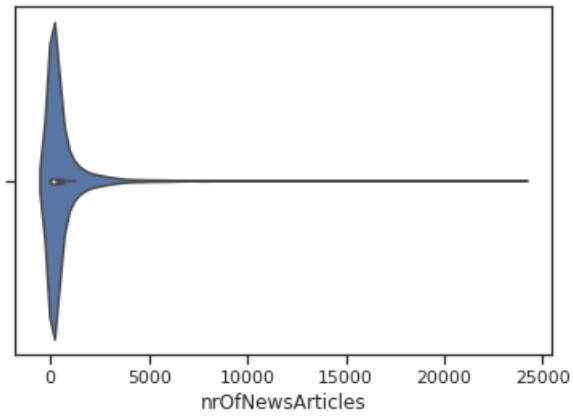

0.0
0.2
0.4
0.6
0.8
1.0
1.2
1e6
ratingCount

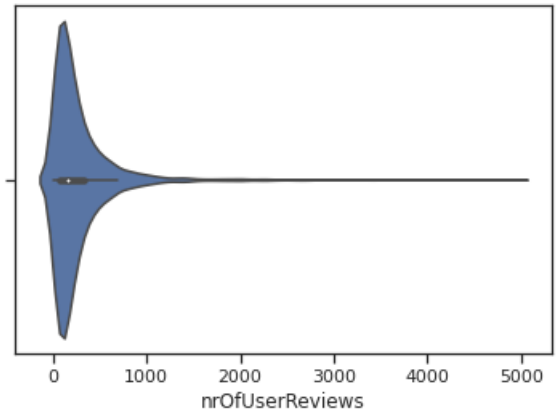

2000
4000
6000
8000
10000
12000
14000
16000
duration

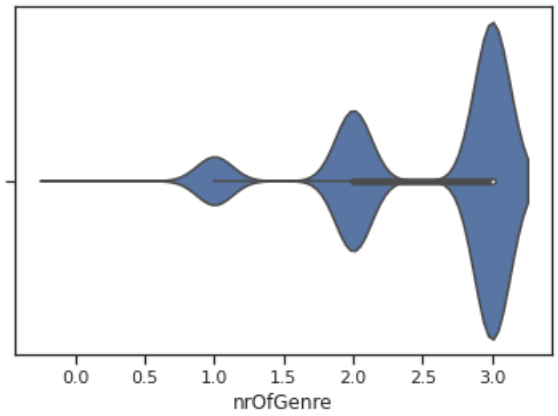

0
20
40
60
80
100
120
140
nrOfWins


0
20
40
60
80
100
120
140









Анализ и заполнение пропусков в данных.

Поскольку в данном наборе пустых значений нет, пропустим данный пункт.

3. Выбор признаков, подходящих для построения моделей. Кодирование категориальных признаков. Масштабирование данных. Формирование вспомогательных признаков, улучшающих качество моделей.

Кодирование категориальных признаков числовыми

In [14]:

```
from sklearn.preprocessing import LabelEncoder
le = LabelEncoder()
data['title'] = le.fit_transform(data['title'])
data.dtypes
```

Out[14]:

```
title               int64
year                int64
lifetime_gross      int64
ratingInteger       int64
ratingCount         int64
duration            int64
nrOfWins            int64
nrOfNominations     int64
nrOfPhotos          int64
nrOfNewsArticles    int64
nrOfUserReviews     int64
nrOfGenre           int64
dtype: object
```

In [15]:

```
data.head()
```

Out[15]:

	title	year	lifetime_gross	ratingInteger	ratingCount	duration	nrOfWins	nrOfNominations	nrOfPhotos	nrOfNewsArticles	nrOfUse
0	1761	1927	1236166	8	81007	9180	3	4	67	428	
1	585	1931	19181	9	70057	5220	2	0	38	187	
2	1797	1936	163577	9	90847	5220	3	1	44	27	
3	1137	1939	198676459	8	160414	14280	10	6	143	1263	
4	3370	1939	22342633	8	209506	6120	6	12	126	2363	

Масштабирование данных.

In [16]:

```
scale_cols = ['year','lifetime_gross', 'ratingInteger', 'ratingCount',
       'duration', 'nrOfWins', 'nrOfNominations', 'nrOfPhotos',
       'nrOfNewsArticles', 'nrOfUserReviews', 'nrOfGenre']
```

In [17]:

```
data.columns
```

Out[17]:

```
Index(['title', 'year', 'lifetime_gross', 'ratingInteger', 'ratingCount',
       'duration', 'nrOfWins', 'nrOfNominations', 'nrOfPhotos',
       'nrOfNewsArticles', 'nrOfUserReviews', 'nrOfGenre'],
      dtype='object')
```

In [18]:

```
sc1 = MinMaxScaler()
```

```
sc1_data = sc1.fit_transform(data[scale_cols])
```

In [19]:

```
# Добавим масштабированные данные в набор данных
for i in range(len(scale_cols)):
    col = scale_cols[i]
    new_col_name = col + '_scaled'
    data[new_col_name] = sc1_data[:,i]
```

In [20]:

```
data.head()
```

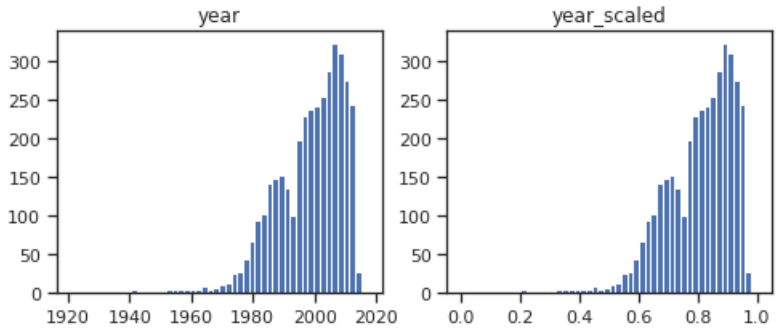
Out[20]:

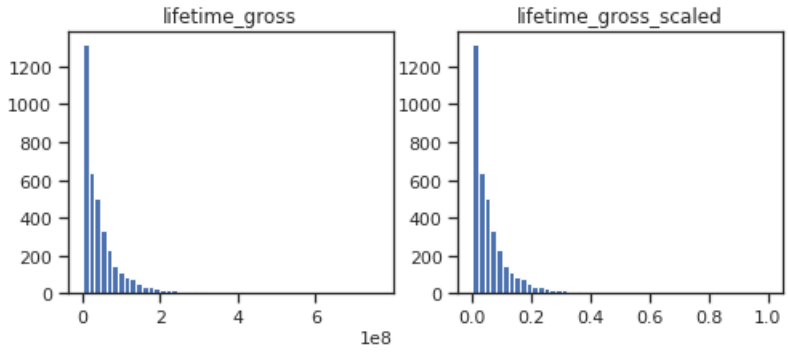
	title	year	lifetime_gross	ratingInteger	ratingCount	duration	nrOfWins	nrOfNominations	nrOfPhotos	nrOfNewsArticles	...	lifeti
0	1761	1927	1236166	8	81007	9180	3	4	67	428	...	
1	585	1931	19181	9	70057	5220	2	0	38	187	...	
2	1797	1936	163577	9	90847	5220	3	1	44	27	...	
3	1137	1939	198676459	8	160414	14280	10	6	143	1263	...	
4	3370	1939	22342633	8	209506	6120	6	12	126	2363	...	

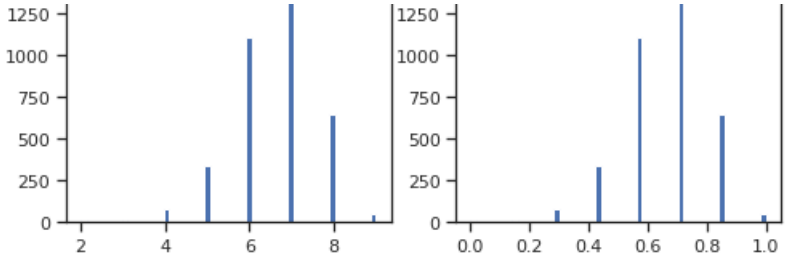
5 rows × 23 columns

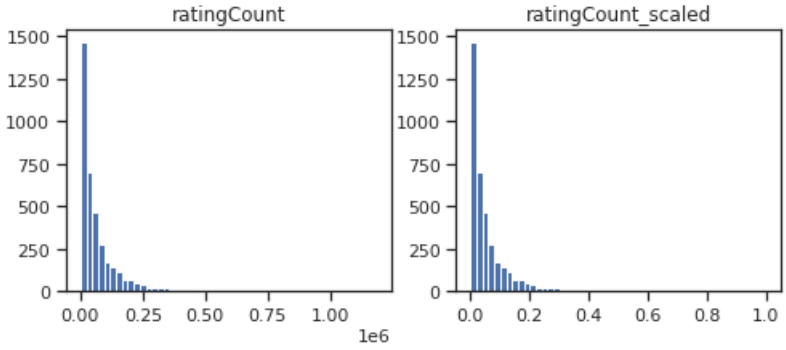
In [21]:

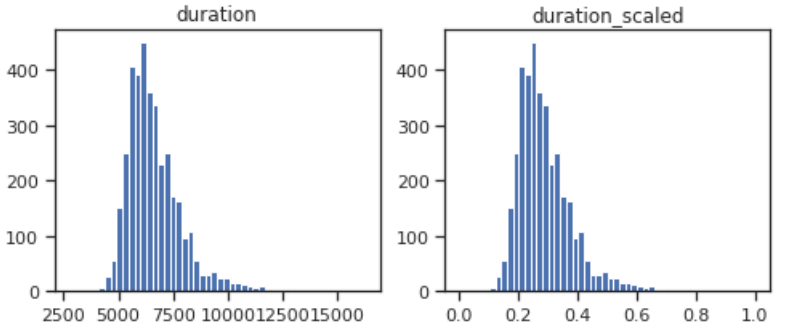
```
# Проверим, что масштабирование не повлияло на распределение данных
for col in scale_cols:
    col_scaled = col + '_scaled'

    fig, ax = plt.subplots(1, 2, figsize=(8,3))
    ax[0].hist(data[col], 50)
    ax[1].hist(data[col_scaled], 50)
    ax[0].title.set_text(col)
    ax[1].title.set_text(col_scaled)
    plt.show()
```

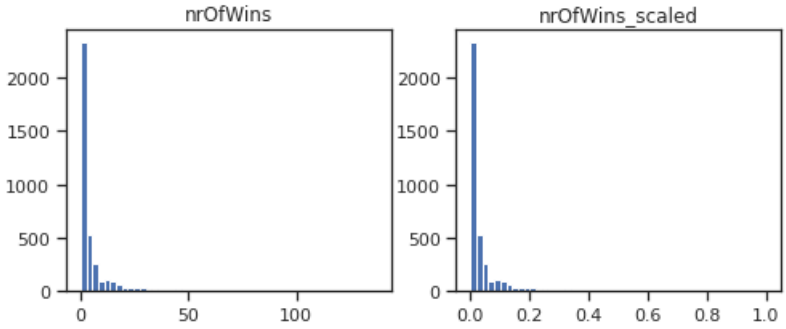


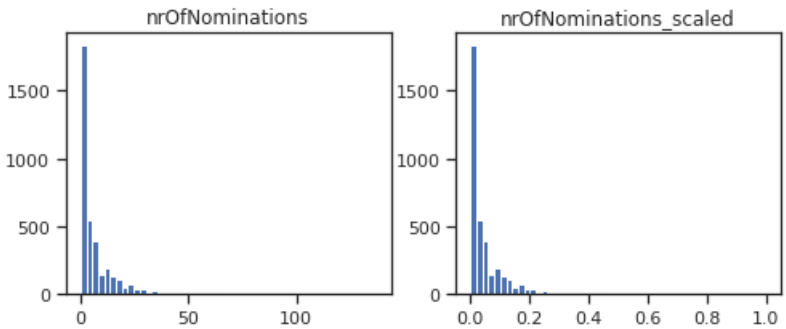


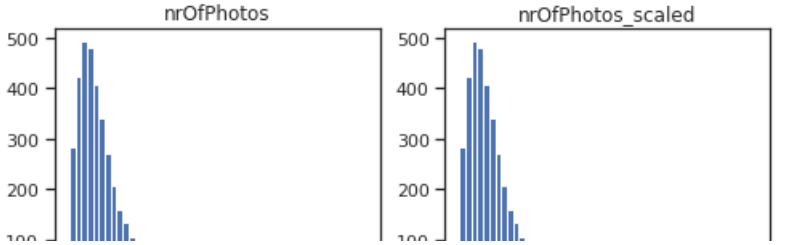


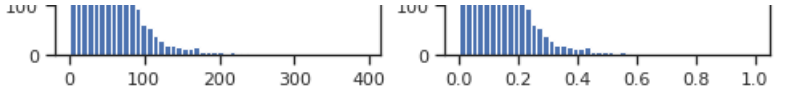

ratingCount
ratingCount_scaled
1e6

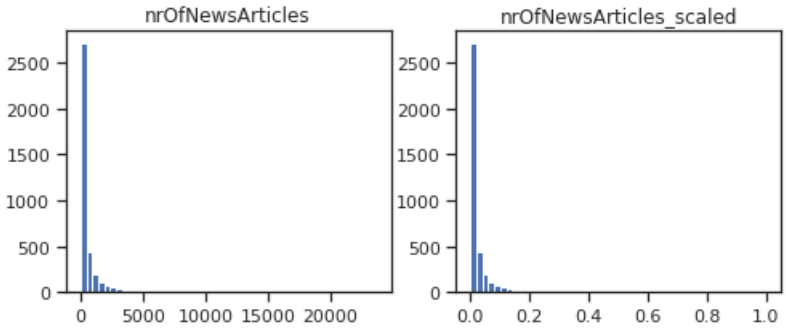

duration
duration_scaled

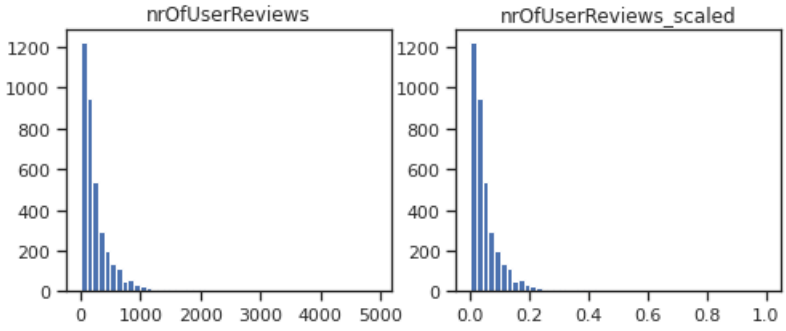

nrOfWins
nrOfWins_scaled

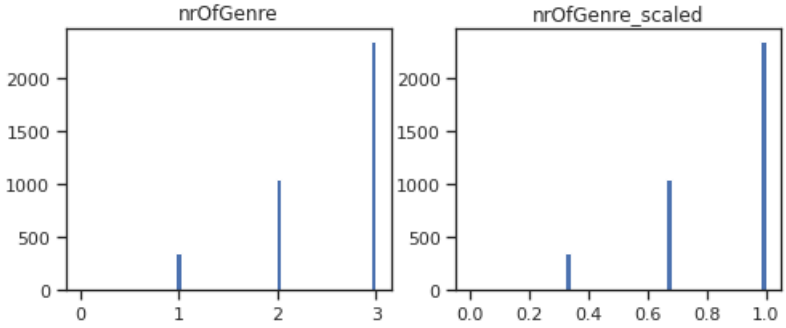

nrOfNominations
nrOfNominations_scaled


nrOfPhotos
nrOfPhotos_scaled









4. Проведение корреляционного анализа данных. Формирование промежуточных выводов о возможности построения моделей машинного обучения.

In [22]:

```
# Воспользуемся наличием тестовых выборок,
# включив их в корреляционную матрицу
corr_cols_1 = scale_cols
corr_cols_1
```

Out[22]:

```
['year',
 'lifetime_gross',
 'ratingInteger',
 'ratingCount',
 'duration',
 'nrOfWins',
 'nrOfNominations',
 'nrOfPhotos',
 'nrOfNewsArticles',
 'nrOfUserReviews',
 'nrOfGenre']
```

In [23]:

```
scale_cols_postfix = [x+'_scaled' for x in scale_cols]
```

```
corr_cols_2 = scale_cols_postfix
corr_cols_2
```

Out[23]:

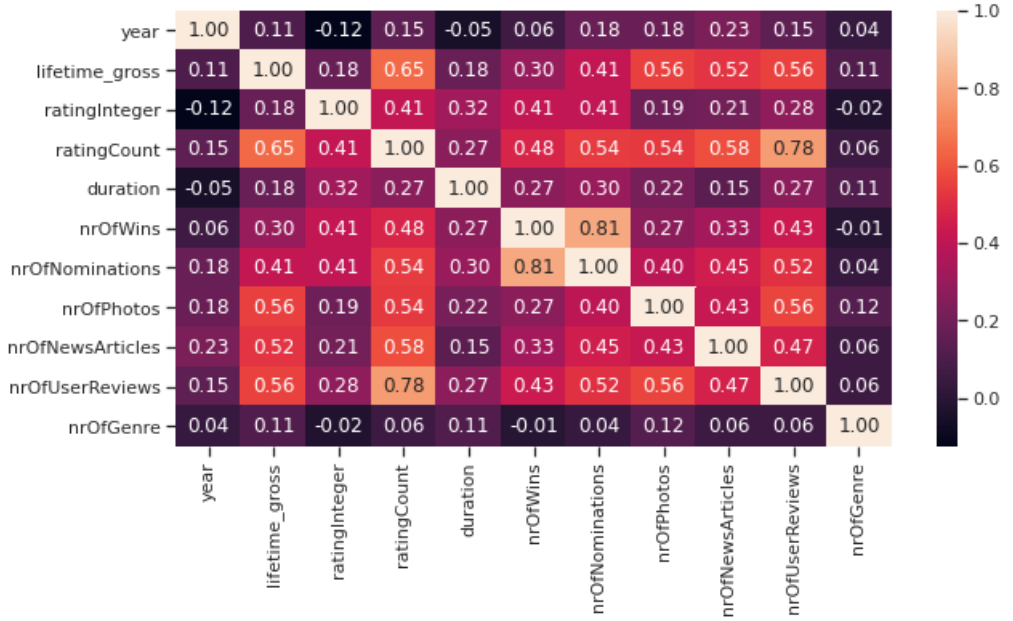
```
['year_scaled',
 'lifetime_gross_scaled',
 'ratingInteger_scaled',
 'ratingCount_scaled',
 'duration_scaled',
 'nrOfWins_scaled',
 'nrOfNominations_scaled',
 'nrOfPhotos_scaled',
 'nrOfNewsArticles_scaled',
 'nrOfUserReviews_scaled',
 'nrOfGenre_scaled']
```

In [24]:

```
fig, ax = plt.subplots(figsize=(10,5))
sns.heatmap(data[corr_cols_1].corr(), annot=True, fmt='.2f')
```

Out[24]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x7f5472d32320>
```

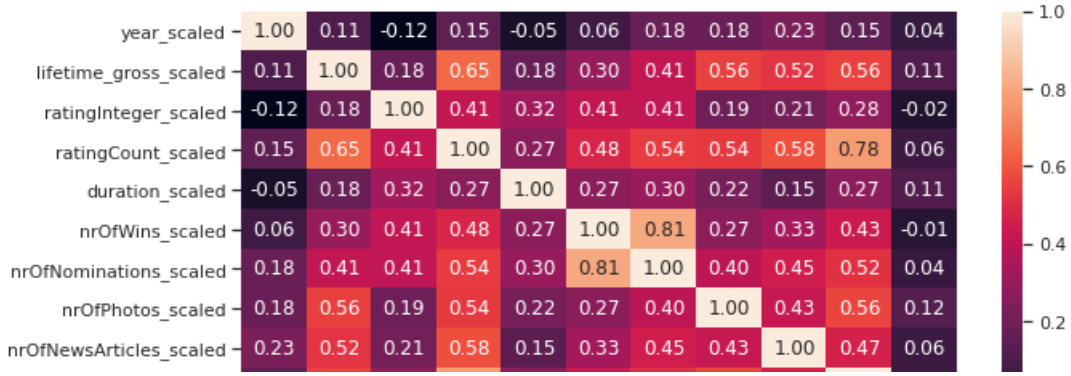


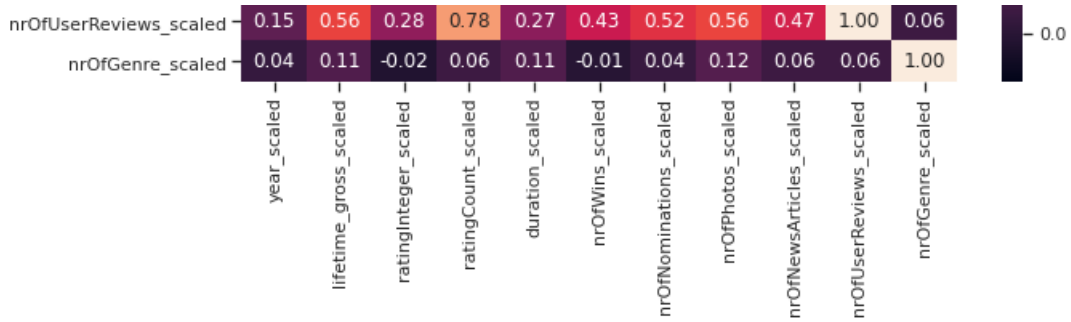
In [25]:

```
fig, ax = plt.subplots(figsize=(10,5))
sns.heatmap(data[corr_cols_2].corr(), annot=True, fmt='.2f')
```

Out[25]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x7f54781b68d0>
```





- Видим, что количество отзывов не сильно коррелирует с данными характеристиками. Наибольшее влияние на количество отзывов оказывает количество отзывов, что очень логично и сборы.

5. Выбор метрик для последующей оценки качества моделей. Необходимо выбрать не менее двух метрик и обосновать выбор.

Возьмем метрики MAE, Median Absolute Error и R^2.

- MAE (Mean Absolute Error) — это среднее модуля ошибки. Данная метрика удобна, она не чувствительна к выбросам, как MSE, показывает среднюю ошибку
- Медиана абсолютного отклонения(Median Absolute Error) - это альтернатива стандартного отклонения, менее чувствительна к воздействию промахов
- Коэффициент детерминации показывает, насколько модель соответствует или не соответствует данным.

In [26]:

```
class MetricLogger:

    def __init__(self):
        self.df = pd.DataFrame(
            {'metric': pd.Series([], dtype='str'),
            'alg': pd.Series([], dtype='str'),
            'value': pd.Series([], dtype='float')})

    def add(self, metric, alg, value):
        """
        Добавление значения
        """
        # Удаление значения если оно уже было ранее добавлено
        self.df.drop(self.df[(self.df['metric']==metric)&(self.df['alg']==alg)].index, inplace = Tr
ue)
        # Добавление нового значения
        temp = [{'metric':metric, 'alg':alg, 'value':value}]
        self.df = self.df.append(temp, ignore_index=True)

    def get_data_for_metric(self, metric, ascending=True):
        """
        Формирование данных с фильтром по метрике
        """
        temp_data = self.df[self.df['metric']==metric]
        temp_data_2 = temp_data.sort_values(by='value', ascending=ascending)
        return temp_data_2['alg'].values, temp_data_2['value'].values

    def plot(self, str_header, metric, ascending=True, figsize=(5, 5)):
        """
        Вывод графика
        """
        array_labels, array_metric = self.get_data_for_metric(metric, ascending)
        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(0.5, a-0.05, str(round(b,3)), color='white')
        plt.show()
```

6. Выбор наиболее подходящих моделей для решения задачи регрессии.

- Возьмем модели случайный лес и дерево решений, поскольку они показали оптимальные результаты.
- В качестве ансамблевой модели возьмем 'TREE+RF=>LR' модель

In [ ]:

```
### 7. Формирование обучающей и тестовой выборок на основе исходного набора данных.
```

In [27]:

```
data_new = shuffle(data)
data_new
```

Out[27]:

	title	year	lifetime_gross	ratingInteger	ratingCount	duration	nrOfWins	nrOfNominations	nrOfPhotos	nrOfNewsArticles	...	l
2037	1946	2013	89107235	7	244627	7440	0	0	48	2834	...	
319	3550	1985	12993175	6	5326	6420	0	0	6	51	...	
1189	2890	1993	183875760	8	177341	7800	12	23	56	418	...	
197	730	2007	8580428	7	74812	5400	2	0	16	455	...	
1907	1329	2011	73864507	8	192078	7560	45	104	88	4508	...	
...	...	...	...	...	...	...	...	...	...	...	...	
851	1301	2011	117538559	7	257383	5880	2	7	59	3413	...	
2540	3112	1979	65200000	8	21409	5700	3	9	41	271	...	
1962	1102	2008	2430627	7	17740	10980	7	16	14	593	...	
816	1217	2004	249541069	8	278537	8520	13	35	128	700	...	
467	3311	1998	36400491	8	114343	10200	20	19	71	801	...	

3747 rows × 23 columns

In [28]:

```
len(data_new)
```

Out[28]:

```
3747
```

In [29]:

```
# На основе масштабированных данных выделим
# обучающую и тестовую выборки
train_data_all = data_new[:2700]
test_data_all = data_new[2701:]
train_data_all.shape, test_data_all.shape
```

Out[29]:

```
((2700, 23), (1046, 23))
```

In [30]:

```
data.columns
```

Out[30]:

```
Index(['title', 'year', 'lifetime_gross', 'ratingInteger', 'ratingCount',
       'duration', 'nrOfWins', 'nrOfNominations', 'nrOfPhotos',
       'nrOfNewsArticles', 'nrOfUserReviews', 'nrOfGenre', 'year_scaled',
       'lifetime_gross_scaled', 'ratingInteger_scaled', 'ratingCount_scaled',
       'duration_scaled', 'nrOfWins_scaled', 'nrOfNominations_scaled',
```

```
       'nrOfPhotos_scaled', 'nrOfNewsArticles_scaled',
       'nrOfUserReviews_scaled', 'nrOfGenre_scaled'],
      dtype='object')
```

In [31]:

```
# Признаки для задачи регресии (опустим название)
task_regr_cols = ['title', 'year', 'lifetime_gross', 'ratingInteger', 'ratingCount',
       'duration', 'nrOfWins', 'nrOfNominations', 'nrOfPhotos',
       'nrOfNewsArticles', 'nrOfUserReviews', 'nrOfGenre', 'year_scaled',
       'lifetime_gross_scaled', 'ratingInteger_scaled', 'ratingCount_scaled',
       'duration_scaled', 'nrOfWins_scaled', 'nrOfNominations_scaled',
       'nrOfPhotos_scaled', 'nrOfNewsArticles_scaled',
       'nrOfUserReviews_scaled', 'nrOfGenre_scaled']
```

In [32]:

```
# Выборки для задачи регресии
regr_X_train = train_data_all[task_regr_cols]
regr_X_test = test_data_all[task_regr_cols]
regr_Y_train = train_data_all['ratingCount']
regr_Y_test = test_data_all['ratingCount']
regr_X_train.shape, regr_X_test.shape, regr_Y_train.shape, regr_Y_test.shape
```

Out[32]:

```
((2700, 23), (1046, 23), (2700,), (1046,))
```

8. Построение базового решения (baseline) для выбранных моделей без подбора гиперпараметров. Производится обучение моделей на основе обучающей выборки и оценка качества моделей на основе тестовой выборки.

In [67]:

```
# Модели
regr_models = {'Tree':DecisionTreeRegressor(max_depth=8),
               'RF':RandomForestRegressor(max_depth=10, n_estimators=30),
              }
```

In [68]:

```
# Сохранение метрик
regrMetricLogger = MetricLogger()
```

In [69]:

```
def regr_train_model(model_name, model, regrMetricLogger):
    model.fit(regr_X_train, regr_Y_train)
    Y_pred = model.predict(regr_X_test)

    mae = mean_absolute_error(regr_Y_test, Y_pred)
    medae = median_absolute_error(regr_Y_test, Y_pred)
    r2 = r2_score(regr_Y_test, Y_pred)

    regrMetricLogger.add('MAE', model_name, mae)
    regrMetricLogger.add('MedAE', model_name, medae)
    regrMetricLogger.add('R2', model_name, r2)

    print('**************************************************')
    print(model)
    print()
    print('MAE={}, MedAE={}, R2={}'.format(
        round(mae, 3), round(medae, 3), round(r2, 3)))
    print('**************************************************')
```

In [70]:

```
for model_name, model in regr_models.items():
    regr_train_model(model_name, model, regrMetricLogger)
```

```
**************************************************
DecisionTreeRegressor(max_depth=8)

MAE=774.395, MedAE=289.652, R2=0.999
**************************************************
**************************************************
RandomForestRegressor(max_depth=10, n_estimators=30)

MAE=553.334, MedAE=40.242, R2=0.995
**************************************************
```

Ансамблевая модель

In [92]:

```
from heamy.estimator import Regressor
from heamy.pipeline import ModelsPipeline
from heamy.dataset import Dataset
# набор данных
dataset = Dataset(regr_X_train, regr_Y_train, regr_X_test)
# Возьмем лучшую модель: 'TREE+RF=>LR'
# модели первого уровня
model_tree = Regressor(dataset=dataset, estimator=DecisionTreeRegressor, parameters={'max_depth':5}
,name='tree')
model_lr = Regressor(dataset=dataset, estimator=LinearRegression, name='lr')
model_rf = Regressor(dataset=dataset, estimator=RandomForestRegressor, parameters={'max_depth':5},n
ame='rf')

# Первый уровень - две модели: дерево и случайный лес
# Второй уровень: линейная регрессия
pipeline = ModelsPipeline(model_tree, model_rf)
stack_ds = pipeline.stack(k=10, seed=1)
# модель второго уровня
stacker = Regressor(dataset=stack_ds, estimator=LinearRegression)
results = stacker.validate(k=10,scorer=mean_absolute_error)


results = stacker.validate(k=10,scorer=median_absolute_error)
```

```
Metric: mean_absolute_error
Folds accuracy: [1045.970386774904, 930.0459954195503, 1129.0613392772195, 1361.2623884771958, 140
6.1153513280067, 1145.938476361386, 980.0840981919788, 2259.7370478803523, 920.4161867116387,
946.7109548967269]
Mean accuracy: 1212.534222531896
Standard Deviation: 385.3830977674812
Variance: 148520.13204486
Metric: median_absolute_error
Folds accuracy: [522.3984805439368, 586.2014349209421, 645.6072837976562, 890.6085993079942,
625.924265548414, 736.8923864693106, 664.2805063108499, 547.7621691388758, 685.2869982277662,
605.0121905217329]
Mean accuracy: 650.9974314787479
Standard Deviation: 100.15476023417993
Variance: 10030.97599756607
```

9. Подбор гиперпараметров для выбранных моделей.

Случайный лес

In [90]:

```
RandomForestRegressor().get_params()
```

Out[90]:

```
{'bootstrap': True,
 'ccp_alpha': 0.0,
 'criterion': 'mse',
 'max_depth': None,
 'max_features': 'auto',
```

```
 'max_leaf_nodes': None,
 'max_samples': None,
 'min_impurity_decrease': 0.0,
 'min_impurity_split': None,
 'min_samples_leaf': 1,
 'min_samples_split': 2,
 'min_weight_fraction_leaf': 0.0,
 'n_estimators': 100,
 'n_jobs': None,
 'oob_score': False,
 'random_state': None,
 'verbose': 0,
 'warm_start': False}
```

In [73]:

```
n_range = np.array(range(0,50,5))
tuned_parameters = [{'max_depth': n_range}]
tuned_parameters
```

Out[73]:

```
[{'max_depth': array([ 0,  5, 10, 15, 20, 25, 30, 35, 40, 45])}]
```

In [74]:

```
%%time
rf_gs = GridSearchCV(RandomForestRegressor(), tuned_parameters, cv=5,
scoring='neg_mean_squared_error')
rf_gs.fit(regr_X_train, regr_Y_train)
```

```
/home/denis/ml/env/lib/python3.6/site-packages/sklearn/model_selection/_validation.py:552:
FitFailedWarning: Estimator fit failed. The score on this train-test partition for these
parameters will be set to nan. Details:
Traceback (most recent call last):
  File "/home/denis/ml/env/lib/python3.6/site-packages/sklearn/model_selection/_validation.py", li
ne 531, in _fit_and_score
    estimator.fit(X_train, y_train, **fit_params)
  File "/home/denis/ml/env/lib/python3.6/site-packages/sklearn/ensemble/_forest.py", line 392, in
fit
    for i, t in enumerate(trees))
  File "/home/denis/ml/env/lib/python3.6/site-packages/joblib/parallel.py", line 1029, in __call__
    if self.dispatch_one_batch(iterator):
  File "/home/denis/ml/env/lib/python3.6/site-packages/joblib/parallel.py", line 847, in
dispatch_one_batch
    self._dispatch(tasks)
  File "/home/denis/ml/env/lib/python3.6/site-packages/joblib/parallel.py", line 765, in _dispatch
    job = self._backend.apply_async(batch, callback=cb)
  File "/home/denis/ml/env/lib/python3.6/site-packages/joblib/_parallel_backends.py", line 206, in
apply_async
    result = ImmediateResult(func)
  File "/home/denis/ml/env/lib/python3.6/site-packages/joblib/_parallel_backends.py", line 570, in
__init__
    self.results = batch()
  File "/home/denis/ml/env/lib/python3.6/site-packages/joblib/parallel.py", line 253, in __call__
    for func, args, kwargs in self.items]
  File "/home/denis/ml/env/lib/python3.6/site-packages/joblib/parallel.py", line 253, in
<listcomp>
    for func, args, kwargs in self.items]
  File "/home/denis/ml/env/lib/python3.6/site-packages/sklearn/ensemble/_forest.py", line 168, in
_parallel_build_trees
    tree.fit(X, y, sample_weight=curr_sample_weight, check_input=False)
  File "/home/denis/ml/env/lib/python3.6/site-packages/sklearn/tree/_classes.py", line 1246, in fi
t
    X_idx_sorted=X_idx_sorted)
  File "/home/denis/ml/env/lib/python3.6/site-packages/sklearn/tree/_classes.py", line 277, in fit
    raise ValueError("max_depth must be greater than zero. ")
ValueError: max_depth must be greater than zero.

  FitFailedWarning)
/home/denis/ml/env/lib/python3.6/site-packages/sklearn/model_selection/_validation.py:552:
FitFailedWarning: Estimator fit failed. The score on this train-test partition for these
parameters will be set to nan. Details:
Traceback (most recent call last):
```

```
  File "/home/denis/ml/env/lib/python3.6/site-packages/sklearn/model_selection/_validation.py", li
ne 531, in _fit_and_score
    estimator.fit(X_train, y_train, **fit_params)
  File "/home/denis/ml/env/lib/python3.6/site-packages/sklearn/ensemble/_forest.py", line 392, in
fit
    for i, t in enumerate(trees))
  File "/home/denis/ml/env/lib/python3.6/site-packages/joblib/parallel.py", line 1029, in __call__
    if self.dispatch_one_batch(iterator):
  File "/home/denis/ml/env/lib/python3.6/site-packages/joblib/parallel.py", line 847, in
dispatch_one_batch
    self._dispatch(tasks)
  File "/home/denis/ml/env/lib/python3.6/site-packages/joblib/parallel.py", line 765, in _dispatch
    job = self._backend.apply_async(batch, callback=cb)
  File "/home/denis/ml/env/lib/python3.6/site-packages/joblib/_parallel_backends.py", line 206, in
apply_async
    result = ImmediateResult(func)
  File "/home/denis/ml/env/lib/python3.6/site-packages/joblib/_parallel_backends.py", line 570, in
__init__
    self.results = batch()
  File "/home/denis/ml/env/lib/python3.6/site-packages/joblib/parallel.py", line 253, in __call__
    for func, args, kwargs in self.items]
  File "/home/denis/ml/env/lib/python3.6/site-packages/joblib/parallel.py", line 253, in
<listcomp>
    for func, args, kwargs in self.items]
  File "/home/denis/ml/env/lib/python3.6/site-packages/sklearn/ensemble/_forest.py", line 168, in
_parallel_build_trees
    tree.fit(X, y, sample_weight=curr_sample_weight, check_input=False)
  File "/home/denis/ml/env/lib/python3.6/site-packages/sklearn/tree/_classes.py", line 1246, in fi
t
    X_idx_sorted=X_idx_sorted)
  File "/home/denis/ml/env/lib/python3.6/site-packages/sklearn/tree/_classes.py", line 277, in fit
    raise ValueError("max_depth must be greater than zero. ")
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ne 531, in _fit_and_score
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  File "/home/denis/ml/env/lib/python3.6/site-packages/sklearn/ensemble/_forest.py", line 392, in
fit
    for i, t in enumerate(trees))
  File "/home/denis/ml/env/lib/python3.6/site-packages/joblib/parallel.py", line 1029, in __call__
    if self.dispatch_one_batch(iterator):
  File "/home/denis/ml/env/lib/python3.6/site-packages/joblib/parallel.py", line 847, in
dispatch_one_batch
    self._dispatch(tasks)
  File "/home/denis/ml/env/lib/python3.6/site-packages/joblib/parallel.py", line 765, in _dispatch
    job = self._backend.apply_async(batch, callback=cb)
  File "/home/denis/ml/env/lib/python3.6/site-packages/joblib/_parallel_backends.py", line 206, in
apply_async
    result = ImmediateResult(func)
  File "/home/denis/ml/env/lib/python3.6/site-packages/joblib/_parallel_backends.py", line 570, in
__init__
    self.results = batch()
  File "/home/denis/ml/env/lib/python3.6/site-packages/joblib/parallel.py", line 253, in __call__
    for func, args, kwargs in self.items]
  File "/home/denis/ml/env/lib/python3.6/site-packages/joblib/parallel.py", line 253, in
<listcomp>
    for func, args, kwargs in self.items]
  File "/home/denis/ml/env/lib/python3.6/site-packages/sklearn/ensemble/_forest.py", line 168, in
_parallel_build_trees
    tree.fit(X, y, sample_weight=curr_sample_weight, check_input=False)
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    estimator.fit(X_train, y_train, **fit_params)
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    X_idx_sorted=X_idx_sorted)
  File "/home/denis/ml/env/lib/python3.6/site-packages/sklearn/tree/_classes.py", line 277, in fit
    raise ValueError("max_depth must be greater than zero. ")
ValueError: max_depth must be greater than zero.

  FitFailedWarning)
```

```
CPU times: user 1min 15s, sys: 282 ms, total: 1min 16s
Wall time: 1min 16s
```

Out[74]:

```
GridSearchCV(cv=5, estimator=RandomForestRegressor(),
             param_grid=[{'max_depth': array([ 0,  5, 10, 15, 20, 25, 30, 35, 40, 45])}],
             scoring='neg_mean_squared_error')
```

In [75]:

```
# Лучшая модель
rf_gs.best_estimator_
```

Out[75]:

```
RandomForestRegressor(max_depth=45)
```

In [76]:

```
# Лучшее значение параметров
rf_gs.best_params_
```

Out[76]:

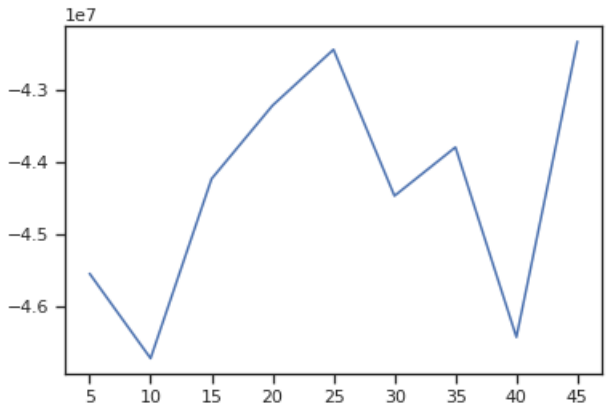
```
{'max_depth': 45}
```

In [44]:

```
# Изменение качества на тестовой выборке в зависимости от К-соседей
plt.plot(n_range, rf_gs.cv_results_['mean_test_score'])
```

Out[44]:

```
[<matplotlib.lines.Line2D at 0x7f547824da20>]
```



Дерево

In [45]:

```
DecisionTreeRegressor().get_params()
```

Out[45]:

```
{'ccp_alpha': 0.0,
 'criterion': 'mse',
 'max_depth': None,
 'max_features': None,
 'max_leaf_nodes': None,
 'min_impurity_decrease': 0.0,
 'min_impurity_split': None,
 'min_samples_leaf': 1,
 'min_samples_split': 2,
 'min_weight_fraction_leaf': 0.0,
```

```
 'presort': 'deprecated',
 'random_state': None,
 'splitter': 'best'}
```

In [46]:

```
n_range = np.array(range(0,50,5))

tuned_parameters = [{'max_depth': n_range}]
tuned_parameters
```

Out[46]:

```
[{'max_depth': array([ 0,  5, 10, 15, 20, 25, 30, 35, 40, 45])}]
```

In [47]:

```
%%time
dt_gs = GridSearchCV(DecisionTreeRegressor(), tuned_parameters, cv=5,
scoring='neg_mean_squared_error')
dt_gs.fit(regr_X_train, regr_Y_train)
```

```
/home/denis/ml/env/lib/python3.6/site-packages/sklearn/model_selection/_validation.py:552:
FitFailedWarning: Estimator fit failed. The score on this train-test partition for these
parameters will be set to nan. Details:
Traceback (most recent call last):
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ne 531, in _fit_and_score
    estimator.fit(X_train, y_train, **fit_params)
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  File "/home/denis/ml/env/lib/python3.6/site-packages/sklearn/tree/_classes.py", line 277, in fit
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  File "/home/denis/ml/env/lib/python3.6/site-packages/sklearn/tree/_classes.py", line 1246, in fi
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  File "/home/denis/ml/env/lib/python3.6/site-packages/sklearn/tree/_classes.py", line 277, in fit
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ne 531, in _fit_and_score
    estimator.fit(X_train, y_train, **fit_params)
```

```
  File "/home/denis/ml/env/lib/python3.6/site-packages/sklearn/tree/_classes.py", line 1246, in fi
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t
    X_idx_sorted=X_idx_sorted)
  File "/home/denis/ml/env/lib/python3.6/site-packages/sklearn/tree/_classes.py", line 277, in fit
    raise ValueError("max_depth must be greater than zero. ")
ValueError: max_depth must be greater than zero.

  FitFailedWarning)
```

```
CPU times: user 1.42 s, sys: 85 µs, total: 1.42 s
Wall time: 1.42 s
```

Out[47]:

```
GridSearchCV(cv=5, estimator=DecisionTreeRegressor(),
             param_grid=[{'max_depth': array([ 0,  5, 10, 15, 20, 25, 30, 35, 40, 45])}],
             scoring='neg_mean_squared_error')
```

In [48]:

```
# Лучшая модель
dt_gs.best_estimator_
```

Out[48]:

```
DecisionTreeRegressor(max_depth=20)
```

In [49]:

```
# Лучшее значение параметров
dt_gs.best_params_
```

Out[49]:

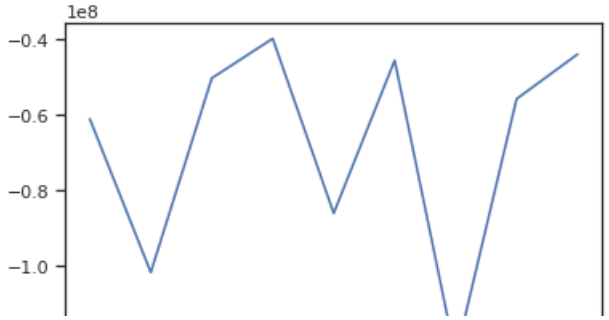
```
{'max_depth': 20}
```

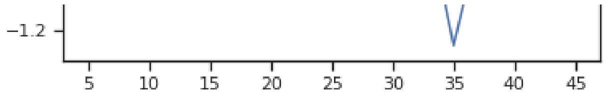
In [50]:

```
# Изменение качества на тестовой выборке
plt.plot(n_range, dt_gs.cv_results_['mean_test_score'])
```

Out[50]:

```
[<matplotlib.lines.Line2D at 0x7f547845c940>]
```





Ансамблевая модель

Decision tree

In [51]:

```
n_range = [0, 0.5, 1, 1.5, 2, 2.5, 3]
tuned_parameters = [{'min_impurity_split': n_range}]
tuned_parameters
```

Out[51]:

```
[{'min_impurity_split': [0, 0.5, 1, 1.5, 2, 2.5, 3]}]
```

In [52]:

```
%%time
ens_dt_gs = GridSearchCV(DecisionTreeRegressor(), tuned_parameters, cv=5,
scoring='neg_mean_squared_error')
ens_dt_gs.fit(regr_X_train, regr_Y_train)
```

```
/home/denis/ml/env/lib/python3.6/site-packages/sklearn/tree/_classes.py:310: FutureWarning: The mi
n_impurity_split parameter is deprecated. Its default value has changed from 1e-7 to 0 in version
0.23, and it will be removed in 0.25. Use the min_impurity_decrease parameter instead.
  FutureWarning)
/home/denis/ml/env/lib/python3.6/site-packages/sklearn/tree/_classes.py:310: FutureWarning: The mi
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```

```
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0.23, and it will be removed in 0.25. Use the min_impurity_decrease parameter instead.
```

```
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n_impurity_split parameter is deprecated. Its default value has changed from 1e-7 to 0 in version
0.23, and it will be removed in 0.25. Use the min_impurity_decrease parameter instead.
  FutureWarning)
```

```
CPU times: user 1.19 s, sys: 4.06 ms, total: 1.19 s
Wall time: 1.18 s
```

```
/home/denis/ml/env/lib/python3.6/site-packages/sklearn/tree/_classes.py:310: FutureWarning: The mi
n_impurity_split parameter is deprecated. Its default value has changed from 1e-7 to 0 in version
0.23, and it will be removed in 0.25. Use the min_impurity_decrease parameter instead.
  FutureWarning)
```

Out[52]:

```
GridSearchCV(cv=5, estimator=DecisionTreeRegressor(),
             param_grid=[{'min_impurity_split': [0, 0.5, 1, 1.5, 2, 2.5, 3]}],
             scoring='neg_mean_squared_error')
```

In [53]:

```
# Лучшая модель
ens_dt_gs.best_estimator_
```

Out[53]:

```
DecisionTreeRegressor(min_impurity_split=0.5)
```

In [54]:

```
# Лучшее значение параметров
ens_dt_gs.best_params_
```

Out[54]:

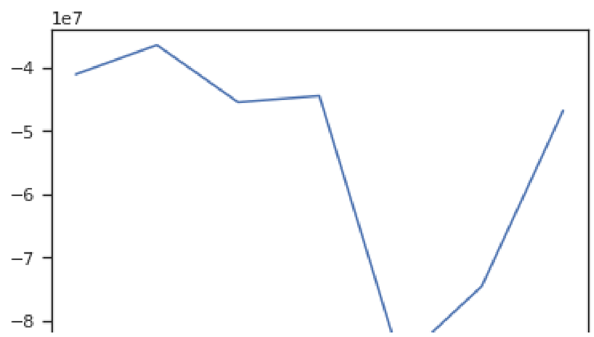
```
{'min_impurity_split': 0.5}
```

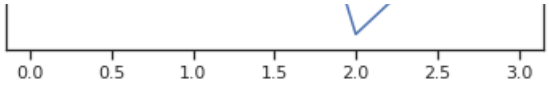
In [55]:

```
# Изменение качества на тестовой выборке
plt.plot(n_range, ens_dt_gs.cv_results_['mean_test_score'])
```

Out[55]:

```
[<matplotlib.lines.Line2D at 0x7f54782b2470>]
```





Random Forest

In [56]:

```
n_range = [1, 5, 10, 20, 30, 40 ,50 ,60]
tuned_parameters = [{'n_estimators': n_range}]
tuned_parameters
```

Out[56]:

```
[{'n_estimators': [1, 5, 10, 20, 30, 40, 50, 60]}]
```

In [57]:

```
%%time
ens_rf_gs = GridSearchCV(RandomForestRegressor(), tuned_parameters, cv=5,
scoring='neg_mean_squared_error')
ens_rf_gs.fit(regr_X_train, regr_Y_train)
```

```
CPU times: user 19.9 s, sys: 11.9 ms, total: 19.9 s
Wall time: 19.9 s
```

Out[57]:

```
GridSearchCV(cv=5, estimator=RandomForestRegressor(),
             param_grid=[{'n_estimators': [1, 5, 10, 20, 30, 40, 50, 60]}],
             scoring='neg_mean_squared_error')
```

In [58]:

```
# Лучшая модель
ens_rf_gs.best_estimator_
```

Out[58]:

```
RandomForestRegressor(n_estimators=60)
```

In [59]:

```
# Лучшее значение параметров
ens_rf_gs.best_params_
```

Out[59]:

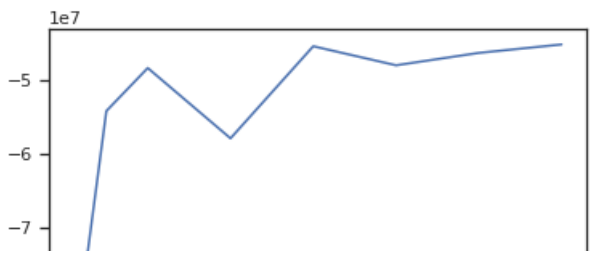
```
{'n_estimators': 60}
```

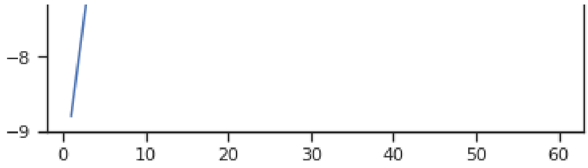
In [60]:

```
# Изменение качества на тестовой выборке
plt.plot(n_range, ens_rf_gs.cv_results_['mean_test_score'])
```

Out[60]:

```
[<matplotlib.lines.Line2D at 0x7f5478338550>]
```





10. Повторение пункта 8 для найденных оптимальных значений гиперпараметров. Сравнение качества полученных моделей с качеством baseline-моделей.

In [77]:

```
regr_models_grid = {'Tree':dt_gs.best_estimator_,
                    'RF': rf_gs.best_estimator_
                    }
```

In [78]:

```
for model_name, model in regr_models_grid.items():
    regr_train_model(model_name, model, regrMetricLogger)
```

```
*****************************************************
DecisionTreeRegressor(max_depth=20)

MAE=774.803, MedAE=51.0, R2=0.994
*****************************************************
*****************************************************
RandomForestRegressor(max_depth=45)

MAE=565.89, MedAE=28.655, R2=0.994
*****************************************************
```

Удалось немного улучшить обе модели по метрике MedAE

Ансамблевый метод

In [81]:

```
# # # Возьмем лучшую модель: 'TREE+RF=>LR'
model_tree = Regressor(dataset=dataset,
                       estimator=DecisionTreeRegressor,
                       parameters={'min_impurity_split':0.5,
                                   'max_depth':20},name='tree')
model_lr = Regressor(dataset=dataset,
                     estimator=LinearRegression,
                     name='lr')
model_rf = Regressor(dataset=dataset,
                     estimator=RandomForestRegressor,
                     parameters={'n_estimators': 60,
                                 'max_depth': 40},name='rf')

pipeline = ModelsPipeline(model_tree, model_rf)
stack_ds = pipeline.stack(k=10, seed=1)
# модель второго уровня
stacker = Regressor(dataset=stack_ds, estimator=LinearRegression)
```

```
/home/denis/ml/env/lib/python3.6/site-packages/sklearn/tree/_classes.py:310: FutureWarning: The mi
n_impurity_split parameter is deprecated. Its default value has changed from 1e-7 to 0 in version
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```

```
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n_impurity_split parameter is deprecated. Its default value has changed from 1e-7 to 0 in version
0.23, and it will be removed in 0.25. Use the min_impurity_decrease parameter instead.
  FutureWarning)
```

In [88]:

```
results = stacker.validate(k=10,scorer=mean_absolute_error)

results = stacker.validate(k=10,scorer=median_absolute_error)
```

```
Metric: mean_absolute_error
Folds accuracy: [598.6504086055367, 685.3752156309035, 741.8975437612055, 856.7357771226596,
1002.4279556690457, 1002.6587996957129, 684.795699844793, 1304.5601993068835, 560.7006745943086, 5
86.705642114385]
Mean accuracy: 802.4507916345435
Standard Deviation: 226.4673533318827
Variance: 51287.462125147795
Metric: median_absolute_error
Folds accuracy: [312.080033205013, 398.24598507362225, 405.3395872823876, 326.4411948100915,
407.28757818367376, 460.2302360872145, 438.0417146439913, 62.52175403803267, 388.8264976380815,
363.7897959108768]
Mean accuracy: 356.2804376872985
Standard Deviation: 107.01119547762202
Variance: 11451.395957549832
```

Удалось добиться небольшого улучшения.

11. Формирование выводов о качестве построенных моделей на основе выбранных метрик.

In [83]:

```
# Метрики качества модели
regr_metrics = regrMetricLogger.df['metric'].unique()
regr_metrics
```

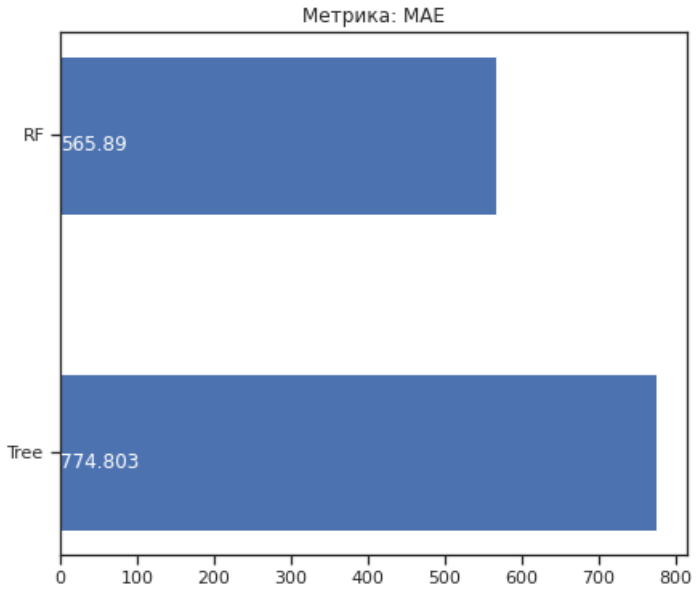
Out[83]:

```
array(['MAE', 'MedAE', 'R2'], dtype=object)
```

In [84]:

```
regrMetricLogger.plot('Метрика: ' + 'MAE', 'MAE',
```

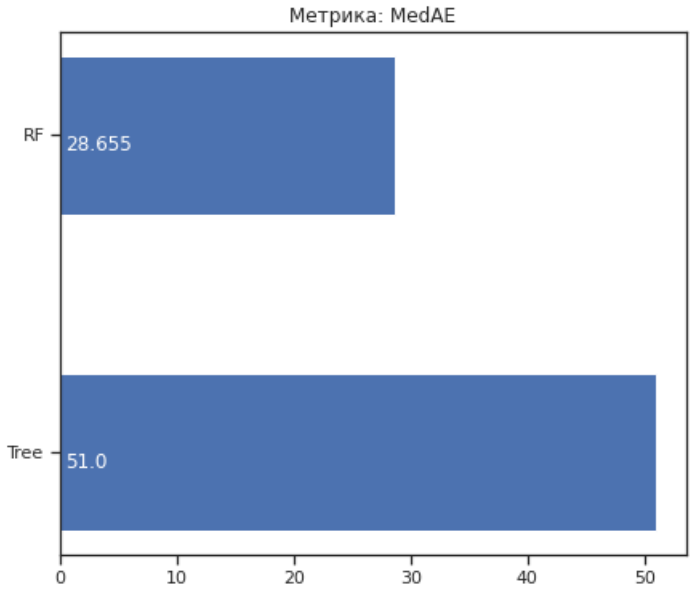
```
                        ascending=False, figsize=(7, 6))
```



Ансамбль - 802.45

In [85]:

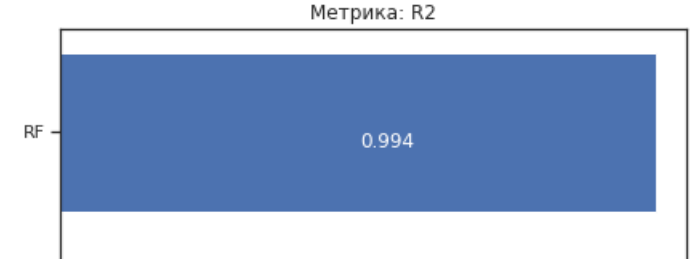
```
regrMetricLogger.plot('Метрика: ' + 'MedAE', 'MedAE',
                      ascending=False, figsize=(7, 6))
```

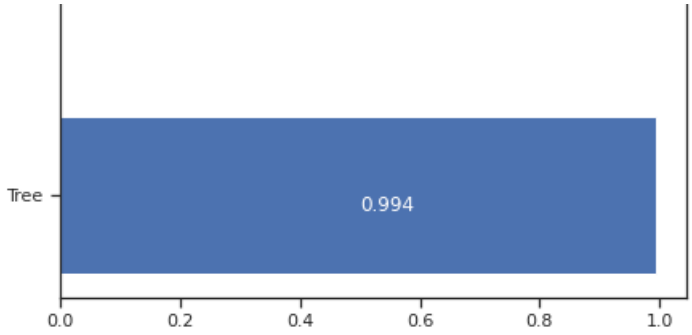


Ансамбль - 356.28

In [87]:

```
regrMetricLogger.plot('Метрика: ' + 'R2', 'R2',
                      ascending=True, figsize=(7, 6))
```





Вывод:

По возрастанию ошибки модели распределились следующим образом:

1. случайный лес
2. дерево решений
3. ансамблевая модель