Double-click (or enter) to edit

This notebooks presentes example usage Python SHAP library as part of Machine Model Interpretability usage. We use Airbnb Berlin data and trying to interpret prediction we had.

```
from google.colab import drive
drive.mount('/content/drive')
```

```
Mounted at /content/drive
```

```
%pip install optuna
```

```
Collecting optuna
  Downloading optuna-4.2.1-py3-none-any.whl.metadata (17 kB)
Collecting alembic>=1.5.0 (from optuna)
  Downloading alembic-1.15.2-py3-none-any.whl.metadata (7.3 kB)
Collecting colorlog (from optuna)
  Downloading colorlog-6.9.0-py3-none-any.whl.metadata (10 kB)
Requirement already satisfied: numpy in /usr/local/lib/python3.11/dist-packages (from optuna) (2.0.2)
Requirement already satisfied: packaging>=20.0 in /usr/local/lib/python3.11/dist-packages (from optuna) (24.2)
Requirement already satisfied: sqlalchemy>=1.4.2 in /usr/local/lib/python3.11/dist-packages (from optuna) (2.0.40)
Requirement already satisfied: tqdm in /usr/local/lib/python3.11/dist-packages (from optuna) (4.67.1)
Requirement already satisfied: PyYAML in /usr/local/lib/python3.11/dist-packages (from optuna) (6.0.2)
Requirement already satisfied: Mako in /usr/lib/python3/dist-packages (from alembic>=1.5.0->optuna) (1.1.3)
Requirement already satisfied: typing-extensions>=4.12 in /usr/local/lib/python3.11/dist-packages (from alembic>=1.5.0->optuna) (4.
Requirement already satisfied: greenlet>=1 in /usr/local/lib/python3.11/dist-packages (from sqlalchemy>=1.4.2->optuna) (3.1.1)
Downloading optuna-4.2.1-py3-none-any.whl (383 kB)
   ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 383.6/383.6 kB 6.7 MB/s eta 0:00:00
Downloading alembic-1.15.2-py3-none-any.whl (231 kB)
   ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 231.9/231.9 kB 11.1 MB/s eta 0:00:00
Downloading colorlog-6.9.0-py3-none-any.whl (11 kB)
Installing collected packages: colorlog, alembic, optuna
Successfully installed alembic-1.15.2 colorlog-6.9.0 optuna-4.2.1
```

```
%pip install plotly==4.14.3
```

```
Collecting plotly==4.14.3
  Downloading plotly-4.14.3-py2.py3-none-any.whl.metadata (7.6 kB)
Collecting retrying>=1.3.3 (from plotly==4.14.3)
  Downloading retrying-1.3.4-py3-none-any.whl.metadata (6.9 kB)
Requirement already satisfied: six in /usr/local/lib/python3.11/dist-packages (from plotly==4.14.3) (1.17.0)
Downloading plotly-4.14.3-py2.py3-none-any.whl (13.2 MB)
   ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 13.2/13.2 MB 45.8 MB/s eta 0:00:00
Downloading retrying-1.3.4-py3-none-any.whl (11 kB)
Installing collected packages: retrying, plotly
  Attempting uninstall: plotly
    Found existing installation: plotly 5.24.1
    Uninstalling plotly-5.24.1:
      Successfully uninstalled plotly-5.24.1
Successfully installed plotly-4.14.3 retrying-1.3.4
```

```
import pandas as pd # for data manipulation
import numpy as np  # fast n-dimensional arrays library
import statsmodels.formula.api as smf # for linear regresion
import seaborn as sns # for data visualization
import matplotlib.pyplot as plt # for data visualization
from sklearn import preprocessing # for preprocessing for LASSO algorithm
from sklearn.metrics import mean_squared_error # metric for comparing models
from sklearn import linear_model # for LASSO algorithm
import xgboost # for XGBoost algorithm
import shap # for visualization output from XGBoost
from PIL import Image # for images manipulation
```

```
# Use python engine for reading CSV
# See: https://www.shanelynn.ie/pandas-csv-error-error-tokenizing-data-c-error-eof-inside-string-starting-at-line/
data = pd.read_csv('/content/listings_berlin_11_2019.csv', encoding='utf-8', engine='python') # orginal berlin
```

```
# Preprocessing - cast price as float
data.price = data.price.apply(lambda x: x.replace("$", ""))
data.price = data.price.apply(lambda x: x.replace(",", ""))
data.price = data.price.astype("float")
```

```
# Enrich data by calculate zip code relation to price
# amenities_len -> value for comparing number of amenities across offerts
# zip_count -> number of offerts in close location
# zip_price -> average price for offerts in the same location
```

```
temp_zipcode = data.zipcode.copy()
data['zipcode2'] = temp_zipcode.str.replace("\D+", "", ).copy()
data.zipcode2.fillna(0, inplace=True)
x_count = data.groupby('zipcode2')['id'].nunique()
x_mean = data.groupby('zipcode2')['price'].mean()

x_count_dict = x_count.to_dict()
x_mean_dict = x_mean.to_dict()

a1 = np.zeros((len(data), 6))
print(a1)
for i in range(0,len(data)):
    val = data.zipcode2[i]
    a1[i][0] = data.id[i]
    a1[i][1] = x_count_dict[val]
    a1[i][2] = x_mean_dict[val]
    #a1[i][3] = val
    a1[i][4] = len(data.amenities[i])

#data['amenities_len'] = a1[:,3]
data['zipcode_count'] = a1[:,1]
data['zipcode_price'] = a1[:,2]
print(data.head())
```

```
                                      name  \
0  Berlin-Mitte Value! Quiet courtyard/very central
1                Prenzlauer Berg close to Mauerpark
2                   Fabulous Flat in great Location
3                  BerlinSpot Schöneberg near KaDeWe
4                   BrightRoom with sunny greenview!

                                             summary  \
0  Great location!  30 of 75 sq meters. This wood...
1                                                NaN
2  This beautiful first floor apartment  is situa...
3  First of all: I prefer short-notice bookings. ...
4  Cozy and large room in the beautiful district ...

                                               space  \
0  A+++ location! This „Einliegerwohnung“ is an e...
1  In the summertime we are spending most of our ...
2  1st floor (68m2) apartment on Kollwitzplatz/ P...
3  Your room is really big and has 26 sqm, is ver...
4  The BrightRoom is an approx. 20 sqm (215ft²), ...

                                         description experiences_offered  \
0  Great location!  30 of 75 sq meters. This wood...                none
1  In the summertime we are spending most of our ...                none
2  This beautiful first floor apartment  is situa...                none
3  First of all: I prefer short-notice bookings. ...                none
4  Cozy and large room in the beautiful district ...                none

                               neighborhood_overview  ... instant_bookable  \
0  It is located in the former East Berlin area o...  ...                f
1                                                NaN  ...                f
2  The neighbourhood is famous for its variety of...  ...                t
3  My flat is in the middle of West-Berlin, direc...  ...                f
4  Great neighborhood with plenty of Cafés, Baker...  ...                f

  is_business_travel_ready          cancellation_policy  \
0                        f  strict_14_with_grace_period
1                        f                     flexible
2                        f  strict_14_with_grace_period
3                        f  strict_14_with_grace_period
4                        f                     moderate

  require_guest_profile_picture require_guest_phone_verification  \
0                             f                                f
1                             f                                f
2                             f                                f
3                             f                                f
4                             f                                f

   calculated_host_listings_count  reviews_per_month zipcode2  zipcode_count  \
0                               4               3.76    10119          537.0
1                               1               1.42    10437          703.0
2                               1               1.25    10405          585.0
3                               1               0.39    10777          182.0
4                               1               1.75    10437          703.0

   zipcode_price
0      88.536313
```

```
# Preprocessing - get rid of outliers
print("99.7% properties have a price lower than {0: .2f}".format(np.percentile(data.price, 99.7)))
data = data[(data.price <= np.percentile(data.price, 99.7)) & (data.price > 0)]
```

```
99.7% properties have a price lower than  550.00
```

```
cols = ['price', 'host_is_superhost', 'bedrooms', 'number_of_reviews', 'review_scores_rating', 'beds', 'bathrooms']
cols2 = ['minimum_nights', 'zipcode_count', 'zipcode_price']
cols = cols + cols2
cols
```

```
['price',
 'host_is_superhost',
 'bedrooms',
 'number_of_reviews',
 'review_scores_rating',
 'beds',
 'bathrooms',
 'minimum_nights',
 'zipcode_count',
 'zipcode_price']
```

```
# Preprocessing - replace NaN values with mean from column
# With checking before and after replacement

print(data[cols].isna().sum())
#data.fillna((data[cols].mean()), inplace=True)
print(data[cols].isna().sum())
```

```
price                      0
host_is_superhost         25
bedrooms                  18
number_of_reviews          0
review_scores_rating    4349
beds                      39
bathrooms                 32
minimum_nights             0
zipcode_count              0
zipcode_price              0
dtype: int64
price                      0
host_is_superhost         25
bedrooms                  18
number_of_reviews          0
review_scores_rating    4349
beds                      39
bathrooms                 32
minimum_nights             0
zipcode_count              0
zipcode_price              0
dtype: int64
```

```
# Convert remaining columns to float type
data['number_of_reviews'] = data['number_of_reviews'].astype(float)
data['accommodates'] = data['accommodates'].astype(float)
#data['amenities_len'] = data['amenities_len'].astype(float)
data['minimum_nights'] = data['minimum_nights'].astype(float)


data_subset = data

data = pd.DataFrame(data_subset)

# Extract target with their names into a pd.Series object with name MEDV
target = pd.Series(data_subset['price'], name="Price")

from sklearn.model_selection import train_test_split
train_data, test_data, train_targets, test_targets = train_test_split(
    data, target, test_size=0.2
)

print(train_data.shape)
print(test_data.shape)
print(train_targets.shape)
print(test_targets.shape)
```

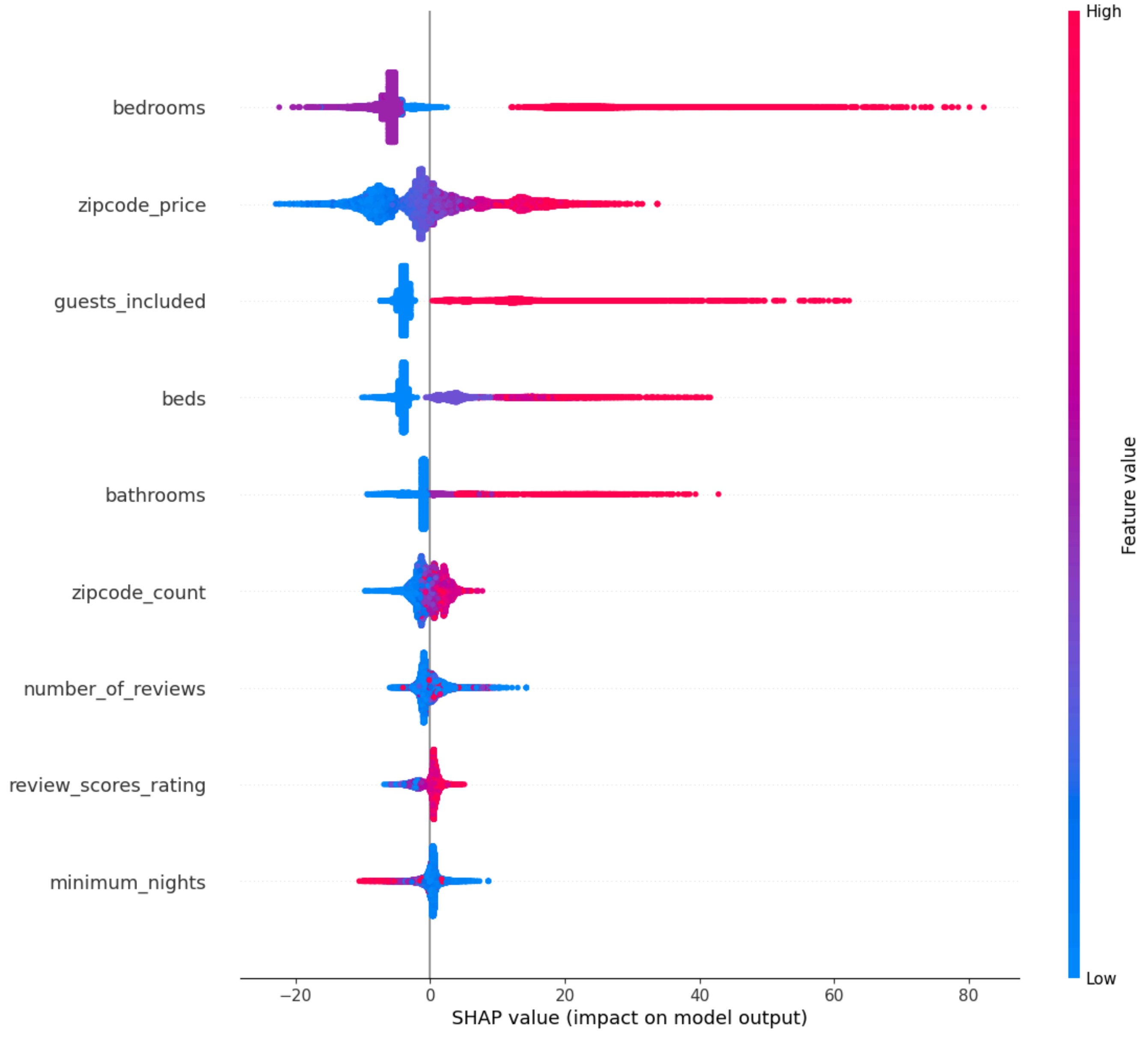
```
(17983, 99)
(4496, 99)
(17983,)
(4496,)
```

```
import requests
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns
import matplotlib.cm as cmap
import math
import numpy as np

from sklearn.ensemble import RandomForestRegressor
from sklearn.model_selection import train_test_split
from sklearn.metrics import mean_squared_error
from sklearn.preprocessing import StandardScaler, RobustScaler
from sklearn.pipeline import make_pipeline

import optuna
from optuna.visualization import plot_contour
from optuna.visualization import plot_edf
from optuna.visualization import plot_optimization_history
from optuna.visualization import plot_parallel_coordinate
from optuna.visualization import plot_param_importances
from optuna.visualization import plot_slice

import shap
from collections import namedtuple


class DataHandling:

    def __init__(self, file_name, columns):
        self.file_name = file_name
        self.columns = columns
        self.day_map = {'mon':0,'tue':1,'wed':2,'thu':3,'fri':4,'sat':5,'sun':6}

    def acquire_data(self, url):
        response = requests.get(url, stream=True)
        with open(self.file_name, "wb") as data:
            data.write(response.content)
        response.close()

    def _load_data(self):
        return pd.read_csv(self.file_name)

    @staticmethod
    def calculate_heat_index(t, h):
        f = ((t * 9/5) + 32)
        t2 = math.pow(f, 2)
        h2 = math.pow(h, 2)

        c = [ 0.363445176, 0.988622465, 4.777114035, -0.114037667, -0.000850208, -0.020716198, 0.000687678, 0.000274954, 0]

        heat_index =  c[0] + (c[1]*f) + (c[2]*h) + (c[3]*f*h) + (c[4]*t2) + (c[5]*h2) + (c[6]*t2*h) + (c[7]*f*h2) + (c[8]*t2*h2)

        return ((heat_index - 32) * 5/9)

    def get_fire_data(self):
        df = self._load_data()
        df.columns = self.columns
        df['month'] = pd.to_datetime(df.month, format='%b').dt.month
        df['day'] = df['day'].apply(lambda x: self.day_map[x])
        df['heat_index'] = df.apply(lambda x: self.calculate_heat_index(x['temperature'], x['relative_humidity']), axis=1)
        return df



class DataValidation:

    def __init__(self, data):
        self.data = data

    def plot_correlation(self):
        corr = self.data.corr()
        with plt.style.context('seaborn-v0_8'):
            fig, ax = plt.subplots(figsize=(14, 12))
            sns.heatmap(corr, ax=ax, cmap=cmap.copper_r)

    def plot_pairwise(self):
        pd.plotting.scatter_matrix(self.data, figsize=(24,24))

    def plot_hist(self, feature, bins):
        with plt.style.context('seaborn-v0_8'):
            fig, ax = plt.subplots(figsize=(14, 10))
            plt.hist(self.data[feature], bins=bins)

    def plot_area_map(self, x, y, column):
        grouped = self.data.groupby([x, y])[column].mean().reset_index()
        pivoted = grouped.pivot(index=y, columns=x, values=column)
        with plt.style.context('seaborn-v0_8'):
            fig, ax = plt.subplots(figsize=(14,12))
            sns.heatmap(pivoted, cmap=cmap.copper_r, ax=ax)
            ax.invert_yaxis()


class ModelScoring:

    def __init__(self, y_test, y_pred, param_count, algorithm):
        self.y_test = y_test
        self.y_pred = y_pred
        self.n = len(y_test)
        self.param_count = param_count
        self.algorithm = algorithm

    def _mse_calc(self):
        return mean_squared_error(self.y_test, self.y_pred)

    def _bic(self):
        return self.n * np.log(self._mse_calc()) + self.param_count * np.log(self.n)

    def _rmse(self):
        return np.sqrt(self._mse_calc())

    def evaluate(self):
        return {'rmse': self._rmse(), 'bic': self._bic()}[self.algorithm]


class DataPrep:

    def __init__(self, data, label, test_size=0.3):
        self.data = data
        self.label = label
        self.test_size = test_size

    def split_features(self):
        Data = namedtuple('Data', 'X y')
        X = self.data.drop([self.label], axis=1)
        y = self.data[self.label]
        return Data(X, y)

    def train_test_split(self, stratify_column):
        TrainTest = namedtuple('Data', 'X_train X_test y_train y_test X y')
        split_data = self.split_features()
        X_train, X_test, y_train, y_test = train_test_split(split_data.X,
                                                            split_data.y,
                                                            #stratify=split_data.X[stratify_column],
                                                            test_size=self.test_size
                                                           )
        return TrainTest(X_train, X_test, y_train, y_test, split_data.X, split_data.y)



class ImageHandling:

    def __init__(self, fig, name):
        self.fig = fig
        self.name = name

    def _resize_plot(self):
        self.fig = plt.gcf()
        self.fig.set_size_inches(12, 12)

    def save_base(self):
        self.fig.savefig(f"{self.name}.png", format='png', bbox_inches='tight')
        self.fig.savefig(f"{self.name}.svg", format='svg', bbox_inches='tight')

    def save_plt(self):
        self._resize_plot()
        self.save_base()

    def save_js(self):
        shap.save_html(self.name, self.fig)
        return self.fig

class ShapConstructor:

    def __init__(self, base_values, data, values, feature_names, shape):
        self.base_values = base_values
        self.data = data
        self.values = values
        self.feature_names = feature_names
        self.shape = shape

class ShapObject:
    def __init__(self, model, data):
        self.model = model
        self.data = data
        self.exp = self.generate_explainer(self.model, self.data)
        shap.initjs()

    @classmethod
    def generate_explainer(self, model, data):
        Explain = namedtuple('Explain', 'shap_values explainer max_row')
        explainer = shap.Explainer(model)
        explainer.expected_value = explainer.expected_value[0]
        shap_values = explainer(data)
        max_row = len(shap_values.values)
        return Explain(shap_values, explainer, max_row)

    def build(self, row=0):
        return ShapConstructor(base_values = self.exp.shap_values[0][0].base_values,
                               values = self.exp.shap_values[row].values,
                               feature_names = self.data.columns,
                               data = self.exp.shap_values[0].data,
                               shape = self.exp.shap_values[0].shape)

    def validate_row(self, row):
        assert row < self.exp.max_row, f"The row value: {row} is invalid. Data has only {self.exp.max_row} rows."

    def plot_waterfall(self, row=0):
        plt.clf()
        self.validate_row(row)
        #fig = shap.waterfall_plot(self.build(row), show=False, max_display=15)
        self.exp = self.generate_explainer(self.model,row)
        fig = shap.waterfall_plot(self.exp)
        ImageHandling(fig, f"summary_{row}").save_plt()
        return fig

    def plot_summary(self):
        fig = shap.plots.beeswarm(self.exp.shap_values, show=False, max_display=15)
        ImageHandling(fig, "summary").save_plt()

    def plot_force_by_row(self, row=0):
        plt.clf()
        self.validate_row(row)
        fig = shap.force_plot(self.exp.explainer.expected_value,
                               self.exp.shap_values.values[row,:],
                               self.data.iloc[row,:],
                               show=False,
                               matplotlib=True
                              )
        ImageHandling(fig, f"force_plot_{row}").save_base()

    def plot_full_force(self):
        fig = shap.plots.force(self.exp.explainer.expected_value,
                               self.exp.shap_values.values,
                               show=False
                              )
        final_fig = ImageHandling(fig, "full_force_plot.htm").save_js()
        return final_fig

    def plot_shap_importances(self):
        fig = shap.plots.bar(self.exp.shap_values, show=False, max_display=15)
        ImageHandling(fig, "shap_importances").save_plt()

    def plot_scatter(self, feature):
        fig = shap.plots.scatter(self.exp.shap_values[:, feature], color=self.exp.shap_values, show=False)
        ImageHandling(fig, f"scatter_{feature}").save_plt()



class RandomForestTuning:

    def __init__(self, data, label, stratify_column, trials, test_size=0.3, metric='rmse'):
        self.data = data
        self.label = label
        self.stratify_column = stratify_column
        self.trials = trials
        self.test_size = test_size
        self.metric = metric

    @staticmethod
    def _random_forest_model(**kwargs):
        model = RandomForestRegressor(n_estimators=kwargs['n_estimators'],
                                      max_depth=kwargs['max_depth'],
                                      min_samples_split=kwargs['min_samples_split'],
                                      min_samples_leaf=kwargs['min_samples_leaf'],
                                      max_leaf_nodes=kwargs['max_leaf_nodes'],
                                      min_impurity_decrease=kwargs['min_impurity_decrease'],
                                      max_features=kwargs['max_features'],
                                      n_jobs=-1
                                     )
        return model

    def _run_trial(self, trial):
        splits = DataPrep(self.data, self.label, self.test_size).train_test_split(self.stratify_column)
        params = {
                 'n_estimators': trial.suggest_int("n_estimators", 50, 2000, 10),
                 'max_depth': trial.suggest_int("max_depth", 2, 24, 1),
                 'min_samples_split': trial.suggest_int("min_samples_split", 2, 25, 1),
                 'min_samples_leaf': trial.suggest_int("min_samples_leaf", 1, 20, 1),
                 'max_leaf_nodes': trial.suggest_int("max_leaf_nodes", 4, 400, 1),
                 'min_impurity_decrease': trial.suggest_loguniform("min_impurity_decrease", 1e-22, 1e-3),
                 'max_features': trial.suggest_categorical("max_features", ['sqrt', 'log2'])
                }

        model = self._random_forest_model(**params).fit(splits.X_train, splits.y_train)

        return ModelScoring(splits.y_test, model.predict(splits.X_test), len(params.keys()), self.metric).evaluate()

    def run(self):
        trial = optuna.create_study(direction='minimize')
        trial.optimize(self._run_trial, self.trials)
        return trial

class RandomForestBuilder:

    def __init__(self, trial, cls):
        self.trial = trial
        self.cls = cls

    def _extract_best_gen_model(self):
        Extract = namedtuple('Extract', 'model X y')
        full_data = DataPrep(self.cls.data,
                             self.cls.label,
                             self.cls.test_size).split_features()
        best_params = self.trial.best_params

        model = self.cls._random_forest_model(**best_params)
        return Extract(model, full_data.X, full_data.y)

    def extract_best_and_build(self):
        ModelData = namedtuple('ModelData', 'model X y')
        model = self._extract_best_gen_model()
        final_model = model.model.fit(model.X, model.y)
        return ModelData(final_model, model.X, model.y)


variables = ['bedrooms','beds','bathrooms','zipcode_count','zipcode_price','number_of_reviews','review_scores_rating', 'guests_included
data.fillna((data[variables + ['price']].mean()), inplace=True)

data_subset = data.loc[:, variables + ['price']]
random_forest_tune = RandomForestTuning(data_subset, 'price', 'minimum_nights', 200, 0.15, 'rmse')
trial_rf = random_forest_tune.run()
final_rf_model = RandomForestBuilder(trial_rf, random_forest_tune).extract_best_and_build()
```

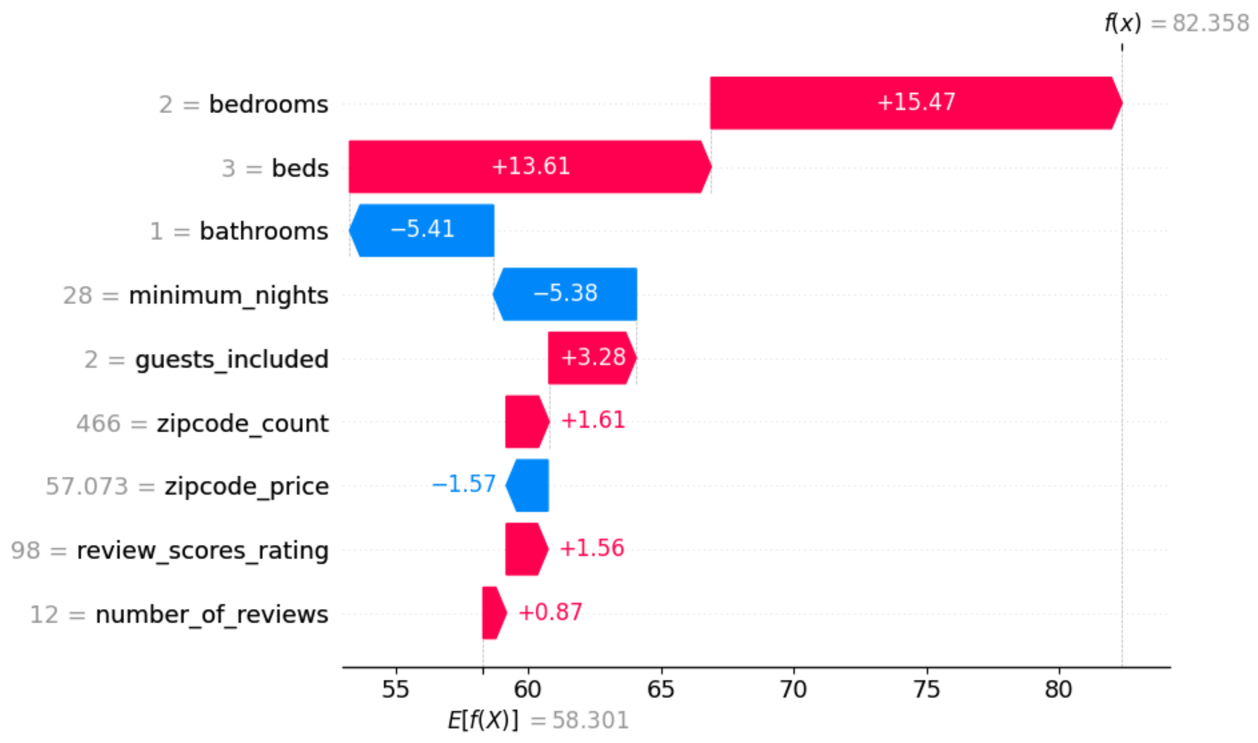
```
[I 2025-04-08 07:46:37,192] A new study created in memory with name: no-name-0c0ede37-d6ea-462e-b13e-25c9f9efed73
<ipython-input-23-037048dbabe2>:27: FutureWarning: suggest_int() got {'step'} as positional arguments but they were expected to be
  'n_estimators': trial.suggest_int("n_estimators", 50, 2000, 10),
<ipython-input-23-037048dbabe2>:28: FutureWarning: suggest_int() got {'step'} as positional arguments but they were expected to be
  'max_depth': trial.suggest_int("max_depth", 2, 24, 1),
<ipython-input-23-037048dbabe2>:29: FutureWarning: suggest_int() got {'step'} as positional arguments but they were expected to be
  'min_samples_split': trial.suggest_int("min_samples_split", 2, 25, 1),
<ipython-input-23-037048dbabe2>:30: FutureWarning: suggest_int() got {'step'} as positional arguments but they were expected to be
  'min_samples_leaf': trial.suggest_int("min_samples_leaf", 1, 20, 1),
<ipython-input-23-037048dbabe2>:31: FutureWarning: suggest_int() got {'step'} as positional arguments but they were expected to be
  'max_leaf_nodes': trial.suggest_int("max_leaf_nodes", 4, 400, 1),
<ipython-input-23-037048dbabe2>:32: FutureWarning: suggest_loguniform has been deprecated in v3.0.0. This feature will be removed
  'min_impurity_decrease': trial.suggest_loguniform("min_impurity_decrease", 1e-22, 1e-3),
[I 2025-04-08 07:46:43,551] Trial 0 finished with value: 34.957045357852465 and parameters: {'n_estimators': 600, 'max_depth': 10,
<ipython-input-23-037048dbabe2>:27: FutureWarning: suggest_int() got {'step'} as positional arguments but they were expected to be
  'n_estimators': trial.suggest_int("n_estimators", 50, 2000, 10),
<ipython-input-23-037048dbabe2>:28: FutureWarning: suggest_int() got {'step'} as positional arguments but they were expected to be
  'max_depth': trial.suggest_int("max_depth", 2, 24, 1),
<ipython-input-23-037048dbabe2>:29: FutureWarning: suggest_int() got {'step'} as positional arguments but they were expected to be
  'min_samples_split': trial.suggest_int("min_samples_split", 2, 25, 1),
<ipython-input-23-037048dbabe2>:30: FutureWarning: suggest_int() got {'step'} as positional arguments but they were expected to be
  'min_samples_leaf': trial.suggest_int("min_samples_leaf", 1, 20, 1),
<ipython-input-23-037048dbabe2>:31: FutureWarning: suggest_int() got {'step'} as positional arguments but they were expected to be
  'max_leaf_nodes': trial.suggest_int("max_leaf_nodes", 4, 400, 1),
<ipython-input-23-037048dbabe2>:32: FutureWarning: suggest_loguniform has been deprecated in v3.0.0. This feature will be removed
```

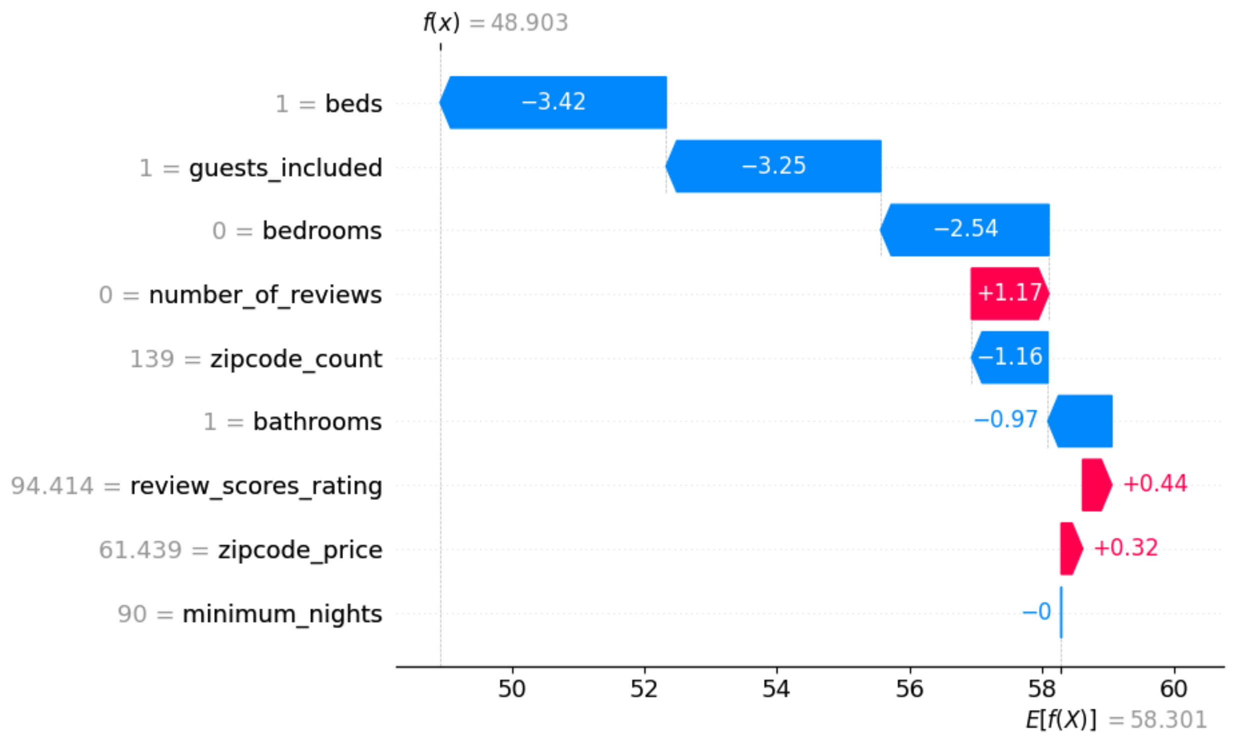
```
  'min_impurity_decrease': trial.suggest_loguniform("min_impurity_decrease", 1e-22, 1e-3),
[I 2025-04-08 07:47:06,689] Trial 1 finished with value: 32.490470689995426 and parameters: {'n_estimators': 1660, 'max_depth': 23
<ipython-input-23-037048dbabe2>:27: FutureWarning: suggest_int() got {'step'} as positional arguments but they were expected to be
  'n_estimators': trial.suggest_int("n_estimators", 50, 2000, 10),
<ipython-input-23-037048dbabe2>:28: FutureWarning: suggest_int() got {'step'} as positional arguments but they were expected to be
  'max_depth': trial.suggest_int("max_depth", 2, 24, 1),
<ipython-input-23-037048dbabe2>:29: FutureWarning: suggest_int() got {'step'} as positional arguments but they were expected to be
  'min_samples_split': trial.suggest_int("min_samples_split", 2, 25, 1),
<ipython-input-23-037048dbabe2>:30: FutureWarning: suggest_int() got {'step'} as positional arguments but they were expected to be
  'min_samples_leaf': trial.suggest_int("min_samples_leaf", 1, 20, 1),
<ipython-input-23-037048dbabe2>:31: FutureWarning: suggest_int() got {'step'} as positional arguments but they were expected to be
  'max_leaf_nodes': trial.suggest_int("max_leaf_nodes", 4, 400, 1),
<ipython-input-23-037048dbabe2>:32: FutureWarning: suggest_loguniform has been deprecated in v3.0.0. This feature will be removed
  'min_impurity_decrease': trial.suggest_loguniform("min_impurity_decrease", 1e-22, 1e-3),
[I 2025-04-08 07:47:17,000] Trial 2 finished with value: 32.154048474682675 and parameters: {'n_estimators': 1010, 'max_depth': 9,
<ipython-input-23-037048dbabe2>:27: FutureWarning: suggest_int() got {'step'} as positional arguments but they were expected to be
  'n_estimators': trial.suggest_int("n_estimators", 50, 2000, 10),
<ipython-input-23-037048dbabe2>:28: FutureWarning: suggest_int() got {'step'} as positional arguments but they were expected to be
  'max_depth': trial.suggest_int("max_depth", 2, 24, 1),
<ipython-input-23-037048dbabe2>:29: FutureWarning: suggest_int() got {'step'} as positional arguments but they were expected to be
  'min_samples_split': trial.suggest_int("min_samples_split", 2, 25, 1),
<ipython-input-23-037048dbabe2>:30: FutureWarning: suggest_int() got {'step'} as positional arguments but they were expected to be
  'min_samples_leaf': trial.suggest_int("min_samples_leaf", 1, 20, 1),
<ipython-input-23-037048dbabe2>:31: FutureWarning: suggest_int() got {'step'} as positional arguments but they were expected to be
  'max_leaf_nodes': trial.suggest_int("max_leaf_nodes", 4, 400, 1),
<ipython-input-23-037048dbabe2>:32: FutureWarning: suggest_loguniform has been deprecated in v3.0.0. This feature will be removed
  'min_impurity_decrease': trial.suggest_loguniform("min_impurity_decrease", 1e-22, 1e-3),
[I 2025-04-08 07:47:20,859] Trial 3 finished with value: 33.810127448034386 and parameters: {'n_estimators': 230, 'max_depth': 12,
<ipython-input-23-037048dbabe2>:27: FutureWarning: suggest_int() got {'step'} as positional arguments but they were expected to be
  'n_estimators': trial.suggest_int("n_estimators", 50, 2000, 10),
<ipython-input-23-037048dbabe2>:28: FutureWarning: suggest_int() got {'step'} as positional arguments but they were expected to be
  'max_depth': trial.suggest_int("max_depth", 2, 24, 1),
```

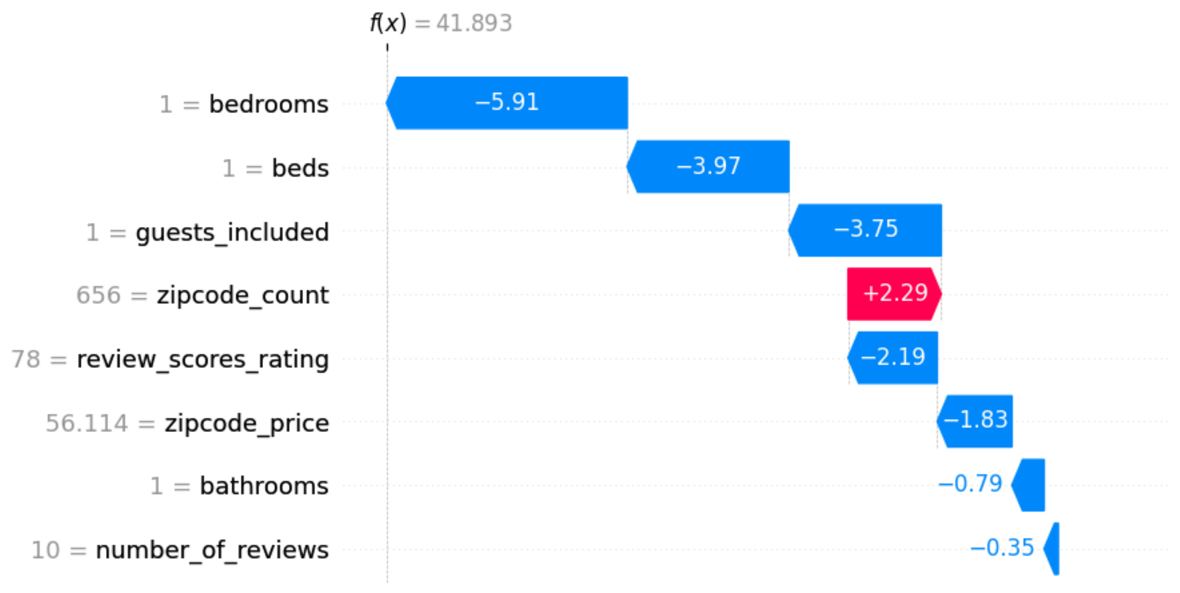
```
shap_obj = ShapObject(final_rf_model.model, final_rf_model.X)
shap_obj.plot_summary()
```

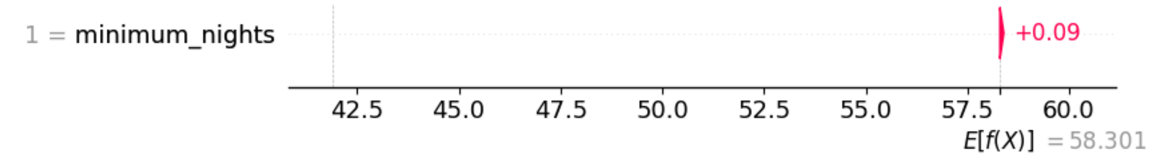


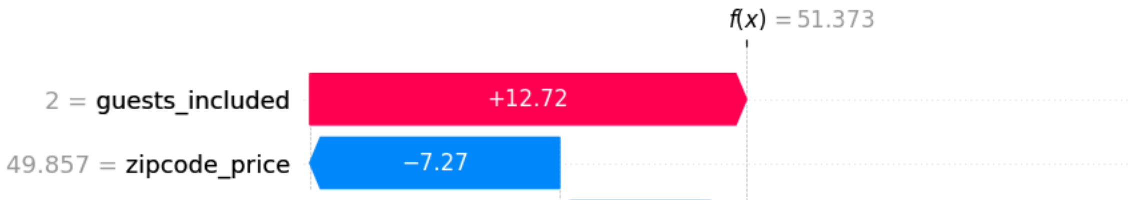
```
interesting_rows = data_subset.nlargest(5, 'price').reset_index()['index'].values
#print(interesting_rows)
waterfalls = [shap.plots.waterfall(shap_obj.exp[0][x]) for x in interesting_rows]
```


f(x) = 82.358
2 = bedrooms
+15.47
3 = beds
+13.61
1 = bathrooms
−5.41
28 = minimum_nights
−5.38
2 = guests_included
+3.28
466 = zipcode_count
+1.61
57.073 = zipcode_price
−1.57
98 = review_scores_rating
+1.56
12 = number_of_reviews
+0.87
55
60
65
70
75
80
E[f(X)] = 58.301


f(x) = 48.903
1 = beds
−3.42
1 = guests_included
−3.25
0 = bedrooms
−2.54
0 = number_of_reviews
+1.17
139 = zipcode_count
−1.16
1 = bathrooms
−0.97
94.414 = review_scores_rating
+0.44
61.439 = zipcode_price
+0.32
90 = minimum_nights
−0
50
52
54
56
58
60
E[f(X)] = 58.301


f(x) = 41.893
1 = bedrooms
−5.91
1 = beds
−3.97
1 = guests_included
−3.75
656 = zipcode_count
+2.29
78 = review_scores_rating
−2.19
56.114 = zipcode_price
−1.83
1 = bathrooms
−0.79
10 = number_of_reviews
−0.35


1 = minimum_nights
+0.09
42.5
45.0
47.5
50.0
52.5
55.0
57.5
60.0
E[f(X)] = 58.301


f(x) = 51.373
2 = guests_included
+12.72
49.857 = zipcode_price
−7.27