ex3_sol

May 9, 2018

1 Exercise 3 - Input Scaling and Regularization

Part of this exercise is taken from http://scikit-learn.org/stable/auto_examples/preprocessing/plot_all_scaling.h

2 Table of Contents

3 Loading the dataset

3.0.1 Task 1: For this exercise we want to use the california housing dataset from scikit learn. Prepare the dataset in the following way:

- Load the dataset (`fetch_california_housing`), inspect it and create a pandas `DataFrame`.
- What kind of problem is this?
- How many example and how many features do we have? What are the features? What is the target?
- How does the target look like?
- Make 2D scatter plots of all input features, where the z-axis shows the target dependence.
- What do you observe?

```
In [1]: from sklearn.datasets import fetch_california_housing

        housing = fetch_california_housing()
        print(housing['DESCR'])
```

```
California housing dataset.

The original database is available from StatLib

    http://lib.stat.cmu.edu/datasets/

The data contains 20,640 observations on 9 variables.
```

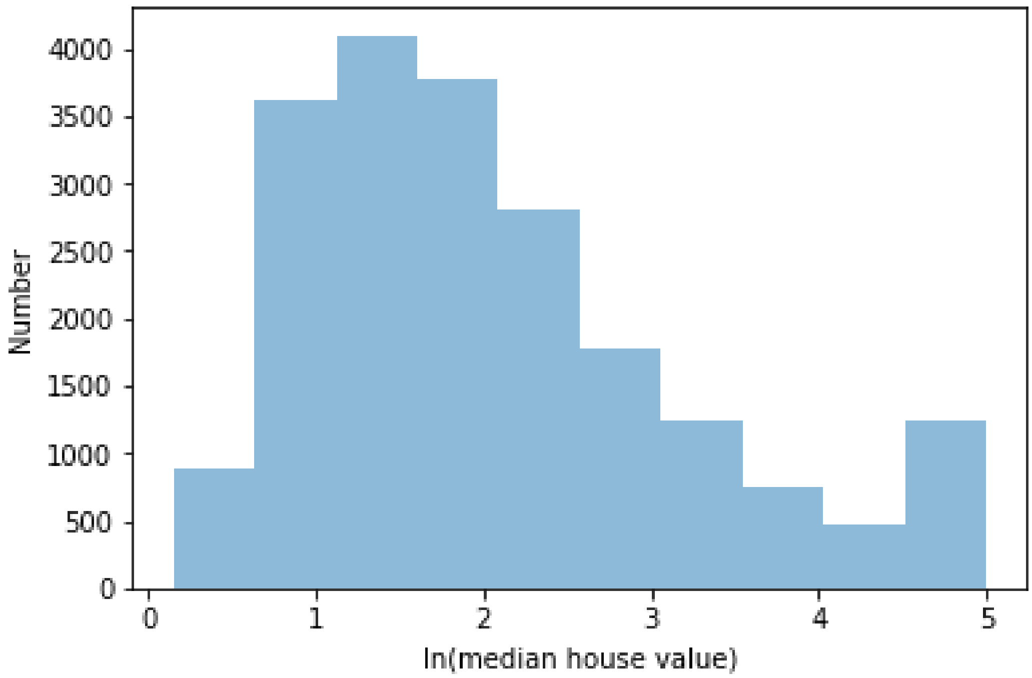
```
This dataset contains the average house value as target variable
and the following input variables (features): average income,
housing average age, average rooms, average bedrooms, population,
average occupation, latitude, and longitude in that order.

References
----------

Pace, R. Kelley and Ronald Barry, Sparse Spatial Autoregressions,
Statistics and Probability Letters, 33 (1997) 291-297.
```

In [2]:
```python
import pandas as pd

df = pd.DataFrame(housing.data, columns=housing.feature_names)
df.head(10)
```

Out[2]:
```
   MedInc  HouseAge  AveRooms  AveBedrms  Population  AveOccup  Latitude  \
0  8.3252      41.0  6.984127   1.023810       322.0  2.555556     37.88
1  8.3014      21.0  6.238137   0.971880      2401.0  2.109842     37.86
2  7.2574      52.0  8.288136   1.073446       496.0  2.802260     37.85
3  5.6431      52.0  5.817352   1.073059       558.0  2.547945     37.85
4  3.8462      52.0  6.281853   1.081081       565.0  2.181467     37.85
5  4.0368      52.0  4.761658   1.103627       413.0  2.139896     37.85
6  3.6591      52.0  4.931907   0.951362      1094.0  2.128405     37.84
7  3.1200      52.0  4.797527   1.061824      1157.0  1.788253     37.84
8  2.0804      42.0  4.294118   1.117647      1206.0  2.026891     37.84
9  3.6912      52.0  4.970588   0.990196      1551.0  2.172269     37.84

   Longitude
0    -122.23
1    -122.22
2    -122.24
3    -122.25
4    -122.25
5    -122.25
6    -122.25
7    -122.25
8    -122.26
9    -122.25
```

In [3]:
```python
%matplotlib inline
import matplotlib.pyplot as plt
plt.hist(housing.target, alpha=0.5)
plt.xlabel('ln(median house value)')
plt.ylabel('Number')
```

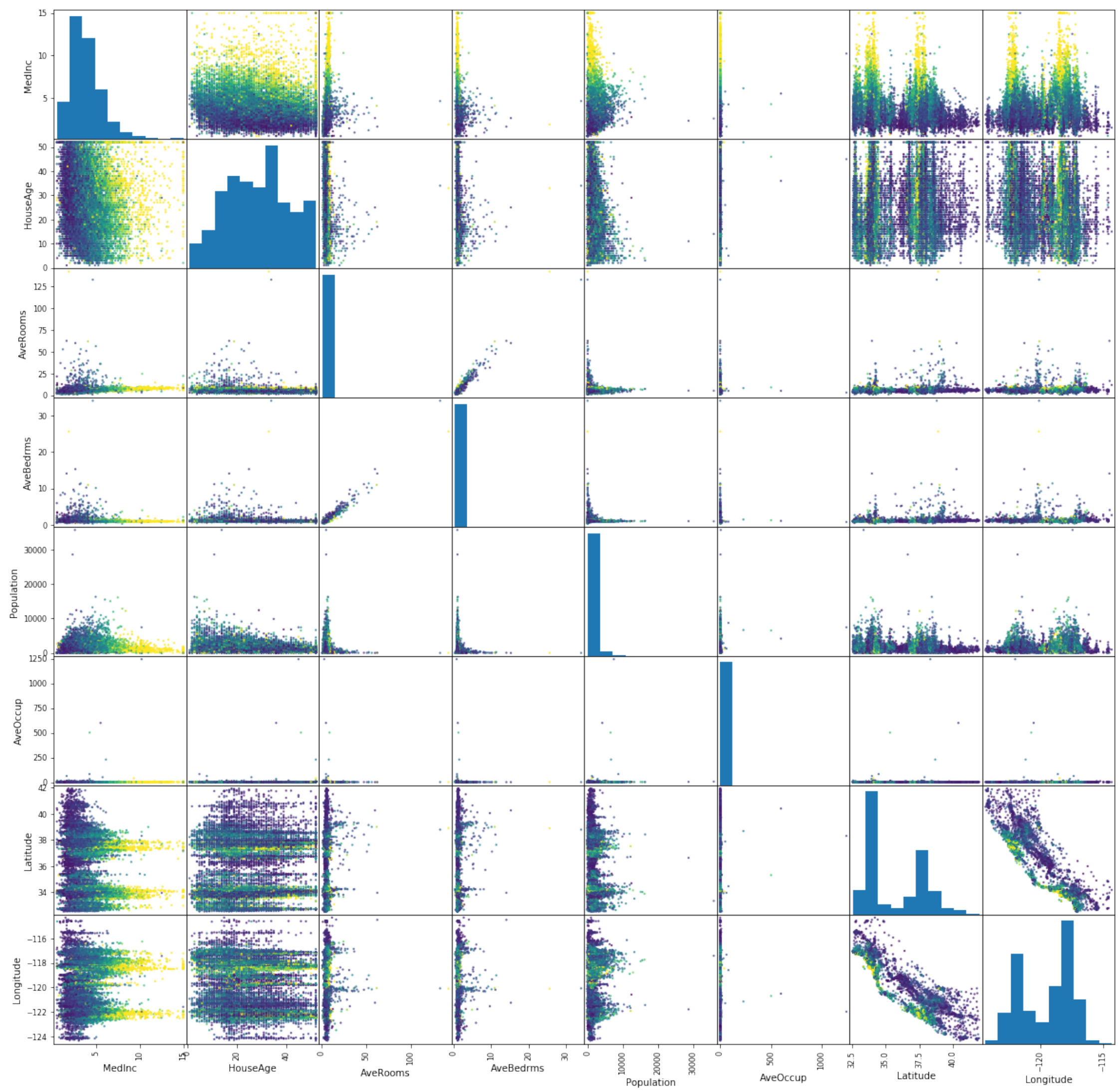
```
Out[3]: Text(0,0.5,u'Number')
```




```
In [4]: df.shape
```

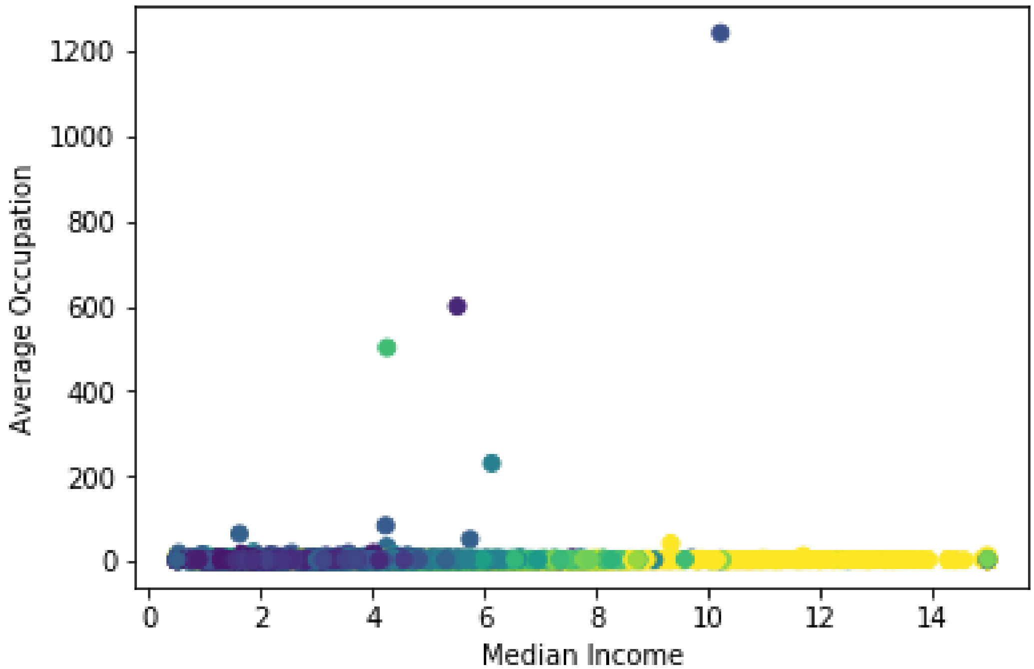
```
Out[4]: (20640, 8)
```

```
In [5]: from pandas.plotting import scatter_matrix
        scatter_matrix(df, c=housing.target, alpha=0.8, figsize=(20, 20), s=20)
        plt.show()
```



4 Comparison of different input scaling

```
In [6]: plt.scatter(df['MedInc'], df['AveOccup'], c=housing.target)
        plt.xlabel('Median Income')
        plt.ylabel('Average Occupation')

Out[6]: Text(0,0.5,u'Average Occupation')
```



Feature 0 (median income in a block) and feature 5 (number of households) of the California housing dataset have very different scales and contain some very large outliers. These two characteristics lead to difficulties to visualize the data and, more importantly, they can degrade the predictive performance of many machine learning algorithms. Unscaled data can also slow down or even prevent the convergence of many gradient-based estimators.

Indeed many estimators are designed with the assumption that each feature takes values close to zero or more importantly that all features vary on comparable scales. In particular, metric-based and gradient-based estimators often assume approximately standardized data (centered features with unit variances). A notable exception are decision tree-based estimators that are robust to arbitrary scaling of the data.

This example uses different scalers, transformers, and normalizers to bring the data within a pre-defined range.

Scalers are linear (or more precisely affine) transformers and differ from each other in the way to estimate the parameters used to shift and scale each feature.

QuantileTransformer provides a non-linear transformation in which distances between marginal outliers and inliers are shrunk.

Unlike the previous transformations, normalization refers to a per sample transformation instead of a per feature transformation.

4.1 Scaling the target

```
In [7]: housing.target
```

```
Out[7]: array([ 4.526,  3.585,  3.521, ...,  0.923,  0.847,  0.894])
```

It often makes sense to scale the target of a regression to something between 0 and 1, because that way you can use activation functions in the output layer which map to that range. If you use functions like sigmoid in the output layer, this keeps the backpropagated error within limits, unlike the case of unbounded linear activation functions. You could even scale to ranges like [0.3, 0.7] in order to focus on the almost linear-part of the sigmoid function. In the following we will scale the target between 0 and 1 also for plotting reasons. We will use the minmax_scale for that

```
In [8]: from sklearn.preprocessing import minmax_scale
        y_full=housing.target
        y = minmax_scale(y_full, feature_range=(0, 1))
        y
```

```
Out[8]: array([ 0.90226638,  0.70824656,  0.69505074, ...,  0.15938285,
                0.14371281,  0.15340349])
```

4.2 Scaling the input

We will focus in the following on the median income [0] and number of households [5] scatter plot and how different scalings impact their range.

```
In [9]: X = housing.data[:, [0, 5]]
```

In the following, I have taken the scaling and plotting code from http://scikit-learn.org/stable/auto_examples/preprocessing/plot_all_scaling.html#results.

You don't need to understand how the scaling and plotting is done for now, but the purpose is mainly to demonstrate how different scalers impact your input

```
In [10]: # Author:  Raghav RV <rvraghav93@gmail.com>
         #          Guillaume Lemaitre <g.lemaitre58@gmail.com>
         #          Thomas Unterthiner
         # License: BSD 3 clause

         import numpy as np

         import matplotlib as mpl
         from matplotlib import pyplot as plt
         from matplotlib import cm

         from sklearn.preprocessing import MinMaxScaler
         from sklearn.preprocessing import MaxAbsScaler
         from sklearn.preprocessing import StandardScaler
         from sklearn.preprocessing import RobustScaler
         from sklearn.preprocessing import Normalizer
         from sklearn.preprocessing.data import QuantileTransformer

         distributions = [
             ('Unscaled data', X),
             ('Data after standard scaling',
                 StandardScaler().fit_transform(X)),
```

```
            ('Data after min-max scaling',
                MinMaxScaler().fit_transform(X)),
            ('Data after max-abs scaling',
                MaxAbsScaler().fit_transform(X)),
            ('Data after robust scaling',
                RobustScaler(quantile_range=(25, 75)).fit_transform(X)),
            ('Data after quantile transformation (uniform pdf)',
                QuantileTransformer(output_distribution='uniform')
                .fit_transform(X)),
            ('Data after quantile transformation (gaussian pdf)',
                QuantileTransformer(output_distribution='normal')
                .fit_transform(X)),
            ('Data after sample-wise L2 normalizing',
                Normalizer().fit_transform(X))
        ]
```

```
In [11]: def create_axes(title, figsize=(16, 6)):
             fig = plt.figure(figsize=figsize)
             fig.suptitle(title)

             # define the axis for the first plot
             left, width = 0.1, 0.22
             bottom, height = 0.1, 0.7
             bottom_h = height + 0.15
             left_h = left + width + 0.02

             rect_scatter = [left, bottom, width, height]
             rect_histx = [left, bottom_h, width, 0.1]
             rect_histy = [left_h, bottom, 0.05, height]

             ax_scatter = plt.axes(rect_scatter)
             ax_histx = plt.axes(rect_histx)
             ax_histy = plt.axes(rect_histy)

             # define the axis for the zoomed-in plot
             left = width + left + 0.2
             left_h = left + width + 0.02

             rect_scatter = [left, bottom, width, height]
             rect_histx = [left, bottom_h, width, 0.1]
             rect_histy = [left_h, bottom, 0.05, height]

             ax_scatter_zoom = plt.axes(rect_scatter)
             ax_histx_zoom = plt.axes(rect_histx)
             ax_histy_zoom = plt.axes(rect_histy)

             # define the axis for the colorbar
             left, width = width + left + 0.13, 0.01
```

```
    rect_colorbar = [left, bottom, width, height]
    ax_colorbar = plt.axes(rect_colorbar)

    return ((ax_scatter, ax_histy, ax_histx),
            (ax_scatter_zoom, ax_histy_zoom, ax_histx_zoom),
            ax_colorbar)


def plot_distribution(axes, X, y, hist_nbins=50, title="",
                      x0_label="", x1_label=""):
    ax, hist_X1, hist_X0 = axes

    ax.set_title(title)
    ax.set_xlabel(x0_label)
    ax.set_ylabel(x1_label)

    # The scatter plot
    colors = cm.plasma_r(y)
    ax.scatter(X[:, 0], X[:, 1], alpha=0.5, marker='o', s=5, lw=0, c=colors)

    # Removing the top and the right spine for aesthetics
    # make nice axis layout
    ax.spines['top'].set_visible(False)
    ax.spines['right'].set_visible(False)
    ax.get_xaxis().tick_bottom()
    ax.get_yaxis().tick_left()
    ax.spines['left'].set_position(('outward', 10))
    ax.spines['bottom'].set_position(('outward', 10))

    # Histogram for axis X1 (feature 5)
    hist_X1.set_ylim(ax.get_ylim())
    hist_X1.hist(X[:, 1], bins=hist_nbins, orientation='horizontal',
                 color='grey', ec='grey')
    hist_X1.axis('off')

    # Histogram for axis X0 (feature 0)
    hist_X0.set_xlim(ax.get_xlim())
    hist_X0.hist(X[:, 0], bins=hist_nbins, orientation='vertical',
                 color='grey', ec='grey')
    hist_X0.axis('off')
```

Two plots will be shown for each scaler/normalizer/transformer. The left figure will show a scatter plot of the full data set while the right figure will exclude the extreme values considering only 99 % of the data set, excluding marginal outliers. In addition, the marginal distributions for each feature will be shown on the side of the scatter plot.

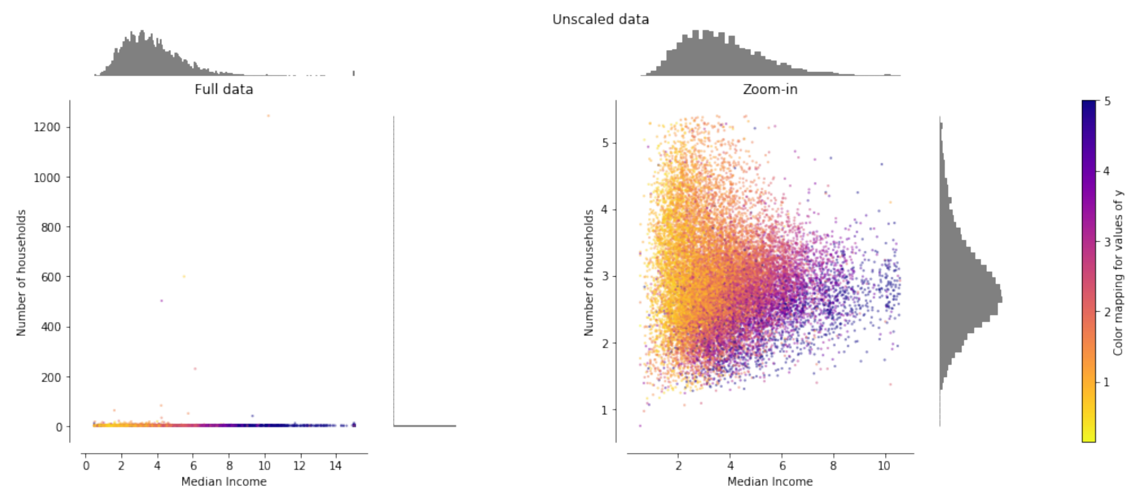
```
In [12]: def make_plot(item_idx):
             title, X = distributions[item_idx]
```

```
ax_zoom_out, ax_zoom_in, ax_colorbar = create_axes(title)
axarr = (ax_zoom_out, ax_zoom_in)
plot_distribution(axarr[0], X, y, hist_nbins=200,
                  x0_label="Median Income",
                  x1_label="Number of households",
                  title="Full data")

# zoom-in
zoom_in_percentile_range = (0, 99)
cutoffs_X0 = np.percentile(X[:, 0], zoom_in_percentile_range)
cutoffs_X1 = np.percentile(X[:, 1], zoom_in_percentile_range)

non_outliers_mask = (
    np.all(X > [cutoffs_X0[0], cutoffs_X1[0]], axis=1) &
    np.all(X < [cutoffs_X0[1], cutoffs_X1[1]], axis=1))
plot_distribution(axarr[1], X[non_outliers_mask], y[non_outliers_mask],
                  hist_nbins=50,
                  x0_label="Median Income",
                  x1_label="Number of households",
                  title="Zoom-in")

norm = mpl.colors.Normalize(y_full.min(), y_full.max())
mpl.colorbar.ColorbarBase(ax_colorbar, cmap=cm.plasma_r,
                          norm=norm, orientation='vertical',
                          label='Color mapping for values of y')
```

4.3 Original data

Each transformation is plotted showing two transformed features, with the left plot showing the entire dataset, and the right zoomed-in to show the dataset without the marginal outliers. A large majority of the samples are compacted to a specific range, [0, 10] for the median income and [0, 6] for the number of households. Note that there are some marginal outliers (some blocks have more than 1200 households). Therefore, a specific pre-processing can be very beneficial depending of the application. In the following, we present some insights and behaviors of those pre-processing methods in the presence of marginal outliers.

```
In [13]: make_plot(0)
```

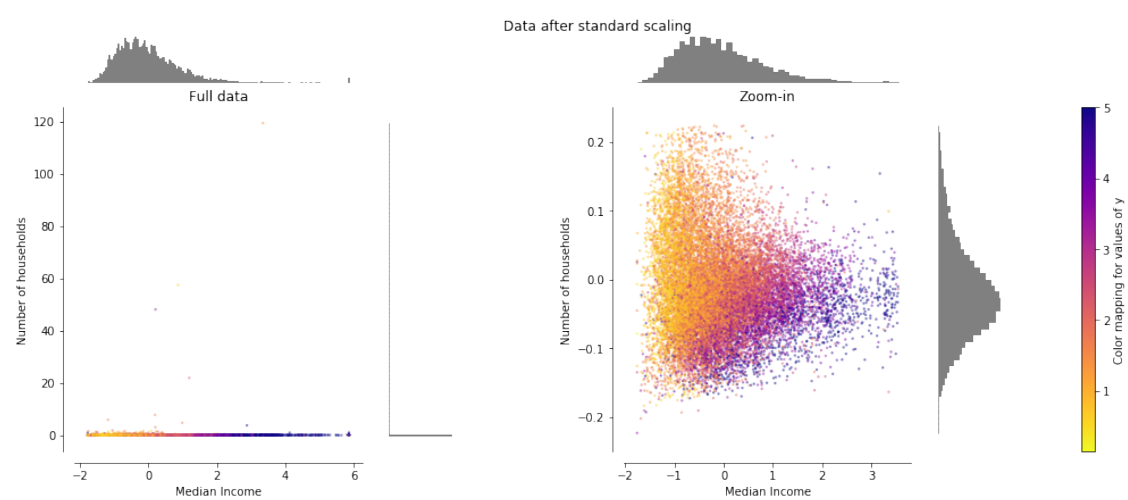


4.4 StandardScaler

`StandardScaler` removes the mean (0) and scales the data to unit variance (1). However, the outliers have an influence when computing the empirical mean and standard deviation which shrink the range of the feature values as shown in the left figure below. Note in particular that because the outliers on each feature have different magnitudes, the spread of the transformed data on each feature is very different: most of the data lie in the [-2, 4] range for the transformed median income feature while the same data is squeezed in the smaller [-0.2, 0.2] range for the transformed number of households.

`StandardScaler` therefore cannot guarantee balanced feature scales in the presence of outliers.

```
In [14]: make_plot(1)
```

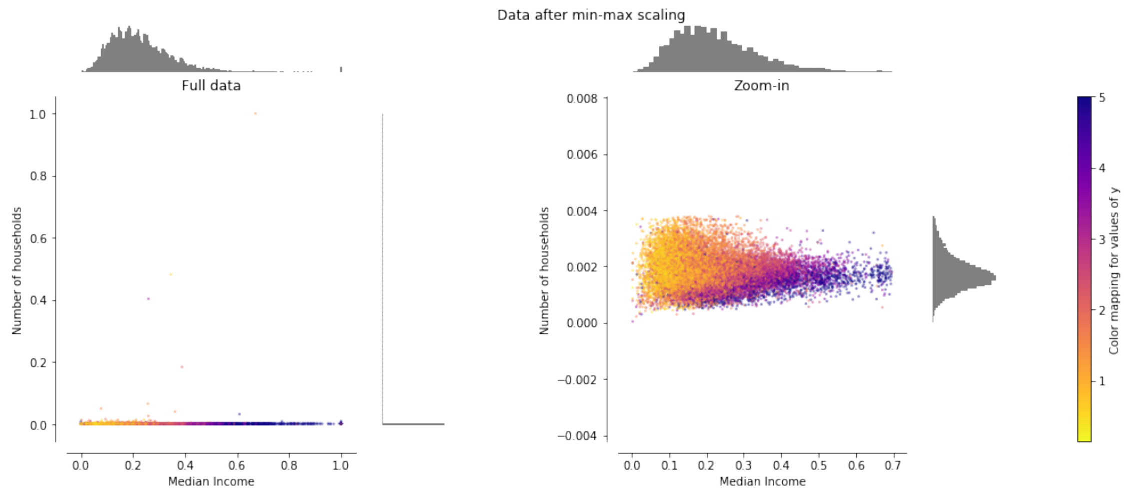


4.5 MinMaxScaler

`MinMaxScaler` rescales the data set such that all feature values are in the range [0, 1] as shown in the right panel below. However, this scaling compress all inliers in the narrow range [0, 0.005] for the transformed number of households.

As `StandardScaler`, `MinMaxScaler` is very sensitive to the presence of outliers.

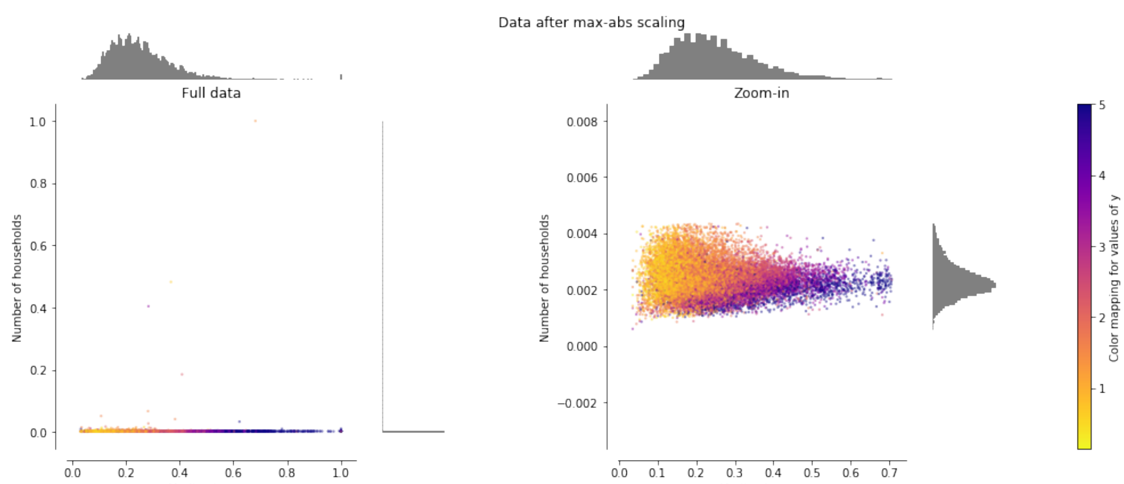
```
In [15]: make_plot(2)
```



4.6 MaxAbsScaler

`MaxAbsScaler` differs from the previous scaler such that the absolute values are mapped in the range [0, 1]. On positive only data, this scaler behaves similarly to `MinMaxScaler` and therefore also suffers from the presence of large outliers.

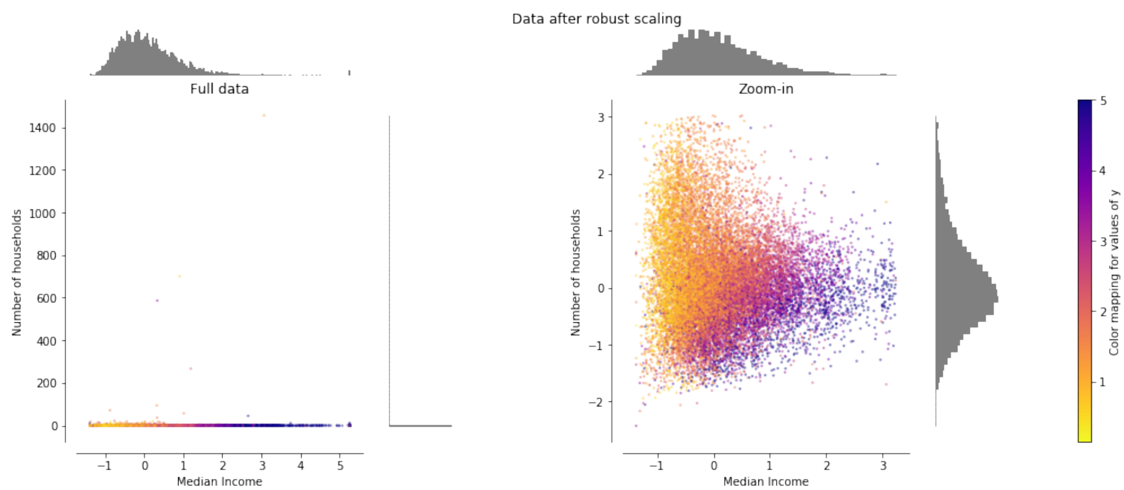
```
In [16]: make_plot(3)
```



4.7 RobustScaler

Unlike the previous scalers, the centering and scaling statistics of this scaler are based on percentiles and are therefore not influenced by a few number of very large marginal outliers. Consequently, the resulting range of the transformed feature values is larger than for the previous scalers and, more importantly, are approximately similar: for both features most of the transformed values lie in a [-2, 3] range as seen in the zoomed-in figure. Note that the outliers themselves are still present in the transformed data. If a separate outlier clipping is desirable, a non-linear transformation is required (see below).

```
In [17]: make_plot(4)
```

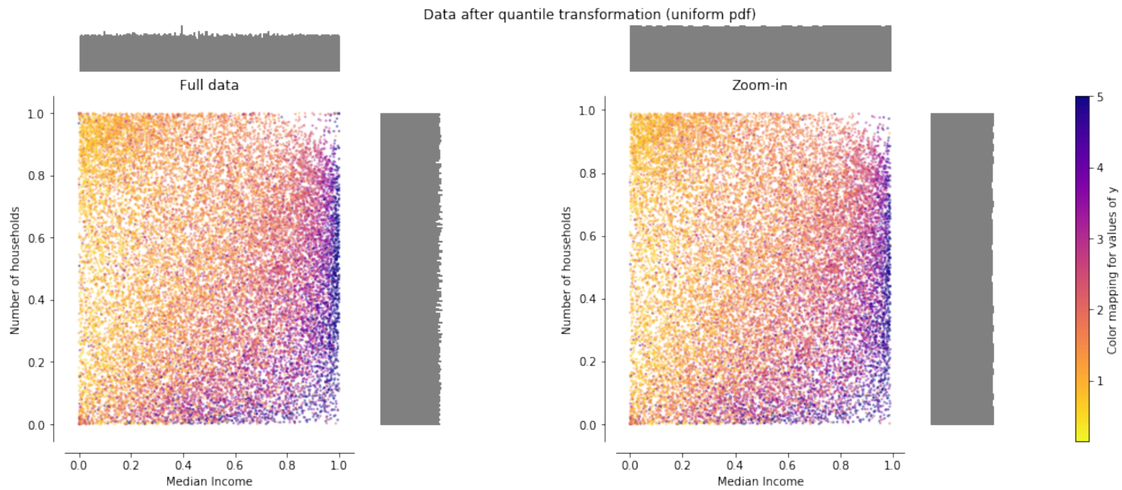


4.8 QuantileTransformer (uniform output)

`QuantileTransformer` applies a non-linear transformation such that the probability density function of each feature will be mapped to a uniform distribution. In this case, all the data will be mapped in the range [0, 1], even the outliers which cannot be distinguished anymore from the inliers.

As `RobustScaler`, `QuantileTransformer` is robust to outliers in the sense that adding or removing outliers in the training set will yield approximately the same transformation on held out data. But contrary to `RobustScaler`, `QuantileTransformer` will also automatically collapse any outlier by setting them to the a priori defined range boundaries (0 and 1).

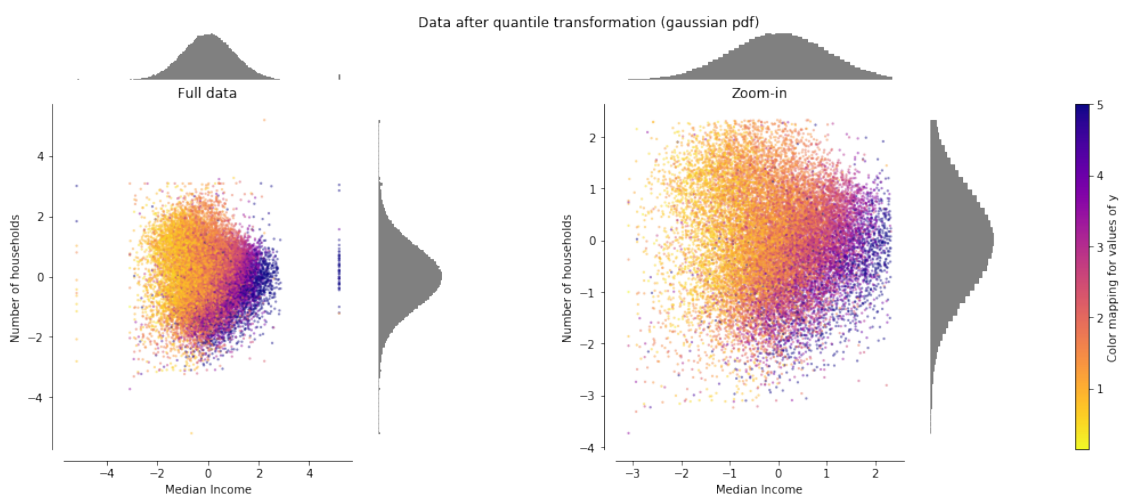
```
In [18]: make_plot(5)
```



4.9 QuantileTransformer (Gaussian output)

`QuantileTransformer` has an additional `output_distribution` parameter allowing to match a Gaussian distribution instead of a uniform distribution. Note that this non-parametetric transformer introduces saturation artifacts for extreme values.

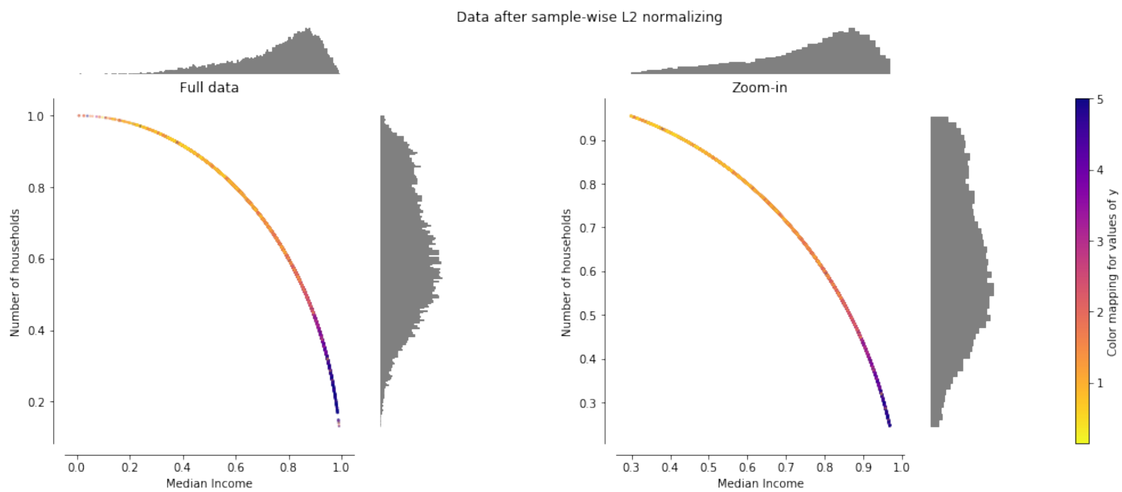
```
In [19]: make_plot(6)
```



4.10 Normalizer

The `Normalizer` rescales the vector for each sample to have unit norm, independently of the distribution of the samples. It can be seen on both figures below where all samples are mapped onto the unit circle. In our example the two selected features have only positive values; therefore the transformed data only lie in the positive quadrant. This would not be the case if some original features had a mix of positive and negative values.

```
In [20]: make_plot(7)
         plt.show()
```



4.11 Which scaler should we use?

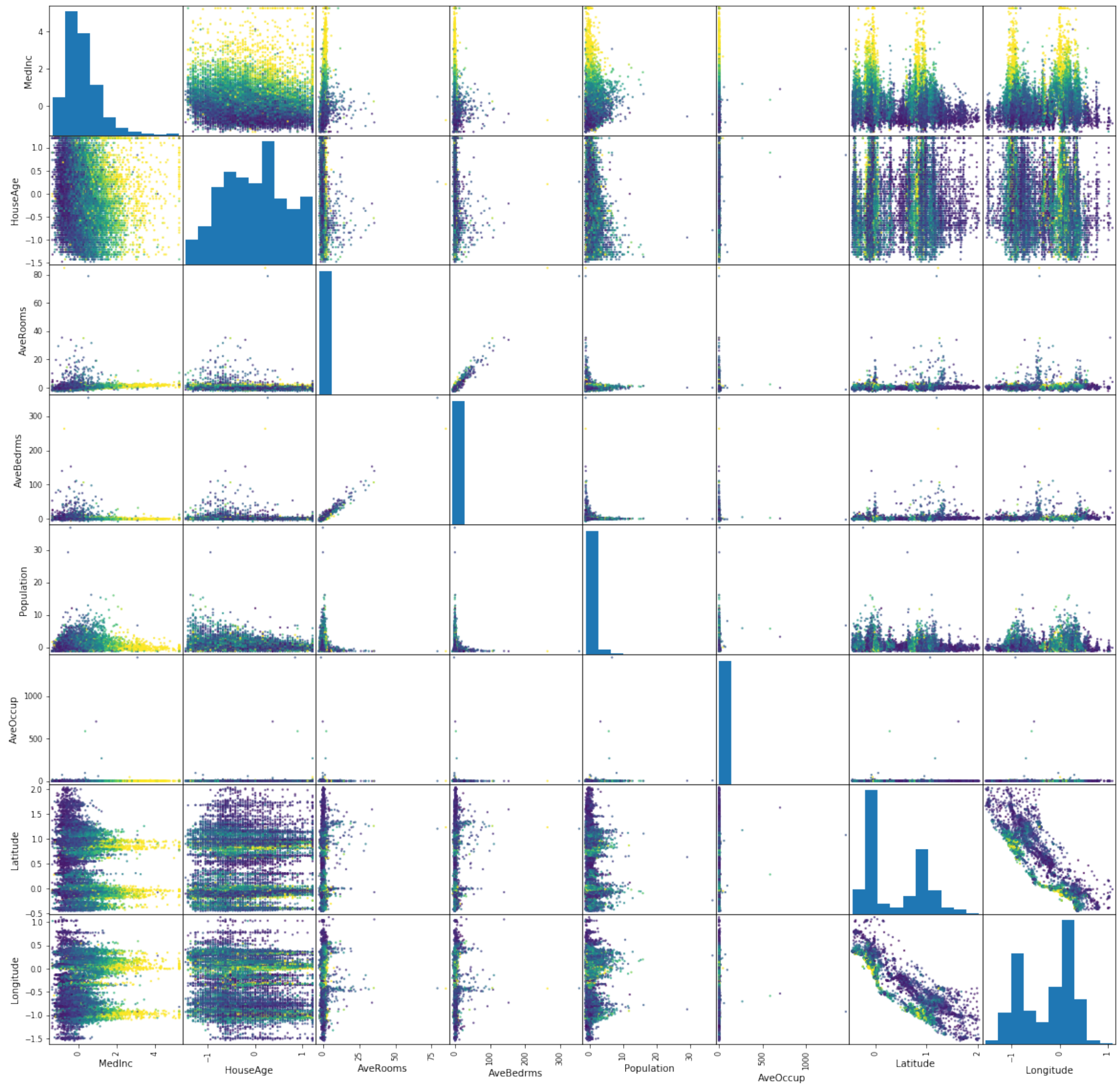
Let's have a closer look at the robust scaler on our entire dataset:

```
In [21]: df_robust = pd.DataFrame(RobustScaler(quantile_range=(25, 75)).fit_transform(df), colum
         df_robust.head(10)
```

```
Out[21]:      MedInc  HouseAge  AveRooms  AveBedrms  Population  AveOccup  Latitude  \
         0  2.197582  0.631579  1.088935  -0.267221   -0.899787 -0.307981  0.957672
         1  2.186664 -0.421053  0.626066  -0.822926    1.316631 -0.830800  0.952381
         2  1.707732  1.210526  1.898042   0.263955   -0.714286 -0.018599  0.949735
         3  0.967177  1.210526  0.364978   0.259814   -0.648188 -0.316908  0.949735
         4  0.142854  1.210526  0.653191   0.345657   -0.640725 -0.746784  0.949735
         5  0.230291  1.210526 -0.290055   0.586926   -0.802772 -0.795547  0.949735
         6  0.057022  1.210526 -0.184419  -1.042501   -0.076759 -0.809026  0.947090
         7 -0.190288  1.210526 -0.267799   0.139580   -0.009595 -1.208021  0.947090
         8 -0.667202  0.684211 -0.580152   0.736958    0.042644 -0.928102  0.947090
         9  0.071748  1.210526 -0.160418  -0.626926    0.410448 -0.757574  0.947090

            Longitude
         0  -0.986807
         1  -0.984169
         2  -0.989446
         3  -0.992084
         4  -0.992084
```

```
5   -0.992084
6   -0.992084
7   -0.992084
8   -0.994723
9   -0.992084
```

In [22]:
```python
scatter_matrix(df_robust, c=housing.target, alpha=0.8, figsize=(20, 20), s=20)
plt.show()
```



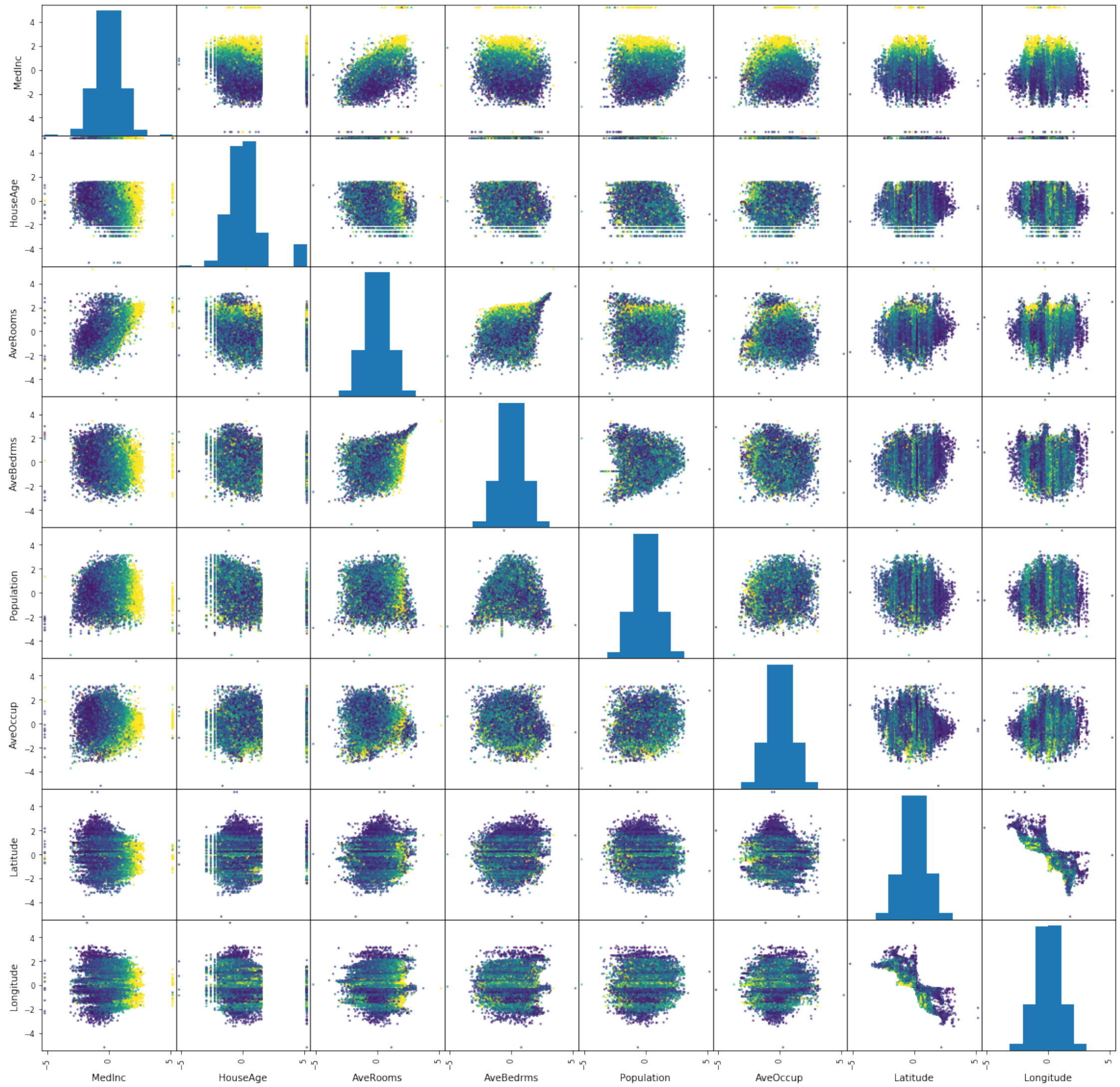
In [24]:
```python
df_gauss = pd.DataFrame(QuantileTransformer(output_distribution='normal').fit_transform
df_gauss.head(10)
```

Out[24]:
```
      MedInc  HouseAge  AveRooms  AveBedrms  Population  AveOccup  Latitude  \
0   1.919185  0.912774  1.294622  -0.388543   -1.697037 -0.450080  0.901416
```

```
1  1.914418 -0.479432  0.822470  -1.197835    1.191955 -1.229273  0.886449
2  1.630171  5.199338  1.933184   0.352143   -1.315958 -0.028306  0.879040
3  1.083447  5.199338  0.495717   0.346959   -1.174755 -0.465169  0.879040
4  0.193151  5.199338  0.852294   0.452858   -1.164444 -1.109257  0.879040
5  0.298746  5.199338 -0.399051   0.720089   -1.492879 -1.181873  0.879040
6  0.084155  5.199338 -0.255539  -1.487964   -0.111890 -1.200185  0.871679
7 -0.270671  5.199338 -0.367135   0.197601   -0.015055 -1.812916  0.871679
8 -1.103892  0.975466 -0.813664   0.861849    0.060256 -1.361386  0.871679
9  0.107135  5.199338 -0.220709  -0.923979    0.493081 -1.126478  0.871679

   Longitude
0  -1.152175
1  -1.137677
2  -1.169401
3  -1.189522
4  -1.189522
5  -1.189522
6  -1.189522
7  -1.189522
8  -1.225943
9  -1.189522
```

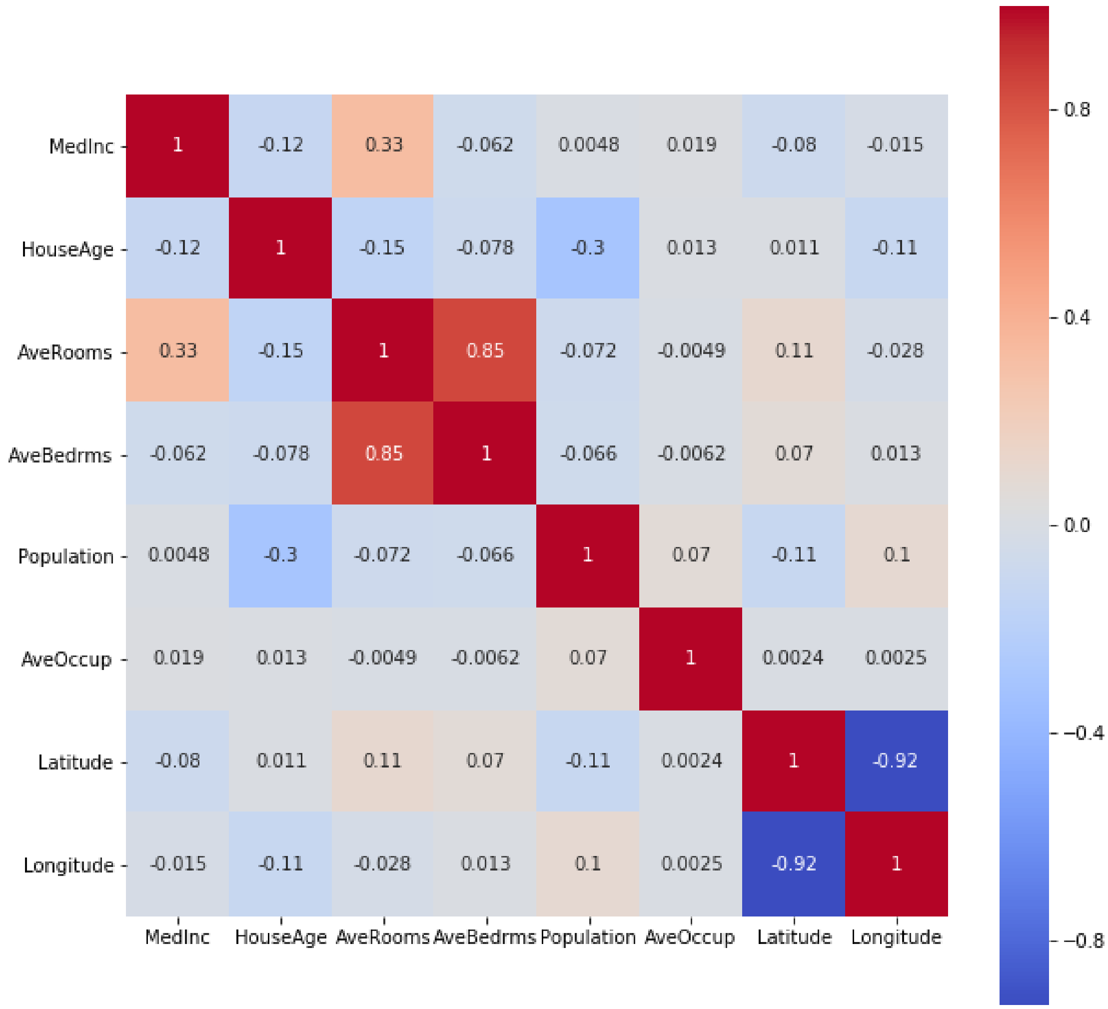
What about the non-linear gaussian transformation, if gaussian distributed shapes are ideal for most machine learning algorithms

In [25]:
```
scatter_matrix(df_gauss, c=housing.target, alpha=0.8, figsize=(20, 20), s=20)
plt.show()
```

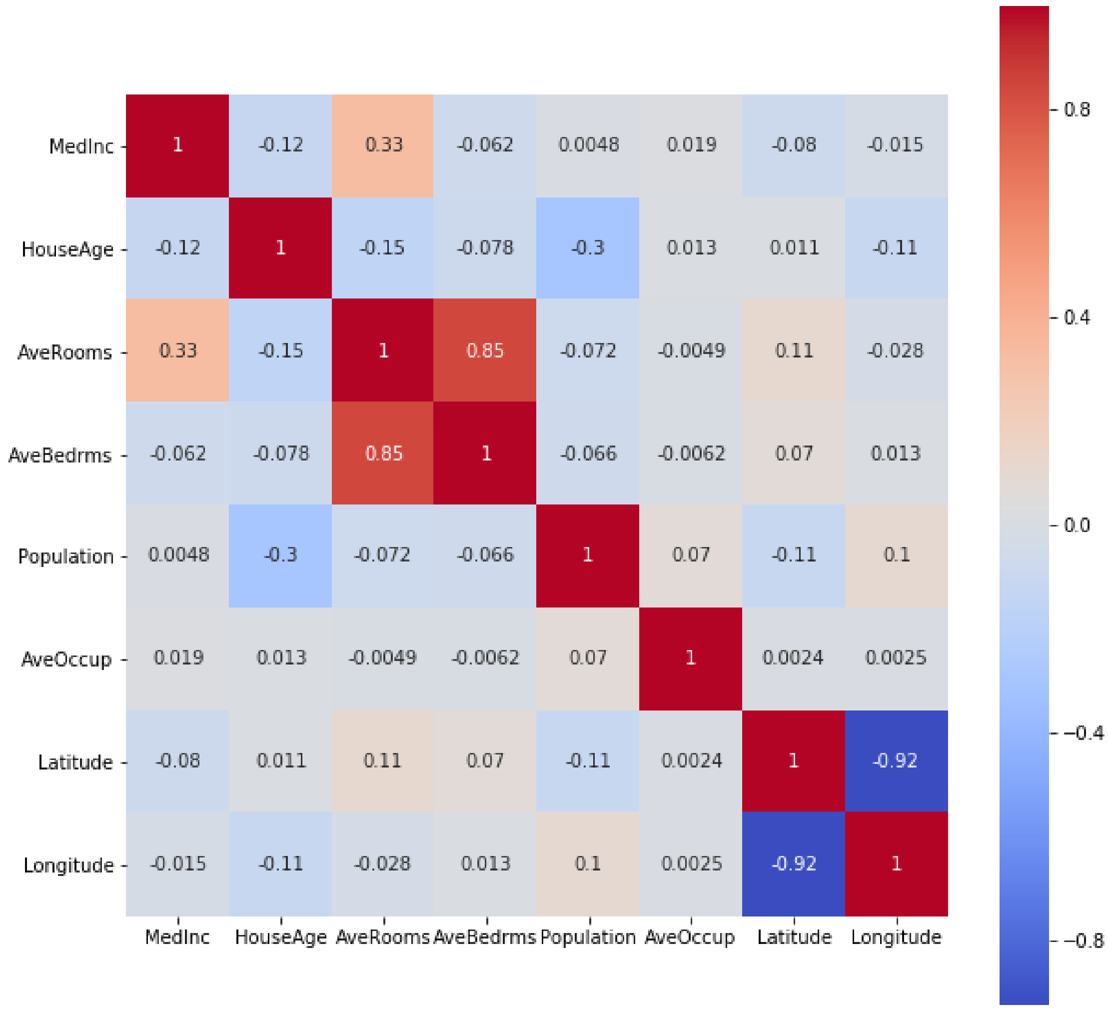


4.12 Impact on the correlations

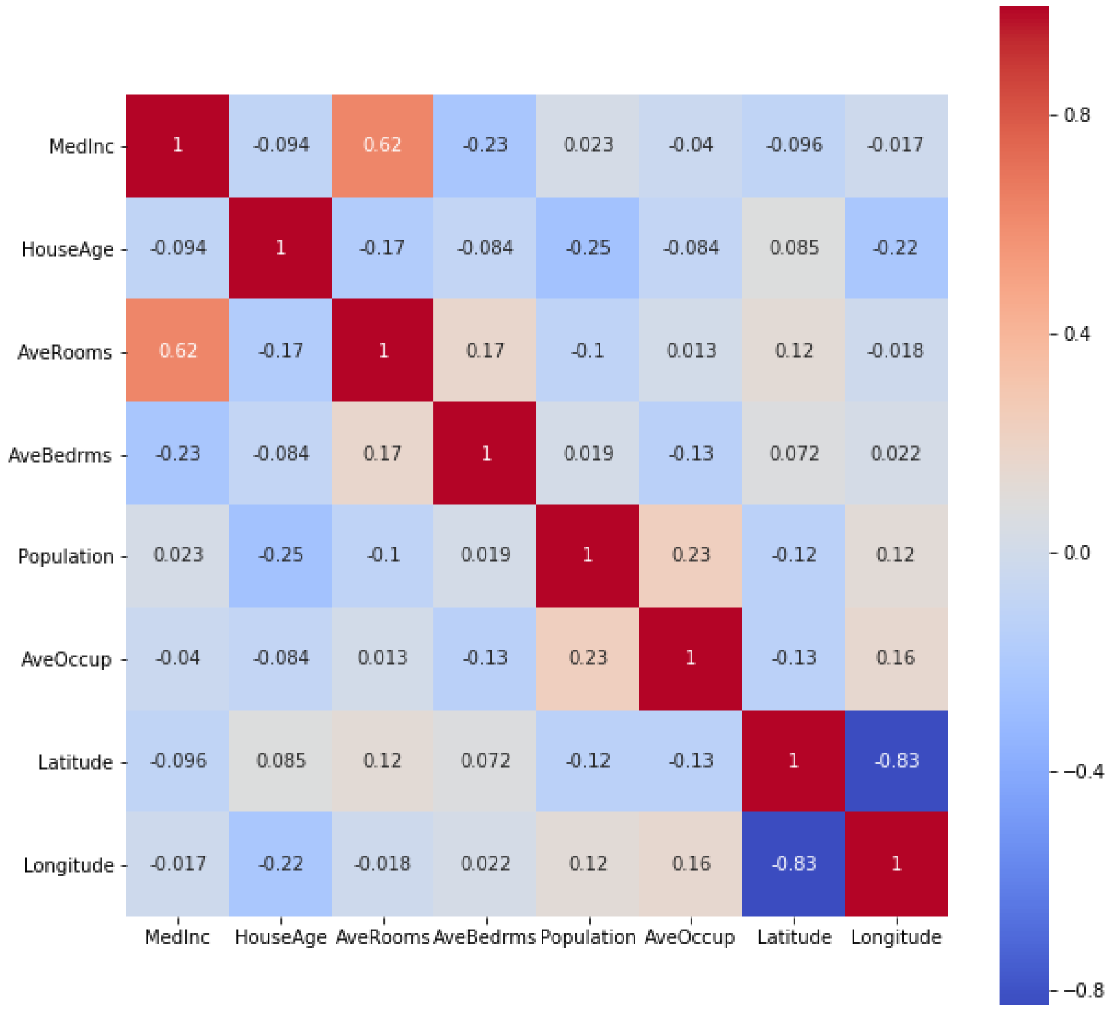
```
In [26]: import seaborn as sns
         plt.figure(figsize=(10,10))
         sns.heatmap(df.corr(), annot=True, square=True, cmap='coolwarm')
         plt.show()
```




```
In [28]: plt.figure(figsize=(10,10))
         sns.heatmap(df_robust.corr(), annot=True, square=True, cmap='coolwarm')

Out[28]: <matplotlib.axes._subplots.AxesSubplot at 0x7fa742593a10>
```




```
In [29]: plt.figure(figsize=(10,10))
         sns.heatmap(df_gauss.corr(), annot=True, square=True, cmap='coolwarm')

Out[29]: <matplotlib.axes._subplots.AxesSubplot at 0x7fa741bbdd90>
```



Non-linear transformations smooth out distributions and are less influenced by outliers. However, they distort correlations and distances within and across features. There is no general answer, which scaler will work best for the problem. Like many things in machine learning, this is simply something one need to test/study.

5 A DNN for regression

5.0.1 Task 2: Design a DNN for this regression problem

- Prepare the data by creating a robust scaled design matrix and a minmax scaled target vector and split into training (70%) and test sample.
- Design a simple fully-connected DNN for regression with 4 hidden layers. Use 30% of the training data for validation. Use `adam` as optimizer and set the batch size to 256.
- What is a good activation function for the output node? What is a good loss function?
- Train the DNN over 300 epochs and plot the loss function and one additional metric for linear regression as a function of epochs.

- Evaluate the obtained model on the testing data, compare the prediction to the true value.
- Use scikit-learn metrics for regression to evaluate the model
- Which feature has the highest linear correlation to the prediction? Plot the true value and the prediction dependent on this feature.

```
In [30]: from sklearn.model_selection import train_test_split
         X_train, X_test, y_train, y_test = train_test_split(df.as_matrix(), housing.target, tes

In [31]: y_train

Out[31]: array([ 1.938,  1.697,  2.598, ...,  2.221,  2.835,  3.25 ])

In [32]: scaler = RobustScaler(quantile_range=(25, 75))
         X_train = scaler.fit_transform(X_train)
         X_test = scaler.transform(X_test)

         scaler_y = MinMaxScaler()
         y_train = scaler_y.fit_transform(y_train.reshape(-1, 1)).reshape(-1)
         y_test = scaler_y.transform(y_test.reshape(-1, 1)).reshape(-1)
         y_train

Out[32]: array([ 0.36866034,  0.31896982,  0.50474225, ...,  0.42701061,
                 0.55360803,  0.63917468])

In [33]: from keras.models import Sequential
         from keras.layers import Dense
         model = Sequential()
         model.add(Dense(units=128, activation='relu', input_dim=8))
         model.add(Dense(units=64, activation='relu'))
         model.add(Dense(units=32, activation='relu'))
         model.add(Dense(units=8 , activation='relu'))
         model.add(Dense(units=1, activation='sigmoid'))
         model.compile(loss='mse', optimizer='adam', metrics=['mae'])

Using TensorFlow backend.


        ---------------------------------------------------------------------------

        RuntimeError                              Traceback (most recent call last)

        RuntimeError: module compiled against API version 0xc but this version of numpy is 0xb



        ---------------------------------------------------------------------------

        RuntimeError                              Traceback (most recent call last)

        RuntimeError: module compiled against API version 0xc but this version of numpy is 0xb
```

```
In [34]: model.summary()
```

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
dense_1 (Dense)              (None, 128)               1152
_________________________________________________________________
dense_2 (Dense)              (None, 64)                8256
_________________________________________________________________
dense_3 (Dense)              (None, 32)                2080
_________________________________________________________________
dense_4 (Dense)              (None, 8)                 264
_________________________________________________________________
dense_5 (Dense)              (None, 1)                 9
=================================================================
Total params: 11,761
Trainable params: 11,761
Non-trainable params: 0
_________________________________________________________________
```

5.0.2 Training

```
In [35]: # fix random seed for reproducibility
         seed = 42
         np.random.seed(seed)

         history = model.fit(X_train, y_train, validation_split=0.3, epochs=300, batch_size=256)
```

```
Train on 10113 samples, validate on 4335 samples
Epoch 1/300
10113/10113 [==============================] - 0s 32us/step - loss: 0.0438 - mean_absolute_error
Epoch 2/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0194 - mean_absolute_error
Epoch 3/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0164 - mean_absolute_error
Epoch 4/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0154 - mean_absolute_error
Epoch 5/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0147 - mean_absolute_error
Epoch 6/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0147 - mean_absolute_error
Epoch 7/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0142 - mean_absolute_error
Epoch 8/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0142 - mean_absolute_error
Epoch 9/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0141 - mean_absolute_error
```

```
Epoch 10/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0140 - mean_absolute_error
Epoch 11/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0156 - mean_absolute_error
Epoch 12/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0139 - mean_absolute_error
Epoch 13/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0134 - mean_absolute_error
Epoch 14/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0132 - mean_absolute_error
Epoch 15/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0132 - mean_absolute_error
Epoch 16/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0136 - mean_absolute_error
Epoch 17/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0129 - mean_absolute_error
Epoch 18/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0133 - mean_absolute_error
Epoch 19/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0130 - mean_absolute_error
Epoch 20/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0126 - mean_absolute_error
Epoch 21/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0126 - mean_absolute_error
Epoch 22/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0124 - mean_absolute_error
Epoch 23/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0126 - mean_absolute_error
Epoch 24/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0129 - mean_absolute_error
Epoch 25/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0124 - mean_absolute_error
Epoch 26/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0121 - mean_absolute_error
Epoch 27/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0120 - mean_absolute_error
Epoch 28/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0118 - mean_absolute_error
Epoch 29/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0118 - mean_absolute_error
Epoch 30/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0147 - mean_absolute_error
Epoch 31/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0141 - mean_absolute_error
Epoch 32/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0128 - mean_absolute_error
Epoch 33/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0124 - mean_absolute_error
```

```
Epoch 34/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0118 - mean_absolute_error
Epoch 35/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0118 - mean_absolute_error
Epoch 36/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0117 - mean_absolute_error
Epoch 37/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0116 - mean_absolute_error
Epoch 38/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0115 - mean_absolute_error
Epoch 39/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0112 - mean_absolute_error
Epoch 40/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0112 - mean_absolute_error
Epoch 41/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0115 - mean_absolute_error
Epoch 42/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0112 - mean_absolute_error
Epoch 43/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0113 - mean_absolute_error
Epoch 44/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0111 - mean_absolute_error
Epoch 45/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0109 - mean_absolute_error
Epoch 46/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0109 - mean_absolute_error
Epoch 47/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0109 - mean_absolute_error
Epoch 48/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0107 - mean_absolute_error
Epoch 49/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0106 - mean_absolute_error
Epoch 50/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0107 - mean_absolute_error
Epoch 51/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0105 - mean_absolute_error
Epoch 52/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0105 - mean_absolute_error
Epoch 53/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0103 - mean_absolute_error
Epoch 54/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0104 - mean_absolute_error
Epoch 55/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0103 - mean_absolute_error
Epoch 56/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0104 - mean_absolute_error
Epoch 57/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0104 - mean_absolute_error
```

```
Epoch 58/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0102 - mean_absolute_error
Epoch 59/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0101 - mean_absolute_error
Epoch 60/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0101 - mean_absolute_error
Epoch 61/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0102 - mean_absolute_error
Epoch 62/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0102 - mean_absolute_error
Epoch 63/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0099 - mean_absolute_error
Epoch 64/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0100 - mean_absolute_error
Epoch 65/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0101 - mean_absolute_error
Epoch 66/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0098 - mean_absolute_error
Epoch 67/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0100 - mean_absolute_error
Epoch 68/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0098 - mean_absolute_error
Epoch 69/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0098 - mean_absolute_error
Epoch 70/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0098 - mean_absolute_error
Epoch 71/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0097 - mean_absolute_error
Epoch 72/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0097 - mean_absolute_error
Epoch 73/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0096 - mean_absolute_error
Epoch 74/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0095 - mean_absolute_error
Epoch 75/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0095 - mean_absolute_error
Epoch 76/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0095 - mean_absolute_error
Epoch 77/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0095 - mean_absolute_error
Epoch 78/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0095 - mean_absolute_error
Epoch 79/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0094 - mean_absolute_error
Epoch 80/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0093 - mean_absolute_error
Epoch 81/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0093 - mean_absolute_error
```

```
Epoch 82/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0095 - mean_absolute_error
Epoch 83/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0092 - mean_absolute_error
Epoch 84/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0093 - mean_absolute_error
Epoch 85/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0091 - mean_absolute_error
Epoch 86/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0091 - mean_absolute_error
Epoch 87/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0091 - mean_absolute_error
Epoch 88/300
10113/10113 [==============================] - 0s 10us/step - loss: 0.0090 - mean_absolute_error
Epoch 89/300
10113/10113 [==============================] - 0s 10us/step - loss: 0.0090 - mean_absolute_error
Epoch 90/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0090 - mean_absolute_error
Epoch 91/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0090 - mean_absolute_error
Epoch 92/300
10113/10113 [==============================] - 0s 10us/step - loss: 0.0091 - mean_absolute_error
Epoch 93/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0088 - mean_absolute_error
Epoch 94/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0087 - mean_absolute_error
Epoch 95/300
10113/10113 [==============================] - 0s 9us/step - loss: 0.0088 - mean_absolute_error:
Epoch 96/300
10113/10113 [==============================] - 0s 9us/step - loss: 0.0087 - mean_absolute_error:
Epoch 97/300
10113/10113 [==============================] - 0s 10us/step - loss: 0.0089 - mean_absolute_error
Epoch 98/300
10113/10113 [==============================] - 0s 10us/step - loss: 0.0092 - mean_absolute_error
Epoch 99/300
10113/10113 [==============================] - 0s 9us/step - loss: 0.0090 - mean_absolute_error:
Epoch 100/300
10113/10113 [==============================] - 0s 10us/step - loss: 0.0090 - mean_absolute_error
Epoch 101/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0096 - mean_absolute_error
Epoch 102/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0091 - mean_absolute_error
Epoch 103/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0087 - mean_absolute_error
Epoch 104/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0086 - mean_absolute_error
Epoch 105/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0087 - mean_absolute_error
```

```
Epoch 106/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0088 - mean_absolute_error
Epoch 107/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0084 - mean_absolute_error
Epoch 108/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0085 - mean_absolute_error
Epoch 109/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0084 - mean_absolute_error
Epoch 110/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0085 - mean_absolute_error
Epoch 111/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0085 - mean_absolute_error
Epoch 112/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0083 - mean_absolute_error
Epoch 113/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0082 - mean_absolute_error
Epoch 114/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0083 - mean_absolute_error
Epoch 115/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0083 - mean_absolute_error
Epoch 116/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0082 - mean_absolute_error
Epoch 117/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0082 - mean_absolute_error
Epoch 118/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0080 - mean_absolute_error
Epoch 119/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0081 - mean_absolute_error
Epoch 120/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0079 - mean_absolute_error
Epoch 121/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0079 - mean_absolute_error
Epoch 122/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0079 - mean_absolute_error
Epoch 123/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0078 - mean_absolute_error
Epoch 124/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0082 - mean_absolute_error
Epoch 125/300
10113/10113 [==============================] - 0s 10us/step - loss: 0.0081 - mean_absolute_error
Epoch 126/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0078 - mean_absolute_error
Epoch 127/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0076 - mean_absolute_error
Epoch 128/300
10113/10113 [==============================] - 0s 10us/step - loss: 0.0077 - mean_absolute_error
Epoch 129/300
10113/10113 [==============================] - 0s 10us/step - loss: 0.0085 - mean_absolute_error
```

```
Epoch 130/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0083 - mean_absolute_error
Epoch 131/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0079 - mean_absolute_error
Epoch 132/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0075 - mean_absolute_error
Epoch 133/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0076 - mean_absolute_error
Epoch 134/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0075 - mean_absolute_error
Epoch 135/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0076 - mean_absolute_error
Epoch 136/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0075 - mean_absolute_error
Epoch 137/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0076 - mean_absolute_error
Epoch 138/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0074 - mean_absolute_error
Epoch 139/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0075 - mean_absolute_error
Epoch 140/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0075 - mean_absolute_error
Epoch 141/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0075 - mean_absolute_error
Epoch 142/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0076 - mean_absolute_error
Epoch 143/300
10113/10113 [==============================] - 0s 10us/step - loss: 0.0074 - mean_absolute_error
Epoch 144/300
10113/10113 [==============================] - 0s 10us/step - loss: 0.0071 - mean_absolute_error
Epoch 145/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0072 - mean_absolute_error
Epoch 146/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0076 - mean_absolute_error
Epoch 147/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0073 - mean_absolute_error
Epoch 148/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0072 - mean_absolute_error
Epoch 149/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0071 - mean_absolute_error
Epoch 150/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0073 - mean_absolute_error
Epoch 151/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0074 - mean_absolute_error
Epoch 152/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0074 - mean_absolute_error
Epoch 153/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0072 - mean_absolute_error
```

```
Epoch 154/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0073 - mean_absolute_error
Epoch 155/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0071 - mean_absolute_error
Epoch 156/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0074 - mean_absolute_error
Epoch 157/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0069 - mean_absolute_error
Epoch 158/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0071 - mean_absolute_error
Epoch 159/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0070 - mean_absolute_error
Epoch 160/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0069 - mean_absolute_error
Epoch 161/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0071 - mean_absolute_error
Epoch 162/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0071 - mean_absolute_error
Epoch 163/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0070 - mean_absolute_error
Epoch 164/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0069 - mean_absolute_error
Epoch 165/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0072 - mean_absolute_error
Epoch 166/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0070 - mean_absolute_error
Epoch 167/300
10113/10113 [==============================] - 0s 14us/step - loss: 0.0068 - mean_absolute_error
Epoch 168/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0068 - mean_absolute_error
Epoch 169/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0068 - mean_absolute_error
Epoch 170/300
10113/10113 [==============================] - 0s 10us/step - loss: 0.0071 - mean_absolute_error
Epoch 171/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0071 - mean_absolute_error
Epoch 172/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0066 - mean_absolute_error
Epoch 173/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0069 - mean_absolute_error
Epoch 174/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0067 - mean_absolute_error
Epoch 175/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0065 - mean_absolute_error
Epoch 176/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0065 - mean_absolute_error
Epoch 177/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0065 - mean_absolute_error
```

```
Epoch 178/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0065 - mean_absolute_error
Epoch 179/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0064 - mean_absolute_error
Epoch 180/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0066 - mean_absolute_error
Epoch 181/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0065 - mean_absolute_error
Epoch 182/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0067 - mean_absolute_error
Epoch 183/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0066 - mean_absolute_error
Epoch 184/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0068 - mean_absolute_error
Epoch 185/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0066 - mean_absolute_error
Epoch 186/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0064 - mean_absolute_error
Epoch 187/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0062 - mean_absolute_error
Epoch 188/300
10113/10113 [==============================] - 0s 10us/step - loss: 0.0064 - mean_absolute_error
Epoch 189/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0061 - mean_absolute_error
Epoch 190/300
10113/10113 [==============================] - 0s 10us/step - loss: 0.0062 - mean_absolute_error
Epoch 191/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0061 - mean_absolute_error
Epoch 192/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0062 - mean_absolute_error
Epoch 193/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0062 - mean_absolute_error
Epoch 194/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0061 - mean_absolute_error
Epoch 195/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0065 - mean_absolute_error
Epoch 196/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0066 - mean_absolute_error
Epoch 197/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0062 - mean_absolute_error
Epoch 198/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0061 - mean_absolute_error
Epoch 199/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0063 - mean_absolute_error
Epoch 200/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0064 - mean_absolute_error
Epoch 201/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0063 - mean_absolute_error
```

```
Epoch 202/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0067 - mean_absolute_error
Epoch 203/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0063 - mean_absolute_error
Epoch 204/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0060 - mean_absolute_error
Epoch 205/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0064 - mean_absolute_error
Epoch 206/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0061 - mean_absolute_error
Epoch 207/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0064 - mean_absolute_error
Epoch 208/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0062 - mean_absolute_error
Epoch 209/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0064 - mean_absolute_error
Epoch 210/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0060 - mean_absolute_error
Epoch 211/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0060 - mean_absolute_error
Epoch 212/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0057 - mean_absolute_error
Epoch 213/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0058 - mean_absolute_error
Epoch 214/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0066 - mean_absolute_error
Epoch 215/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0063 - mean_absolute_error
Epoch 216/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0058 - mean_absolute_error
Epoch 217/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0058 - mean_absolute_error
Epoch 218/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0060 - mean_absolute_error
Epoch 219/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0058 - mean_absolute_error
Epoch 220/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0061 - mean_absolute_error
Epoch 221/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0058 - mean_absolute_error
Epoch 222/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0058 - mean_absolute_error
Epoch 223/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0062 - mean_absolute_error
Epoch 224/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0063 - mean_absolute_error
Epoch 225/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0057 - mean_absolute_error
```

```
Epoch 226/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0057 - mean_absolute_error
Epoch 227/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0058 - mean_absolute_error
Epoch 228/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0060 - mean_absolute_error
Epoch 229/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0056 - mean_absolute_error
Epoch 230/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0055 - mean_absolute_error
Epoch 231/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0055 - mean_absolute_error
Epoch 232/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0054 - mean_absolute_error
Epoch 233/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0054 - mean_absolute_error
Epoch 234/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0056 - mean_absolute_error
Epoch 235/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0060 - mean_absolute_error
Epoch 236/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0060 - mean_absolute_error
Epoch 237/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0059 - mean_absolute_error
Epoch 238/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0056 - mean_absolute_error
Epoch 239/300
10113/10113 [==============================] - 0s 14us/step - loss: 0.0056 - mean_absolute_error
Epoch 240/300
10113/10113 [==============================] - 0s 14us/step - loss: 0.0055 - mean_absolute_error
Epoch 241/300
10113/10113 [==============================] - 0s 14us/step - loss: 0.0054 - mean_absolute_error
Epoch 242/300
10113/10113 [==============================] - 0s 14us/step - loss: 0.0058 - mean_absolute_error
Epoch 243/300
10113/10113 [==============================] - 0s 14us/step - loss: 0.0057 - mean_absolute_error
Epoch 244/300
10113/10113 [==============================] - 0s 14us/step - loss: 0.0056 - mean_absolute_error
Epoch 245/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0056 - mean_absolute_error
Epoch 246/300
10113/10113 [==============================] - 0s 14us/step - loss: 0.0055 - mean_absolute_error
Epoch 247/300
10113/10113 [==============================] - 0s 14us/step - loss: 0.0053 - mean_absolute_error
Epoch 248/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0053 - mean_absolute_error
Epoch 249/300
10113/10113 [==============================] - 0s 14us/step - loss: 0.0055 - mean_absolute_error
```

```
Epoch 250/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0054 - mean_absolute_error
Epoch 251/300
10113/10113 [==============================] - 0s 15us/step - loss: 0.0052 - mean_absolute_error
Epoch 252/300
10113/10113 [==============================] - 0s 14us/step - loss: 0.0054 - mean_absolute_error
Epoch 253/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0055 - mean_absolute_error
Epoch 254/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0053 - mean_absolute_error
Epoch 255/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0053 - mean_absolute_error
Epoch 256/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0053 - mean_absolute_error
Epoch 257/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0054 - mean_absolute_error
Epoch 258/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0052 - mean_absolute_error
Epoch 259/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0053 - mean_absolute_error
Epoch 260/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0054 - mean_absolute_error
Epoch 261/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0052 - mean_absolute_error
Epoch 262/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0052 - mean_absolute_error
Epoch 263/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0052 - mean_absolute_error
Epoch 264/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0053 - mean_absolute_error
Epoch 265/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0051 - mean_absolute_error
Epoch 266/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0053 - mean_absolute_error
Epoch 267/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0052 - mean_absolute_error
Epoch 268/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0050 - mean_absolute_error
Epoch 269/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0053 - mean_absolute_error
Epoch 270/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0053 - mean_absolute_error
Epoch 271/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0052 - mean_absolute_error
Epoch 272/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0050 - mean_absolute_error
Epoch 273/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0050 - mean_absolute_error
```

```
Epoch 274/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0050 - mean_absolute_error
Epoch 275/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0054 - mean_absolute_error
Epoch 276/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0053 - mean_absolute_error
Epoch 277/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0053 - mean_absolute_error
Epoch 278/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0053 - mean_absolute_error
Epoch 279/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0052 - mean_absolute_error
Epoch 280/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0050 - mean_absolute_error
Epoch 281/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0053 - mean_absolute_error
Epoch 282/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0051 - mean_absolute_error
Epoch 283/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0050 - mean_absolute_error
Epoch 284/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0048 - mean_absolute_error
Epoch 285/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0051 - mean_absolute_error
Epoch 286/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0051 - mean_absolute_error
Epoch 287/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0049 - mean_absolute_error
Epoch 288/300
10113/10113 [==============================] - 0s 14us/step - loss: 0.0051 - mean_absolute_error
Epoch 289/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0051 - mean_absolute_error
Epoch 290/300
10113/10113 [==============================] - 0s 14us/step - loss: 0.0051 - mean_absolute_error
Epoch 291/300
10113/10113 [==============================] - 0s 14us/step - loss: 0.0047 - mean_absolute_error
Epoch 292/300
10113/10113 [==============================] - 0s 14us/step - loss: 0.0050 - mean_absolute_error
Epoch 293/300
10113/10113 [==============================] - 0s 14us/step - loss: 0.0051 - mean_absolute_error
Epoch 294/300
10113/10113 [==============================] - 0s 14us/step - loss: 0.0051 - mean_absolute_error
Epoch 295/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0050 - mean_absolute_error
Epoch 296/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0049 - mean_absolute_error
Epoch 297/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0050 - mean_absolute_error
```

```
Epoch 298/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0049 - mean_absolute_error
Epoch 299/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0048 - mean_absolute_error
Epoch 300/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0047 - mean_absolute_error
```

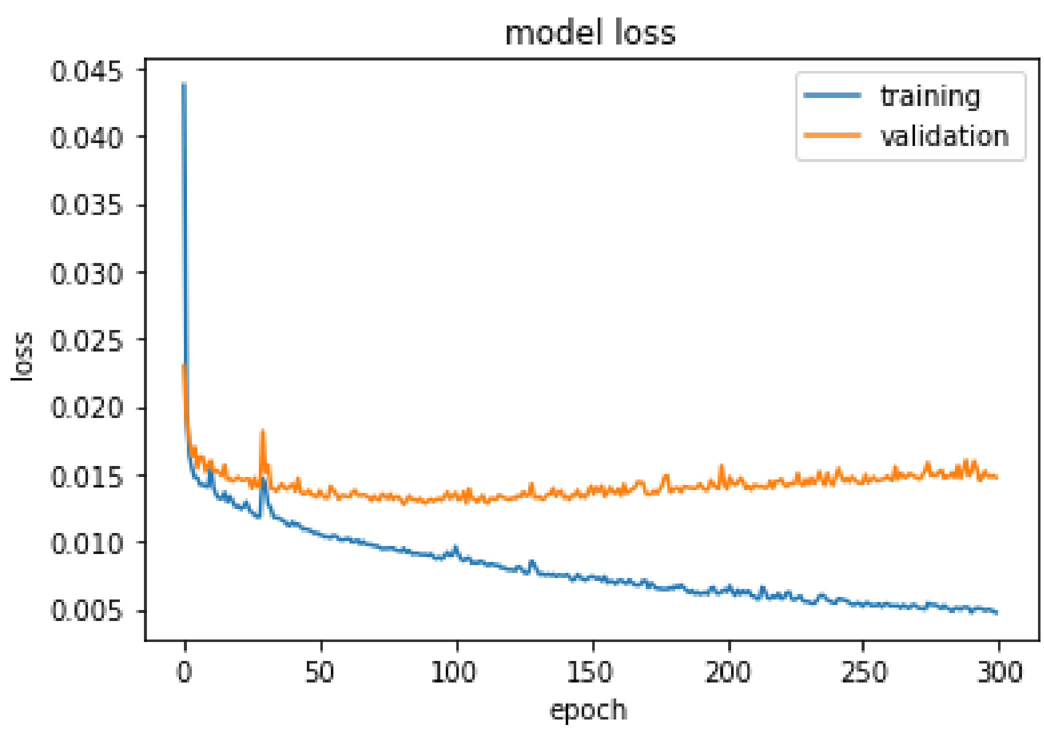
During the training process we have saved the loss and the defined metrics of the training and validation data:

```
In [36]: print(history.history.keys())
```

```
['val_mean_absolute_error', 'loss', 'mean_absolute_error', 'val_loss']
```

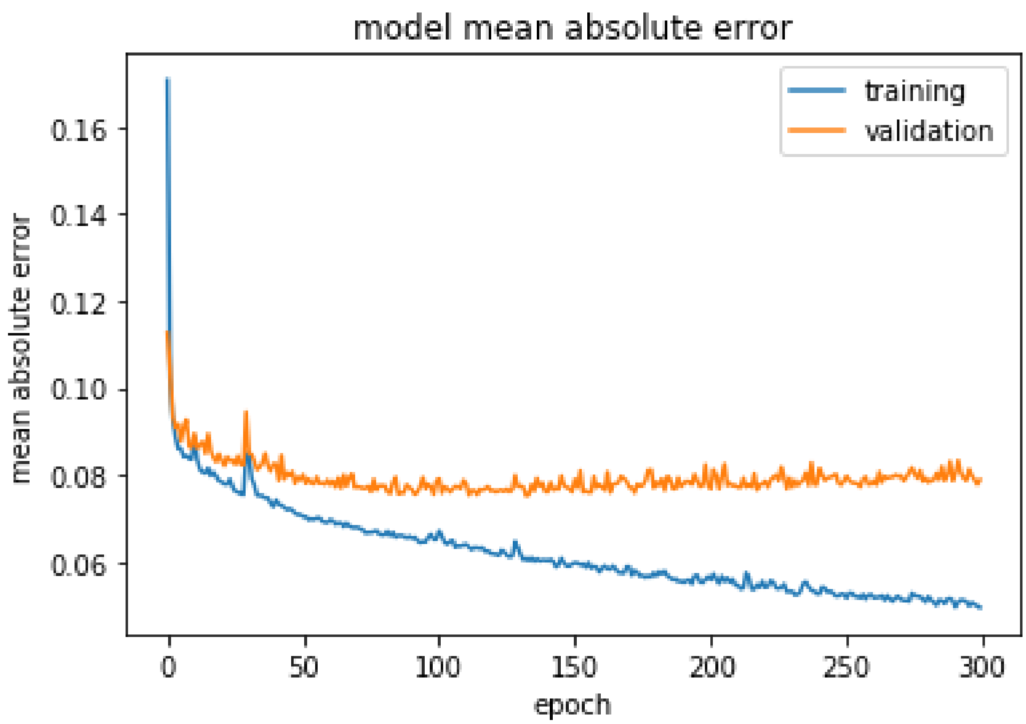
We can now plot the loss evolution over the training epochs for the training and validation dataset:

```
In [37]: # summarize history for loss
         plt.plot(history.history['loss'])
         plt.plot(history.history['val_loss'])
         plt.title('model loss')
         plt.ylabel('loss')
         plt.xlabel('epoch')
         plt.legend(['training', 'validation'], loc='upper right')
         plt.show()
```



Similarly, we can plot the mean absolute error

```
In [38]: # summarize history for mse
         plt.plot(history.history['mean_absolute_error'])
         plt.plot(history.history['val_mean_absolute_error'])
         plt.title('model mean absolute error')
         plt.ylabel('mean absolute error')
         plt.xlabel('epoch')
         plt.legend(['training', 'validation'], loc='upper right')
         plt.show()
```



5.0.3 Evaluation

Let's evaluate the loss and mean absolute error on our test data:

```
In [39]: loss_and_metrics = model.evaluate(X_test, y_test, batch_size=256)
         print loss_and_metrics
```

```
6192/6192 [==============================] - 0s 4us/step
[0.014450883290679881, 0.07822265982042599]
```

Let's make the prediction for our test data:

```
In [40]: print 'Testing...'
         y_pred = model.predict(X_test, verbose = True, batch_size=256)
```

```
Testing...
6192/6192 [==============================] - 0s 7us/step
```

```
In [41]: # predictions
         y_pred.reshape(-1)
```

```
Out[41]: array([ 0.04962008,  0.24929287,  0.99948633, ...,  0.27626351,
                 0.26855168,  0.34332156], dtype=float32)
```

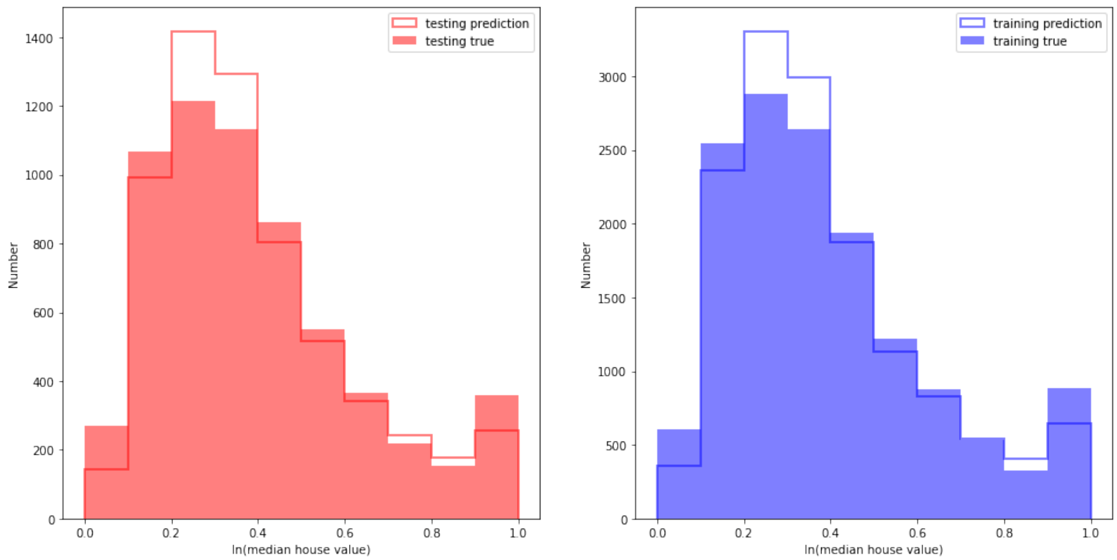
In order to compare the test prediction with the training prediction, we will also obtain a training prediction:

```
In [42]: y_train_pred = model.predict(X_train, verbose = True, batch_size=256)
         y_train_pred = y_train_pred.reshape(-1)
```

```
14448/14448 [==============================] - 0s 3us/step
```

```
In [43]: plt.figure(figsize=(16,8))
         plt.subplot(121)
         plt.hist(y_test, alpha=0.5, color='red', range=[0, 1], bins=10)
         plt.hist(y_pred, alpha=0.5, color='red', range=[0, 1], bins=10, histtype='step', linewi
         plt.xlabel('ln(median house value)')
         plt.ylabel('Number')
         plt.legend(['testing prediction', 'testing true'], loc='upper right')
         plt.subplot(122)
         plt.hist(y_train, alpha=0.5, color='blue', range=[0, 1], bins=10)
         plt.hist(y_train_pred, alpha=0.5, color='blue', range=[0, 1], bins=10, histtype='step',
         plt.xlabel('ln(median house value)')
         plt.ylabel('Number')
         plt.legend(['training prediction', 'training true'], loc='upper right')
```

```
Out[43]: <matplotlib.legend.Legend at 0x7fa728125f10>
```

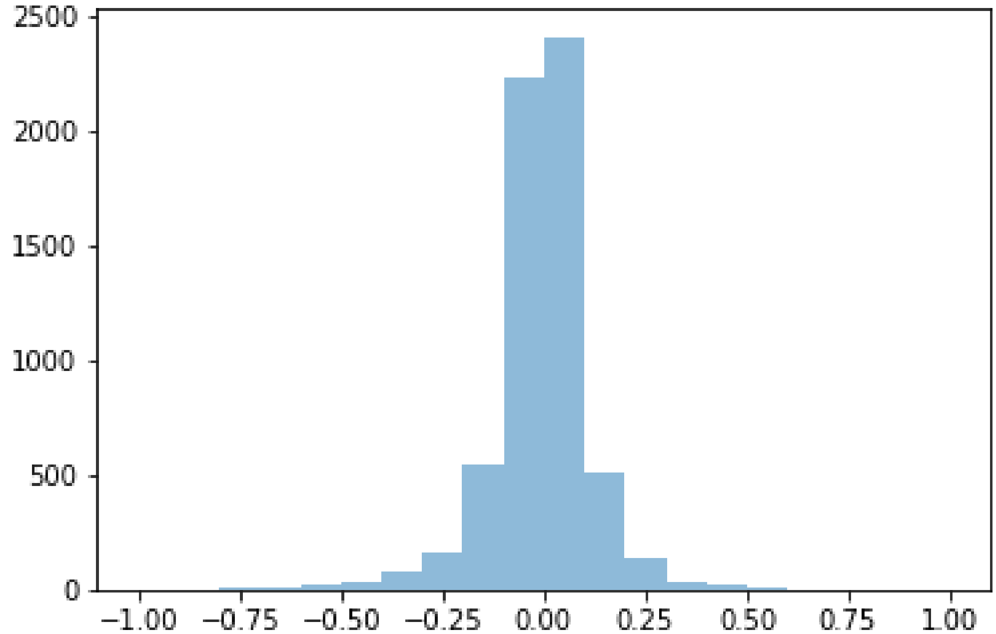


How well do the histograms agree? We can use the Kolmogorov-Smirnov statistic to quantify that:

```
In [44]: from scipy.stats import ks_2samp
         print ('Testing KS:', ks_2samp(y_test, y_pred.reshape(-1)))
         print ('Training KS:', ks_2samp(y_train, y_train_pred.reshape(-1)))

('Testing KS:', Ks_2sampResult(statistic=0.044735142118863092, pvalue=7.8666657512336019e-06))
('Training KS:', Ks_2sampResult(statistic=0.048795681063122931, pvalue=2.080715627219334e-15))
```

Alternatively, we could also look at the difference between the true and prediction values in order to see the spread on example basis:

```
In [45]: plt.hist(y_pred.reshape(-1)-y_test, alpha=0.5, range=[-1, 1], bins=20)

Out[45]: (array([  1.00000000e+00,   1.00000000e+00,   4.00000000e+00,
                   9.00000000e+00,   1.60000000e+01,   3.40000000e+01,
                   8.20000000e+01,   1.60000000e+02,   5.39000000e+02,
                   2.22900000e+03,   2.40900000e+03,   5.07000000e+02,
                   1.36000000e+02,   3.50000000e+01,   1.70000000e+01,
                   8.00000000e+00,   3.00000000e+00,   1.00000000e+00,
                   1.00000000e+00,   0.00000000e+00]),
          array([-1. , -0.9, -0.8, -0.7, -0.6, -0.5, -0.4, -0.3, -0.2, -0.1,  0. ,
                  0.1,  0.2,  0.3,  0.4,  0.5,  0.6,  0.7,  0.8,  0.9,  1. ]),
          <a list of 20 Patch objects>)
```



5.0.4 Use the scikit learn metrics to evaluate the model

In [46]:
```
from sklearn.metrics import r2_score, mean_squared_error, mean_absolute_error

# Explained variance score: 1 is perfect prediction
print('Coefficient of determination: %.2f' % r2_score(y_test, y_pred))
# The mean squared error
print("Mean squared error: %.2f" % mean_squared_error(y_test, y_pred))
# The mean squared error
print("Mean absolute error: %.2f" % mean_absolute_error(y_test, y_pred))
```

```
Coefficient of determination: 0.74
Mean squared error: 0.01
Mean absolute error: 0.08
```

5.0.5 Plot the correlations of the input features to the predictions

In [47]:
```
df_out = pd.DataFrame(X_test, columns=housing.feature_names)
```

In [48]:
```
df_out.head()
```

Out[48]:
```
     MedInc  HouseAge  AveRooms  AveBedrms  Population  AveOccup  Latitude  \
0 -0.848027 -0.210526 -0.645394  -0.290855    0.239316  1.249230  0.473545
1 -0.460004  0.052632 -0.119769   1.539384    0.424145 -0.161828  0.230159
2 -0.026930  1.210526 -0.778816   1.457971    0.151709 -1.716414  0.933862
```

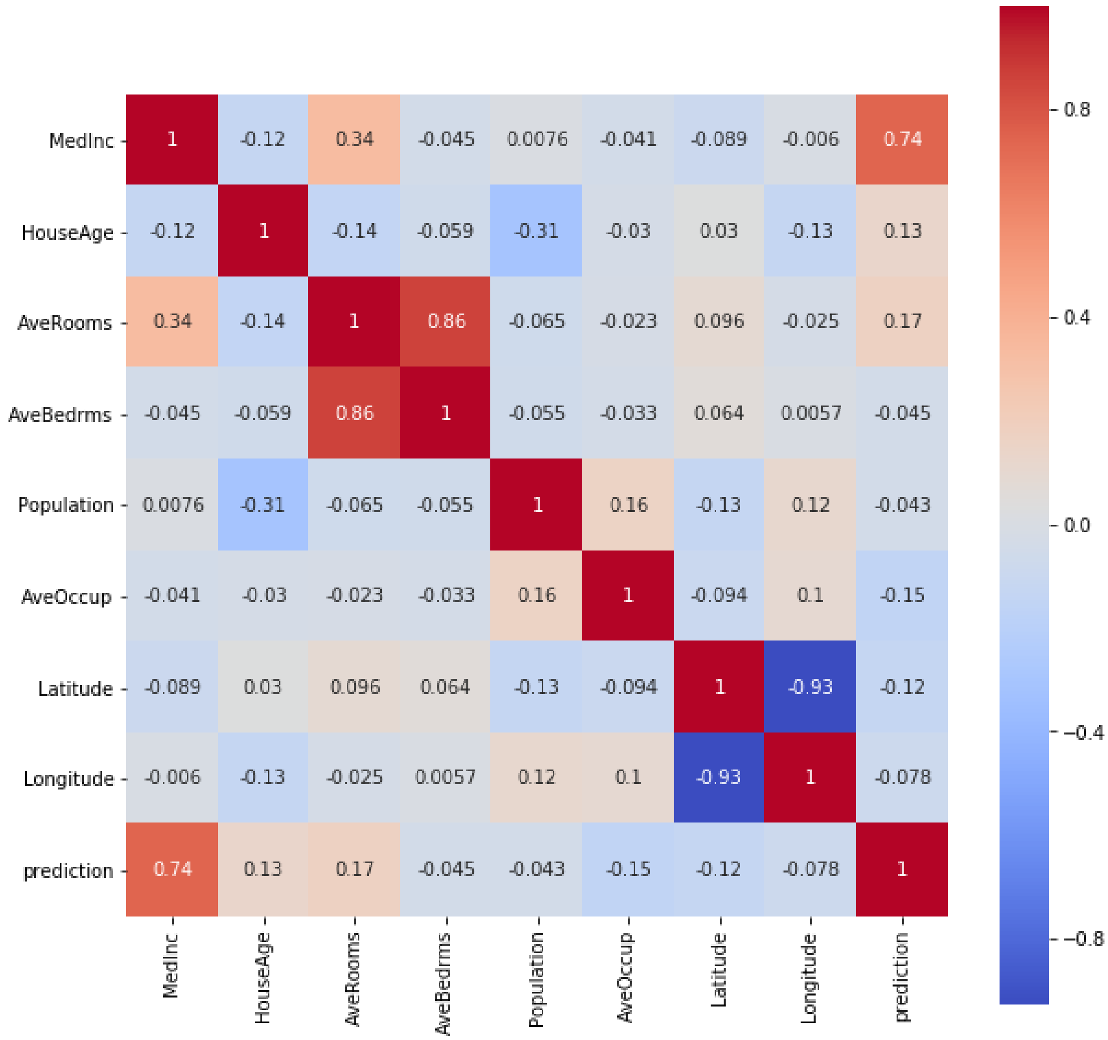
```
3  1.003492 -0.631579  0.577761  -0.313113    0.573718  0.739080  0.002646
4  0.084853  0.263158  0.161667  -0.229352   -0.112179 -0.392931  0.621693

   Longitude
0  -0.131926
1  -0.250660
2  -1.036939
3  -0.055409
4  -0.902375
```

In [49]:
```python
df_out = df_out.assign(prediction=y_pred)
df_out.head()
```

Out[49]:
```
     MedInc  HouseAge  AveRooms  AveBedrms  Population  AveOccup  Latitude  \
0 -0.848027 -0.210526 -0.645394  -0.290855    0.239316  1.249230  0.473545
1 -0.460004  0.052632 -0.119769   1.539384    0.424145 -0.161828  0.230159
2 -0.026930  1.210526 -0.778816   1.457971    0.151709 -1.716414  0.933862
3  1.003492 -0.631579  0.577761  -0.313113    0.573718  0.739080  0.002646
4  0.084853  0.263158  0.161667  -0.229352   -0.112179 -0.392931  0.621693

   Longitude  prediction
0  -0.131926    0.049620
1  -0.250660    0.249293
2  -1.036939    0.999486
3  -0.055409    0.577571
4  -0.902375    0.642027
```

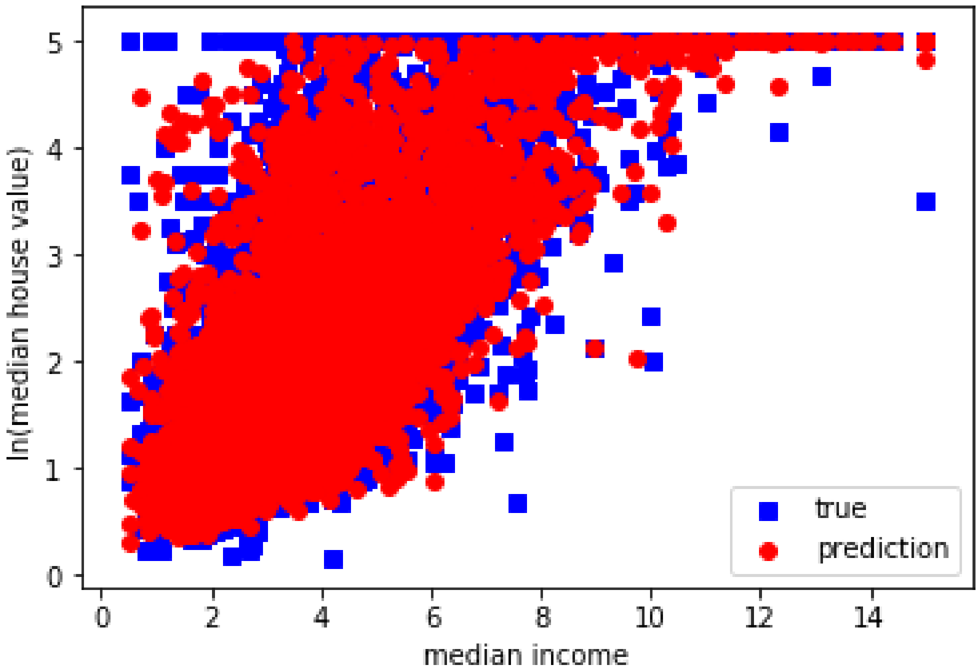
In [50]:
```python
plt.figure(figsize=(10,10))
sns.heatmap(df_out.corr(), annot=True, square=True, cmap='coolwarm')
```

Out[50]:
```
<matplotlib.axes._subplots.AxesSubplot at 0x7fa710786310>
```



5.0.6 Plot the most important input feature dependent on the true value and the prediction

In [51]:
```
X_test = scaler.inverse_transform(X_test)
y_pred = scaler_y.inverse_transform(y_pred)
y_test = scaler_y.inverse_transform(y_test.reshape(-1,1))
plt.scatter(X_test[:,0], y_test, c='blue', marker='s')
plt.scatter(X_test[:,0], y_pred, color='red')
plt.legend(['true', 'prediction'], loc='lower right')
plt.xlabel('median income')
plt.ylabel('ln(median house value) ');
```



6 Regularization

The training and validation loss function diverge during the training resulting in a considerably higher validation loss than the data. Can we use regularizer in order to control that?

6.1 L1/L2 Regularizer

6.1.1 Task 3: Train and evaluate the same DNN with an L2 Regularizer

- The regularizer can be simply set by importing `from keras.regularizers import l2` and adding `kernel_regularizer=l2(l2_lambda)` as option to the Dense layer
- Choose l2_lambda=0.0001
- Perform the same scaling of the inputs
- How does the loss function evaluation change?
- How does the performance and the prediction change?

```
In [52]: from sklearn.model_selection import train_test_split
         X_train, X_test, y_train, y_test = train_test_split(df.as_matrix(), housing.target, tes

         scaler = RobustScaler(quantile_range=(25, 75))
         X_train = scaler.fit_transform(X_train)
         X_test = scaler.transform(X_test)

         scaler_y = MinMaxScaler(feature_range=(0, 1))
```

```
y_train = scaler_y.fit_transform(y_train.reshape(-1, 1)).reshape(-1)
y_test = scaler_y.transform(y_test.reshape(-1, 1)).reshape(-1)
y_train
```

Out[52]:
```
array([ 0.36866034,  0.31896982,  0.50474225, ...,  0.42701061,
        0.55360803,  0.63917468])
```

In [53]:
```
from keras.regularizers import l2
model = Sequential()
l2_lambda = 0.0001
model.add(Dense(units=128, activation='relu', kernel_regularizer=l2(l2_lambda), input_d
model.add(Dense(units=64, activation='relu', kernel_regularizer=l2(l2_lambda)))
model.add(Dense(units=32, activation='relu', kernel_regularizer=l2(l2_lambda)))
model.add(Dense(units=8 , activation='relu', kernel_regularizer=l2(l2_lambda)))
model.add(Dense(units=1, activation='sigmoid'))
model.compile(loss='mse', optimizer='adam', metrics=['mae'])
model.summary()
```

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
dense_6 (Dense)              (None, 128)               1152
_________________________________________________________________
dense_7 (Dense)              (None, 64)                8256
_________________________________________________________________
dense_8 (Dense)              (None, 32)                2080
_________________________________________________________________
dense_9 (Dense)              (None, 8)                 264
_________________________________________________________________
dense_10 (Dense)             (None, 1)                 9
=================================================================
Total params: 11,761
Trainable params: 11,761
Non-trainable params: 0
_________________________________________________________________
```

In [54]:
```
history = model.fit(X_train, y_train, validation_split=0.3, epochs=300, batch_size=256)
```

```
Train on 10113 samples, validate on 4335 samples
Epoch 1/300
10113/10113 [==============================] - 0s 39us/step - loss: 0.0507 - mean_absolute_error
Epoch 2/300
10113/10113 [==============================] - 0s 14us/step - loss: 0.0321 - mean_absolute_error
Epoch 3/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0286 - mean_absolute_error
Epoch 4/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0268 - mean_absolute_error
Epoch 5/300
```

```
10113/10113 [==============================] - 0s 12us/step - loss: 0.0255 - mean_absolute_error
Epoch 6/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0242 - mean_absolute_error
Epoch 7/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0250 - mean_absolute_error
Epoch 8/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0242 - mean_absolute_error
Epoch 9/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0228 - mean_absolute_error
Epoch 10/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0218 - mean_absolute_error
Epoch 11/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0230 - mean_absolute_error
Epoch 12/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0219 - mean_absolute_error
Epoch 13/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0211 - mean_absolute_error
Epoch 14/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0207 - mean_absolute_error
Epoch 15/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0203 - mean_absolute_error
Epoch 16/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0204 - mean_absolute_error
Epoch 17/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0212 - mean_absolute_error
Epoch 18/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0218 - mean_absolute_error
Epoch 19/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0207 - mean_absolute_error
Epoch 20/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0198 - mean_absolute_error
Epoch 21/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0193 - mean_absolute_error
Epoch 22/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0192 - mean_absolute_error
Epoch 23/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0193 - mean_absolute_error
Epoch 24/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0188 - mean_absolute_error
Epoch 25/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0194 - mean_absolute_error
Epoch 26/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0190 - mean_absolute_error
Epoch 27/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0186 - mean_absolute_error
Epoch 28/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0183 - mean_absolute_error
Epoch 29/300
```

```
10113/10113 [==============================] - 0s 12us/step - loss: 0.0180 - mean_absolute_error
Epoch 30/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0179 - mean_absolute_error
Epoch 31/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0179 - mean_absolute_error
Epoch 32/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0178 - mean_absolute_error
Epoch 33/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0177 - mean_absolute_error
Epoch 34/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0176 - mean_absolute_error
Epoch 35/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0173 - mean_absolute_error
Epoch 36/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0173 - mean_absolute_error
Epoch 37/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0171 - mean_absolute_error
Epoch 38/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0173 - mean_absolute_error
Epoch 39/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0169 - mean_absolute_error
Epoch 40/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0169 - mean_absolute_error
Epoch 41/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0168 - mean_absolute_error
Epoch 42/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0168 - mean_absolute_error
Epoch 43/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0165 - mean_absolute_error
Epoch 44/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0166 - mean_absolute_error
Epoch 45/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0166 - mean_absolute_error
Epoch 46/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0164 - mean_absolute_error
Epoch 47/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0164 - mean_absolute_error
Epoch 48/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0161 - mean_absolute_error
Epoch 49/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0163 - mean_absolute_error
Epoch 50/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0162 - mean_absolute_error
Epoch 51/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0160 - mean_absolute_error
Epoch 52/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0159 - mean_absolute_error
Epoch 53/300
```

```
10113/10113 [==============================] - 0s 12us/step - loss: 0.0163 - mean_absolute_error
Epoch 54/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0159 - mean_absolute_error
Epoch 55/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0158 - mean_absolute_error
Epoch 56/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0158 - mean_absolute_error
Epoch 57/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0157 - mean_absolute_error
Epoch 58/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0165 - mean_absolute_error
Epoch 59/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0170 - mean_absolute_error
Epoch 60/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0159 - mean_absolute_error
Epoch 61/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0155 - mean_absolute_error
Epoch 62/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0157 - mean_absolute_error
Epoch 63/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0155 - mean_absolute_error
Epoch 64/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0154 - mean_absolute_error
Epoch 65/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0156 - mean_absolute_error
Epoch 66/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0151 - mean_absolute_error
Epoch 67/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0150 - mean_absolute_error
Epoch 68/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0197 - mean_absolute_error
Epoch 69/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0176 - mean_absolute_error
Epoch 70/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0164 - mean_absolute_error
Epoch 71/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0161 - mean_absolute_error
Epoch 72/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0156 - mean_absolute_error
Epoch 73/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0155 - mean_absolute_error
Epoch 74/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0152 - mean_absolute_error
Epoch 75/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0151 - mean_absolute_error
Epoch 76/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0150 - mean_absolute_error
Epoch 77/300
```

```
10113/10113 [==============================] - 0s 13us/step - loss: 0.0149 - mean_absolute_error
Epoch 78/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0152 - mean_absolute_error
Epoch 79/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0147 - mean_absolute_error
Epoch 80/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0150 - mean_absolute_error
Epoch 81/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0148 - mean_absolute_error
Epoch 82/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0148 - mean_absolute_error
Epoch 83/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0147 - mean_absolute_error
Epoch 84/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0145 - mean_absolute_error
Epoch 85/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0146 - mean_absolute_error
Epoch 86/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0150 - mean_absolute_error
Epoch 87/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0149 - mean_absolute_error
Epoch 88/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0145 - mean_absolute_error
Epoch 89/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0145 - mean_absolute_error
Epoch 90/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0144 - mean_absolute_error
Epoch 91/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0143 - mean_absolute_error
Epoch 92/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0143 - mean_absolute_error
Epoch 93/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0143 - mean_absolute_error
Epoch 94/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0142 - mean_absolute_error
Epoch 95/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0142 - mean_absolute_error
Epoch 96/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0143 - mean_absolute_error
Epoch 97/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0143 - mean_absolute_error
Epoch 98/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0150 - mean_absolute_error
Epoch 99/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0144 - mean_absolute_error
Epoch 100/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0144 - mean_absolute_error
Epoch 101/300
```

```
10113/10113 [==============================] - 0s 12us/step - loss: 0.0141 - mean_absolute_error
Epoch 102/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0143 - mean_absolute_error
Epoch 103/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0139 - mean_absolute_error
Epoch 104/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0142 - mean_absolute_error
Epoch 105/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0140 - mean_absolute_error
Epoch 106/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0138 - mean_absolute_error
Epoch 107/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0138 - mean_absolute_error
Epoch 108/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0138 - mean_absolute_error
Epoch 109/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0141 - mean_absolute_error
Epoch 110/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0139 - mean_absolute_error
Epoch 111/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0136 - mean_absolute_error
Epoch 112/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0136 - mean_absolute_error
Epoch 113/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0137 - mean_absolute_error
Epoch 114/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0136 - mean_absolute_error
Epoch 115/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0137 - mean_absolute_error
Epoch 116/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0135 - mean_absolute_error
Epoch 117/300
10113/10113 [==============================] - 0s 16us/step - loss: 0.0135 - mean_absolute_error
Epoch 118/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0136 - mean_absolute_error
Epoch 119/300
10113/10113 [==============================] - 0s 10us/step - loss: 0.0139 - mean_absolute_error
Epoch 120/300
10113/10113 [==============================] - 0s 10us/step - loss: 0.0136 - mean_absolute_error
Epoch 121/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0134 - mean_absolute_error
Epoch 122/300
10113/10113 [==============================] - 0s 10us/step - loss: 0.0135 - mean_absolute_error
Epoch 123/300
10113/10113 [==============================] - 0s 10us/step - loss: 0.0134 - mean_absolute_error
Epoch 124/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0137 - mean_absolute_error
Epoch 125/300
```

```
10113/10113 [==============================] - 0s 12us/step - loss: 0.0136 - mean_absolute_error
Epoch 126/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0134 - mean_absolute_error
Epoch 127/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0133 - mean_absolute_error
Epoch 128/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0133 - mean_absolute_error
Epoch 129/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0133 - mean_absolute_error
Epoch 130/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0132 - mean_absolute_error
Epoch 131/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0132 - mean_absolute_error
Epoch 132/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0135 - mean_absolute_error
Epoch 133/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0134 - mean_absolute_error
Epoch 134/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0131 - mean_absolute_error
Epoch 135/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0131 - mean_absolute_error
Epoch 136/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0131 - mean_absolute_error
Epoch 137/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0134 - mean_absolute_error
Epoch 138/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0138 - mean_absolute_error
Epoch 139/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0142 - mean_absolute_error
Epoch 140/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0135 - mean_absolute_error
Epoch 141/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0133 - mean_absolute_error
Epoch 142/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0132 - mean_absolute_error
Epoch 143/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0130 - mean_absolute_error
Epoch 144/300
10113/10113 [==============================] - ETA: 0s - loss: 0.0131 - mean_absolute_error: 0.0
Epoch 145/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0129 - mean_absolute_error
Epoch 146/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0130 - mean_absolute_error
Epoch 147/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0130 - mean_absolute_error
Epoch 148/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0129 - mean_absolute_error
Epoch 149/300
```

```
10113/10113 [==============================] - 0s 12us/step - loss: 0.0128 - mean_absolute_error
Epoch 150/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0131 - mean_absolute_error
Epoch 151/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0131 - mean_absolute_error
Epoch 152/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0129 - mean_absolute_error
Epoch 153/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0131 - mean_absolute_error
Epoch 154/300
10113/10113 [==============================] - 0s 11us/step - loss: 0.0129 - mean_absolute_error
Epoch 155/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0130 - mean_absolute_error
Epoch 156/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0128 - mean_absolute_error
Epoch 157/300
10113/10113 [==============================] - 0s 14us/step - loss: 0.0128 - mean_absolute_error
Epoch 158/300
10113/10113 [==============================] - 0s 14us/step - loss: 0.0128 - mean_absolute_error
Epoch 159/300
10113/10113 [==============================] - 0s 14us/step - loss: 0.0128 - mean_absolute_error
Epoch 160/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0127 - mean_absolute_error
Epoch 161/300
10113/10113 [==============================] - 0s 14us/step - loss: 0.0127 - mean_absolute_error
Epoch 162/300
10113/10113 [==============================] - 0s 14us/step - loss: 0.0128 - mean_absolute_error
Epoch 163/300
10113/10113 [==============================] - 0s 14us/step - loss: 0.0128 - mean_absolute_error
Epoch 164/300
10113/10113 [==============================] - 0s 14us/step - loss: 0.0127 - mean_absolute_error
Epoch 165/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0127 - mean_absolute_error
Epoch 166/300
10113/10113 [==============================] - 0s 14us/step - loss: 0.0126 - mean_absolute_error
Epoch 167/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0129 - mean_absolute_error
Epoch 168/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0128 - mean_absolute_error
Epoch 169/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0127 - mean_absolute_error
Epoch 170/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0129 - mean_absolute_error
Epoch 171/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0143 - mean_absolute_error
Epoch 172/300
10113/10113 [==============================] - 0s 14us/step - loss: 0.0132 - mean_absolute_error
Epoch 173/300
```

```
10113/10113 [==============================] - 0s 13us/step - loss: 0.0129 - mean_absolute_error
Epoch 174/300
10113/10113 [==============================] - 0s 14us/step - loss: 0.0131 - mean_absolute_error
Epoch 175/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0126 - mean_absolute_error
Epoch 176/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0127 - mean_absolute_error
Epoch 177/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0125 - mean_absolute_error
Epoch 178/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0127 - mean_absolute_error
Epoch 179/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0126 - mean_absolute_error
Epoch 180/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0125 - mean_absolute_error
Epoch 181/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0125 - mean_absolute_error
Epoch 182/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0125 - mean_absolute_error
Epoch 183/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0126 - mean_absolute_error
Epoch 184/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0126 - mean_absolute_error
Epoch 185/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0124 - mean_absolute_error
Epoch 186/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0124 - mean_absolute_error
Epoch 187/300
10113/10113 [==============================] - 0s 12us/step - loss: 0.0125 - mean_absolute_error
Epoch 188/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0124 - mean_absolute_error
Epoch 189/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0124 - mean_absolute_error
Epoch 190/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0125 - mean_absolute_error
Epoch 191/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0124 - mean_absolute_error
Epoch 192/300
10113/10113 [==============================] - 0s 14us/step - loss: 0.0125 - mean_absolute_error
Epoch 193/300
10113/10113 [==============================] - 0s 14us/step - loss: 0.0125 - mean_absolute_error
Epoch 194/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0124 - mean_absolute_error
Epoch 195/300
10113/10113 [==============================] - 0s 14us/step - loss: 0.0125 - mean_absolute_error
Epoch 196/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0122 - mean_absolute_error
Epoch 197/300
```

```
10113/10113 [==============================] - 0s 14us/step - loss: 0.0122 - mean_absolute_error
Epoch 198/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0124 - mean_absolute_error
Epoch 199/300
10113/10113 [==============================] - 0s 14us/step - loss: 0.0122 - mean_absolute_error
Epoch 200/300
10113/10113 [==============================] - 0s 14us/step - loss: 0.0124 - mean_absolute_error
Epoch 201/300
10113/10113 [==============================] - 0s 14us/step - loss: 0.0131 - mean_absolute_error
Epoch 202/300
10113/10113 [==============================] - 0s 14us/step - loss: 0.0132 - mean_absolute_error
Epoch 203/300
10113/10113 [==============================] - 0s 14us/step - loss: 0.0126 - mean_absolute_error
Epoch 204/300
10113/10113 [==============================] - 0s 14us/step - loss: 0.0124 - mean_absolute_error
Epoch 205/300
10113/10113 [==============================] - 0s 13us/step - loss: 0.0123 - mean_absolute_error
Epoch 206/300
10113/10113 [==============================] - 0s 14us/step - loss: 0.0123 - mean_absolute_error
Epoch 207/300
10113/10113 [==============================] - 0s 16us/step - loss: 0.0125 - mean_absolute_error
Epoch 208/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0121 - mean_absolute_error
Epoch 209/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0123 - mean_absolute_error
Epoch 210/300
10113/10113 [==============================] - 0s 16us/step - loss: 0.0122 - mean_absolute_error
Epoch 211/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0125 - mean_absolute_error
Epoch 212/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0122 - mean_absolute_error
Epoch 213/300
10113/10113 [==============================] - 0s 18us/step - loss: 0.0124 - mean_absolute_error
Epoch 214/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0125 - mean_absolute_error
Epoch 215/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0124 - mean_absolute_error
Epoch 216/300
10113/10113 [==============================] - 0s 18us/step - loss: 0.0125 - mean_absolute_error
Epoch 217/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0122 - mean_absolute_error
Epoch 218/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0121 - mean_absolute_error
Epoch 219/300
10113/10113 [==============================] - 0s 16us/step - loss: 0.0121 - mean_absolute_error
Epoch 220/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0122 - mean_absolute_error
Epoch 221/300
```

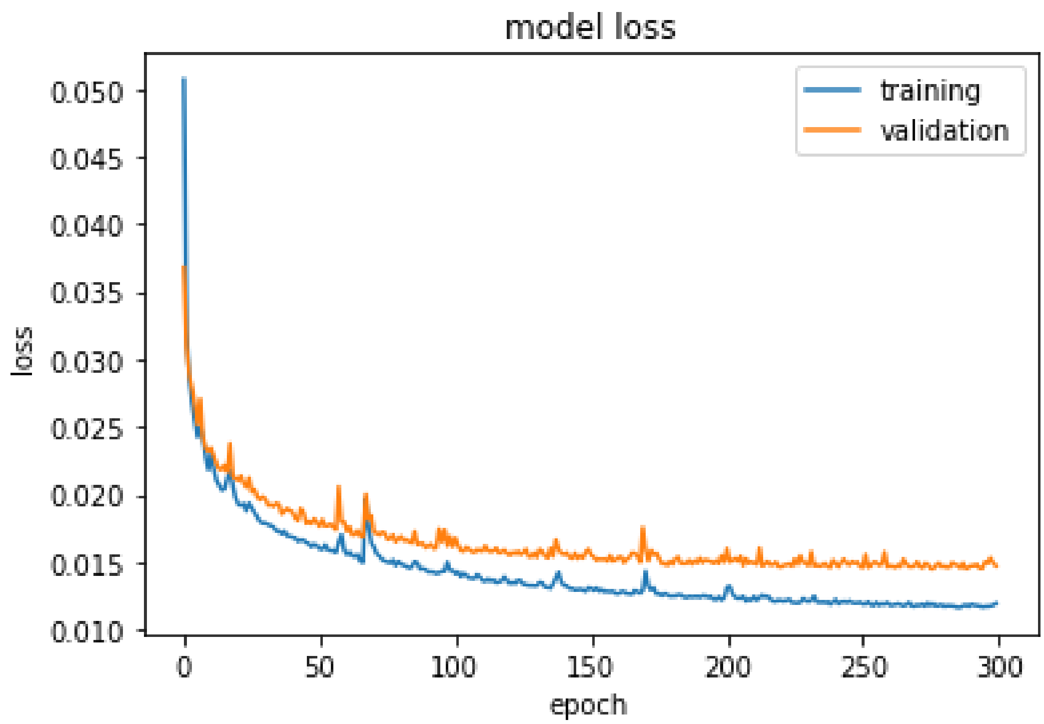
```
10113/10113 [==============================] - 0s 17us/step - loss: 0.0121 - mean_absolute_error
Epoch 222/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0121 - mean_absolute_error
Epoch 223/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0122 - mean_absolute_error
Epoch 224/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0122 - mean_absolute_error
Epoch 225/300
10113/10113 [==============================] - 0s 16us/step - loss: 0.0120 - mean_absolute_error
Epoch 226/300
10113/10113 [==============================] - 0s 16us/step - loss: 0.0120 - mean_absolute_error
Epoch 227/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0120 - mean_absolute_error
Epoch 228/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0120 - mean_absolute_error
Epoch 229/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0123 - mean_absolute_error
Epoch 230/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0122 - mean_absolute_error
Epoch 231/300
10113/10113 [==============================] - 0s 16us/step - loss: 0.0121 - mean_absolute_error
Epoch 232/300
10113/10113 [==============================] - 0s 18us/step - loss: 0.0122 - mean_absolute_error
Epoch 233/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0125 - mean_absolute_error
Epoch 234/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0121 - mean_absolute_error
Epoch 235/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0120 - mean_absolute_error
Epoch 236/300
10113/10113 [==============================] - 0s 16us/step - loss: 0.0121 - mean_absolute_error
Epoch 237/300
10113/10113 [==============================] - 0s 18us/step - loss: 0.0120 - mean_absolute_error
Epoch 238/300
10113/10113 [==============================] - 0s 19us/step - loss: 0.0121 - mean_absolute_error
Epoch 239/300
10113/10113 [==============================] - 0s 18us/step - loss: 0.0119 - mean_absolute_error
Epoch 240/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0121 - mean_absolute_error
Epoch 241/300
10113/10113 [==============================] - 0s 18us/step - loss: 0.0122 - mean_absolute_error
Epoch 242/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0119 - mean_absolute_error
Epoch 243/300
10113/10113 [==============================] - 0s 18us/step - loss: 0.0120 - mean_absolute_error
Epoch 244/300
10113/10113 [==============================] - 0s 18us/step - loss: 0.0121 - mean_absolute_error
Epoch 245/300
```

```
10113/10113 [==============================] - 0s 18us/step - loss: 0.0120 - mean_absolute_error
Epoch 246/300
10113/10113 [==============================] - 0s 18us/step - loss: 0.0121 - mean_absolute_error
Epoch 247/300
10113/10113 [==============================] - 0s 16us/step - loss: 0.0120 - mean_absolute_error
Epoch 248/300
10113/10113 [==============================] - 0s 16us/step - loss: 0.0120 - mean_absolute_error
Epoch 249/300
10113/10113 [==============================] - 0s 15us/step - loss: 0.0120 - mean_absolute_error
Epoch 250/300
10113/10113 [==============================] - 0s 16us/step - loss: 0.0120 - mean_absolute_error
Epoch 251/300
10113/10113 [==============================] - 0s 16us/step - loss: 0.0119 - mean_absolute_error
Epoch 252/300
10113/10113 [==============================] - 0s 15us/step - loss: 0.0119 - mean_absolute_error
Epoch 253/300
10113/10113 [==============================] - 0s 15us/step - loss: 0.0121 - mean_absolute_error
Epoch 254/300
10113/10113 [==============================] - 0s 15us/step - loss: 0.0118 - mean_absolute_error
Epoch 255/300
10113/10113 [==============================] - 0s 16us/step - loss: 0.0118 - mean_absolute_error
Epoch 256/300
10113/10113 [==============================] - 0s 15us/step - loss: 0.0120 - mean_absolute_error
Epoch 257/300
10113/10113 [==============================] - 0s 15us/step - loss: 0.0118 - mean_absolute_error
Epoch 258/300
10113/10113 [==============================] - 0s 16us/step - loss: 0.0119 - mean_absolute_error
Epoch 259/300
10113/10113 [==============================] - 0s 15us/step - loss: 0.0119 - mean_absolute_error
Epoch 260/300
10113/10113 [==============================] - 0s 15us/step - loss: 0.0120 - mean_absolute_error
Epoch 261/300
10113/10113 [==============================] - 0s 15us/step - loss: 0.0118 - mean_absolute_error
Epoch 262/300
10113/10113 [==============================] - 0s 16us/step - loss: 0.0118 - mean_absolute_error
Epoch 263/300
10113/10113 [==============================] - 0s 15us/step - loss: 0.0118 - mean_absolute_error
Epoch 264/300
10113/10113 [==============================] - 0s 16us/step - loss: 0.0119 - mean_absolute_error
Epoch 265/300
10113/10113 [==============================] - 0s 15us/step - loss: 0.0118 - mean_absolute_error
Epoch 266/300
10113/10113 [==============================] - 0s 16us/step - loss: 0.0118 - mean_absolute_error
Epoch 267/300
10113/10113 [==============================] - 0s 15us/step - loss: 0.0118 - mean_absolute_error
Epoch 268/300
10113/10113 [==============================] - 0s 16us/step - loss: 0.0120 - mean_absolute_error
Epoch 269/300
```

```
10113/10113 [==============================] - 0s 15us/step - loss: 0.0118 - mean_absolute_error
Epoch 270/300
10113/10113 [==============================] - 0s 15us/step - loss: 0.0117 - mean_absolute_error
Epoch 271/300
10113/10113 [==============================] - 0s 15us/step - loss: 0.0118 - mean_absolute_error
Epoch 272/300
10113/10113 [==============================] - 0s 16us/step - loss: 0.0118 - mean_absolute_error
Epoch 273/300
10113/10113 [==============================] - 0s 15us/step - loss: 0.0119 - mean_absolute_error
Epoch 274/300
10113/10113 [==============================] - 0s 15us/step - loss: 0.0117 - mean_absolute_error
Epoch 275/300
10113/10113 [==============================] - 0s 15us/step - loss: 0.0120 - mean_absolute_error
Epoch 276/300
10113/10113 [==============================] - 0s 15us/step - loss: 0.0118 - mean_absolute_error
Epoch 277/300
10113/10113 [==============================] - 0s 15us/step - loss: 0.0119 - mean_absolute_error
Epoch 278/300
10113/10113 [==============================] - 0s 15us/step - loss: 0.0117 - mean_absolute_error
Epoch 279/300
10113/10113 [==============================] - 0s 14us/step - loss: 0.0118 - mean_absolute_error
Epoch 280/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0118 - mean_absolute_error
Epoch 281/300
10113/10113 [==============================] - 0s 15us/step - loss: 0.0117 - mean_absolute_error
Epoch 282/300
10113/10113 [==============================] - 0s 15us/step - loss: 0.0118 - mean_absolute_error
Epoch 283/300
10113/10113 [==============================] - 0s 16us/step - loss: 0.0118 - mean_absolute_error
Epoch 284/300
10113/10113 [==============================] - 0s 15us/step - loss: 0.0117 - mean_absolute_error
Epoch 285/300
10113/10113 [==============================] - 0s 15us/step - loss: 0.0117 - mean_absolute_error
Epoch 286/300
10113/10113 [==============================] - 0s 15us/step - loss: 0.0116 - mean_absolute_error
Epoch 287/300
10113/10113 [==============================] - 0s 16us/step - loss: 0.0117 - mean_absolute_error
Epoch 288/300
10113/10113 [==============================] - 0s 15us/step - loss: 0.0118 - mean_absolute_error
Epoch 289/300
10113/10113 [==============================] - 0s 16us/step - loss: 0.0118 - mean_absolute_error
Epoch 290/300
10113/10113 [==============================] - 0s 15us/step - loss: 0.0117 - mean_absolute_error
Epoch 291/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0119 - mean_absolute_error
Epoch 292/300
10113/10113 [==============================] - 0s 15us/step - loss: 0.0118 - mean_absolute_error
Epoch 293/300
```

```
10113/10113 [==============================] - 0s 16us/step - loss: 0.0118 - mean_absolute_error
Epoch 294/300
10113/10113 [==============================] - 0s 15us/step - loss: 0.0117 - mean_absolute_error
Epoch 295/300
10113/10113 [==============================] - 0s 16us/step - loss: 0.0117 - mean_absolute_error
Epoch 296/300
10113/10113 [==============================] - 0s 15us/step - loss: 0.0117 - mean_absolute_error
Epoch 297/300
10113/10113 [==============================] - 0s 15us/step - loss: 0.0117 - mean_absolute_error
Epoch 298/300
10113/10113 [==============================] - 0s 14us/step - loss: 0.0118 - mean_absolute_error
Epoch 299/300
10113/10113 [==============================] - 0s 15us/step - loss: 0.0118 - mean_absolute_error
Epoch 300/300
10113/10113 [==============================] - 0s 14us/step - loss: 0.0119 - mean_absolute_error
```

```
In [55]: # summarize history for loss
         plt.plot(history.history['loss'])
         plt.plot(history.history['val_loss'])
         plt.title('model loss')
         plt.ylabel('loss')
         plt.xlabel('epoch')
         plt.legend(['training', 'validation'], loc='upper right')
         plt.show()
```



```
In [56]: loss_and_metrics = model.evaluate(X_test, y_test, batch_size=256)
         print loss_and_metrics
         y_pred = model.predict(X_test, verbose = True, batch_size=256)
```

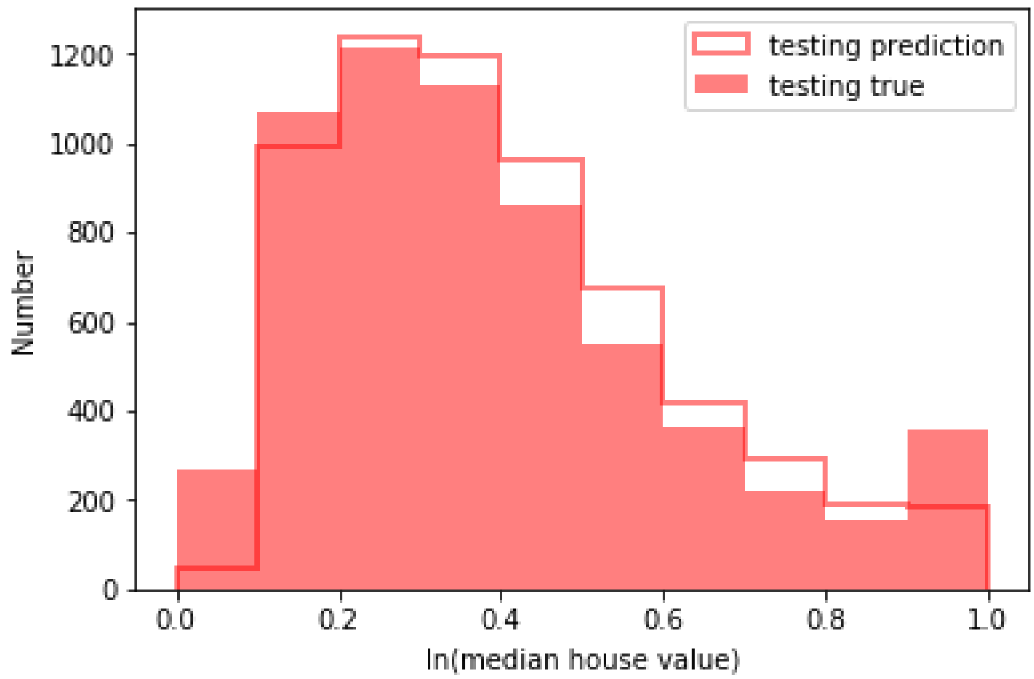
```
6192/6192 [==============================] - 0s 6us/step
[0.01388180063609082, 0.074833445847804533]
6192/6192 [==============================] - 0s 12us/step
```

```
In [57]: # Explained variance score: 1 is perfect prediction
         print('Coefficient of determination: %.2f' % r2_score(y_test, y_pred))
         # The mean squared error
         print("Mean squared error: %.2f" % mean_squared_error(y_test, y_pred))
         # The mean squared error
         print("Mean absolute error: %.2f" % mean_absolute_error(y_test, y_pred))
```

```
Coefficient of determination: 0.79
Mean squared error: 0.01
Mean absolute error: 0.07
```

```
In [58]: # predictions
         y_pred.reshape(-1)

         plt.hist(y_test, alpha=0.5, color='red', range=[0, 1], bins=10)
         plt.hist(y_pred, alpha=0.5, color='red', range=[0, 1], bins=10, histtype='step', linewi
         plt.xlabel('ln(median house value)')
         plt.ylabel('Number')
         plt.legend(['testing prediction', 'testing true'], loc='upper right')
```

```
Out[58]: <matplotlib.legend.Legend at 0x7fa6d355d990>
```



6.2 Dropout

In [59]:
```
from sklearn.model_selection import train_test_split
X_train, X_test, y_train, y_test = train_test_split(df.as_matrix(), housing.target, tes

scaler = RobustScaler(quantile_range=(25, 75))
X_train = scaler.fit_transform(X_train)
X_test = scaler.transform(X_test)

scaler_y = MinMaxScaler()
y_train = scaler_y.fit_transform(y_train.reshape(-1, 1)).reshape(-1)
y_test = scaler_y.transform(y_test.reshape(-1, 1)).reshape(-1)
y_train
```

Out[59]:
```
array([ 0.36866034,  0.31896982,  0.50474225, ...,  0.42701061,
        0.55360803,  0.63917468])
```

In [60]:
```
from keras.layers import Dropout
model = Sequential()
dropout=0.2
model.add(Dense(units=128, activation='relu', input_dim=8))
model.add(Dropout(dropout))
model.add(Dense(units=64, activation='relu'))
model.add(Dropout(dropout))
model.add(Dense(units=32, activation='relu'))
```

```
model.add(Dropout(dropout))
model.add(Dense(units=8 , activation='relu'))
model.add(Dropout(dropout))
model.add(Dense(units=1, activation='sigmoid'))
model.compile(loss='mse', optimizer='adam', metrics=['mae'])
model.summary()
```

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
dense_11 (Dense)             (None, 128)               1152
_________________________________________________________________
dropout_1 (Dropout)          (None, 128)               0
_________________________________________________________________
dense_12 (Dense)             (None, 64)                8256
_________________________________________________________________
dropout_2 (Dropout)          (None, 64)                0
_________________________________________________________________
dense_13 (Dense)             (None, 32)                2080
_________________________________________________________________
dropout_3 (Dropout)          (None, 32)                0
_________________________________________________________________
dense_14 (Dense)             (None, 8)                 264
_________________________________________________________________
dropout_4 (Dropout)          (None, 8)                 0
_________________________________________________________________
dense_15 (Dense)             (None, 1)                 9
=================================================================
Total params: 11,761
Trainable params: 11,761
Non-trainable params: 0
_________________________________________________________________
```

In [61]:
```
history = model.fit(X_train, y_train, validation_split=0.3, epochs=300, batch_size=256)
```

```
Train on 10113 samples, validate on 4335 samples
Epoch 1/300
10113/10113 [==============================] - 1s 49us/step - loss: 0.0522 - mean_absolute_error
Epoch 2/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0321 - mean_absolute_error
Epoch 3/300
10113/10113 [==============================] - 0s 19us/step - loss: 0.0260 - mean_absolute_error
Epoch 4/300
10113/10113 [==============================] - 0s 18us/step - loss: 0.0229 - mean_absolute_error
Epoch 5/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0221 - mean_absolute_error
Epoch 6/300
```

```
10113/10113 [==============================] - 0s 17us/step - loss: 0.0209 - mean_absolute_error
Epoch 7/300
10113/10113 [==============================] - 0s 16us/step - loss: 0.0203 - mean_absolute_error
Epoch 8/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0200 - mean_absolute_error
Epoch 9/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0192 - mean_absolute_error
Epoch 10/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0190 - mean_absolute_error
Epoch 11/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0189 - mean_absolute_error
Epoch 12/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0187 - mean_absolute_error
Epoch 13/300
10113/10113 [==============================] - 0s 16us/step - loss: 0.0182 - mean_absolute_error
Epoch 14/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0180 - mean_absolute_error
Epoch 15/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0175 - mean_absolute_error
Epoch 16/300
10113/10113 [==============================] - 0s 16us/step - loss: 0.0177 - mean_absolute_error
Epoch 17/300
10113/10113 [==============================] - 0s 16us/step - loss: 0.0171 - mean_absolute_error
Epoch 18/300
10113/10113 [==============================] - 0s 16us/step - loss: 0.0170 - mean_absolute_error
Epoch 19/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0171 - mean_absolute_error
Epoch 20/300
10113/10113 [==============================] - 0s 18us/step - loss: 0.0169 - mean_absolute_error
Epoch 21/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0168 - mean_absolute_error
Epoch 22/300
10113/10113 [==============================] - 0s 16us/step - loss: 0.0165 - mean_absolute_error
Epoch 23/300
10113/10113 [==============================] - 0s 16us/step - loss: 0.0165 - mean_absolute_error
Epoch 24/300
10113/10113 [==============================] - 0s 16us/step - loss: 0.0163 - mean_absolute_error
Epoch 25/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0164 - mean_absolute_error
Epoch 26/300
10113/10113 [==============================] - 0s 14us/step - loss: 0.0161 - mean_absolute_error
Epoch 27/300
10113/10113 [==============================] - 0s 16us/step - loss: 0.0160 - mean_absolute_error
Epoch 28/300
10113/10113 [==============================] - 0s 16us/step - loss: 0.0160 - mean_absolute_error
Epoch 29/300
10113/10113 [==============================] - 0s 16us/step - loss: 0.0158 - mean_absolute_error
Epoch 30/300
```

```
10113/10113 [==============================] - 0s 16us/step - loss: 0.0156 - mean_absolute_error
Epoch 31/300
10113/10113 [==============================] - 0s 16us/step - loss: 0.0154 - mean_absolute_error
Epoch 32/300
10113/10113 [==============================] - 0s 16us/step - loss: 0.0155 - mean_absolute_error
Epoch 33/300
10113/10113 [==============================] - 0s 16us/step - loss: 0.0156 - mean_absolute_error
Epoch 34/300
10113/10113 [==============================] - 0s 15us/step - loss: 0.0157 - mean_absolute_error
Epoch 35/300
10113/10113 [==============================] - 0s 16us/step - loss: 0.0159 - mean_absolute_error
Epoch 36/300
10113/10113 [==============================] - 0s 16us/step - loss: 0.0150 - mean_absolute_error
Epoch 37/300
10113/10113 [==============================] - 0s 16us/step - loss: 0.0154 - mean_absolute_error
Epoch 38/300
10113/10113 [==============================] - 0s 16us/step - loss: 0.0149 - mean_absolute_error
Epoch 39/300
10113/10113 [==============================] - 0s 16us/step - loss: 0.0149 - mean_absolute_error
Epoch 40/300
10113/10113 [==============================] - 0s 15us/step - loss: 0.0152 - mean_absolute_error
Epoch 41/300
10113/10113 [==============================] - 0s 16us/step - loss: 0.0151 - mean_absolute_error
Epoch 42/300
10113/10113 [==============================] - 0s 16us/step - loss: 0.0149 - mean_absolute_error
Epoch 43/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0149 - mean_absolute_error
Epoch 44/300
10113/10113 [==============================] - 0s 16us/step - loss: 0.0148 - mean_absolute_error
Epoch 45/300
10113/10113 [==============================] - 0s 16us/step - loss: 0.0149 - mean_absolute_error
Epoch 46/300
10113/10113 [==============================] - 0s 16us/step - loss: 0.0149 - mean_absolute_error
Epoch 47/300
10113/10113 [==============================] - 0s 16us/step - loss: 0.0147 - mean_absolute_error
Epoch 48/300
10113/10113 [==============================] - 0s 16us/step - loss: 0.0146 - mean_absolute_error
Epoch 49/300
10113/10113 [==============================] - 0s 16us/step - loss: 0.0146 - mean_absolute_error
Epoch 50/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0148 - mean_absolute_error
Epoch 51/300
10113/10113 [==============================] - 0s 16us/step - loss: 0.0145 - mean_absolute_error
Epoch 52/300
10113/10113 [==============================] - 0s 16us/step - loss: 0.0143 - mean_absolute_error
Epoch 53/300
10113/10113 [==============================] - 0s 16us/step - loss: 0.0144 - mean_absolute_error
Epoch 54/300
```

```
10113/10113 [==============================] - 0s 16us/step - loss: 0.0142 - mean_absolute_error
Epoch 55/300
10113/10113 [==============================] - 0s 16us/step - loss: 0.0141 - mean_absolute_error
Epoch 56/300
10113/10113 [==============================] - 0s 16us/step - loss: 0.0141 - mean_absolute_error
Epoch 57/300
10113/10113 [==============================] - 0s 16us/step - loss: 0.0142 - mean_absolute_error
Epoch 58/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0142 - mean_absolute_error
Epoch 59/300
10113/10113 [==============================] - 0s 16us/step - loss: 0.0143 - mean_absolute_error
Epoch 60/300
10113/10113 [==============================] - 0s 16us/step - loss: 0.0141 - mean_absolute_error
Epoch 61/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0141 - mean_absolute_error
Epoch 62/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0139 - mean_absolute_error
Epoch 63/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0141 - mean_absolute_error
Epoch 64/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0139 - mean_absolute_error
Epoch 65/300
10113/10113 [==============================] - 0s 18us/step - loss: 0.0141 - mean_absolute_error
Epoch 66/300
10113/10113 [==============================] - 0s 18us/step - loss: 0.0138 - mean_absolute_error
Epoch 67/300
10113/10113 [==============================] - 0s 18us/step - loss: 0.0140 - mean_absolute_error
Epoch 68/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0139 - mean_absolute_error
Epoch 69/300
10113/10113 [==============================] - 0s 18us/step - loss: 0.0138 - mean_absolute_error
Epoch 70/300
10113/10113 [==============================] - 0s 18us/step - loss: 0.0137 - mean_absolute_error
Epoch 71/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0139 - mean_absolute_error
Epoch 72/300
10113/10113 [==============================] - 0s 18us/step - loss: 0.0135 - mean_absolute_error
Epoch 73/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0135 - mean_absolute_error
Epoch 74/300
10113/10113 [==============================] - 0s 18us/step - loss: 0.0133 - mean_absolute_error
Epoch 75/300
10113/10113 [==============================] - 0s 18us/step - loss: 0.0138 - mean_absolute_error
Epoch 76/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0137 - mean_absolute_error
Epoch 77/300
10113/10113 [==============================] - 0s 18us/step - loss: 0.0131 - mean_absolute_error
Epoch 78/300
```

```
10113/10113 [==============================] - 0s 17us/step - loss: 0.0132 - mean_absolute_error
Epoch 79/300
10113/10113 [==============================] - 0s 18us/step - loss: 0.0135 - mean_absolute_error
Epoch 80/300
10113/10113 [==============================] - 0s 18us/step - loss: 0.0134 - mean_absolute_error
Epoch 81/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0134 - mean_absolute_error
Epoch 82/300
10113/10113 [==============================] - 0s 18us/step - loss: 0.0134 - mean_absolute_error
Epoch 83/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0133 - mean_absolute_error
Epoch 84/300
10113/10113 [==============================] - 0s 18us/step - loss: 0.0134 - mean_absolute_error
Epoch 85/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0131 - mean_absolute_error
Epoch 86/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0131 - mean_absolute_error
Epoch 87/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0131 - mean_absolute_error
Epoch 88/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0129 - mean_absolute_error
Epoch 89/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0132 - mean_absolute_error
Epoch 90/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0133 - mean_absolute_error
Epoch 91/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0133 - mean_absolute_error
Epoch 92/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0132 - mean_absolute_error
Epoch 93/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0131 - mean_absolute_error
Epoch 94/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0130 - mean_absolute_error
Epoch 95/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0130 - mean_absolute_error
Epoch 96/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0129 - mean_absolute_error
Epoch 97/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0132 - mean_absolute_error
Epoch 98/300
10113/10113 [==============================] - 0s 19us/step - loss: 0.0130 - mean_absolute_error
Epoch 99/300
10113/10113 [==============================] - 0s 18us/step - loss: 0.0130 - mean_absolute_error
Epoch 100/300
10113/10113 [==============================] - 0s 18us/step - loss: 0.0131 - mean_absolute_error
Epoch 101/300
10113/10113 [==============================] - 0s 18us/step - loss: 0.0129 - mean_absolute_error
Epoch 102/300
```

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10113/10113 [==============================] - 0s 19us/step - loss: 0.0129 - mean_absolute_error
Epoch 103/300
10113/10113 [==============================] - 0s 19us/step - loss: 0.0127 - mean_absolute_error
Epoch 104/300
10113/10113 [==============================] - 0s 16us/step - loss: 0.0129 - mean_absolute_error
Epoch 105/300
10113/10113 [==============================] - 0s 16us/step - loss: 0.0125 - mean_absolute_error
Epoch 106/300
10113/10113 [==============================] - 0s 16us/step - loss: 0.0128 - mean_absolute_error
Epoch 107/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0126 - mean_absolute_error
Epoch 108/300
10113/10113 [==============================] - 0s 16us/step - loss: 0.0125 - mean_absolute_error
Epoch 109/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0128 - mean_absolute_error
Epoch 110/300
10113/10113 [==============================] - 0s 16us/step - loss: 0.0126 - mean_absolute_error
Epoch 111/300
10113/10113 [==============================] - 0s 16us/step - loss: 0.0127 - mean_absolute_error
Epoch 112/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0128 - mean_absolute_error
Epoch 113/300
10113/10113 [==============================] - 0s 16us/step - loss: 0.0124 - mean_absolute_error
Epoch 114/300
10113/10113 [==============================] - 0s 16us/step - loss: 0.0126 - mean_absolute_error
Epoch 115/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0130 - mean_absolute_error
Epoch 116/300
10113/10113 [==============================] - 0s 16us/step - loss: 0.0126 - mean_absolute_error
Epoch 117/300
10113/10113 [==============================] - 0s 16us/step - loss: 0.0124 - mean_absolute_error
Epoch 118/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0125 - mean_absolute_error
Epoch 119/300
10113/10113 [==============================] - 0s 16us/step - loss: 0.0124 - mean_absolute_error
Epoch 120/300
10113/10113 [==============================] - 0s 16us/step - loss: 0.0126 - mean_absolute_error
Epoch 121/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0126 - mean_absolute_error
Epoch 122/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0127 - mean_absolute_error
Epoch 123/300
10113/10113 [==============================] - 0s 18us/step - loss: 0.0122 - mean_absolute_error
Epoch 124/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0124 - mean_absolute_error
Epoch 125/300
10113/10113 [==============================] - 0s 21us/step - loss: 0.0125 - mean_absolute_error
Epoch 126/300
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10113/10113 [==============================] - 0s 19us/step - loss: 0.0122 - mean_absolute_error
Epoch 127/300
10113/10113 [==============================] - 0s 15us/step - loss: 0.0122 - mean_absolute_error
Epoch 128/300
10113/10113 [==============================] - 0s 16us/step - loss: 0.0124 - mean_absolute_error
Epoch 129/300
10113/10113 [==============================] - 0s 18us/step - loss: 0.0124 - mean_absolute_error
Epoch 130/300
10113/10113 [==============================] - 0s 16us/step - loss: 0.0122 - mean_absolute_error
Epoch 131/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0126 - mean_absolute_error
Epoch 132/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0122 - mean_absolute_error
Epoch 133/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0123 - mean_absolute_error
Epoch 134/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0123 - mean_absolute_error
Epoch 135/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0123 - mean_absolute_error
Epoch 136/300
10113/10113 [==============================] - 0s 18us/step - loss: 0.0122 - mean_absolute_error
Epoch 137/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0121 - mean_absolute_error
Epoch 138/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0121 - mean_absolute_error
Epoch 139/300
10113/10113 [==============================] - 0s 16us/step - loss: 0.0121 - mean_absolute_error
Epoch 140/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0121 - mean_absolute_error
Epoch 141/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0119 - mean_absolute_error
Epoch 142/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0121 - mean_absolute_error
Epoch 143/300
10113/10113 [==============================] - 0s 17us/step - loss: 0.0121 - mean_absolute_error
Epoch 144/300
10113/10113 [==============================] - 0s 22us/step - loss: 0.0121 - mean_absolute_error
Epoch 145/300
10113/10113 [==============================] - 0s 23us/step - loss: 0.0120 - mean_absolute_error
Epoch 146/300
10113/10113 [==============================] - 0s 23us/step - loss: 0.0118 - mean_absolute_error
Epoch 147/300
10113/10113 [==============================] - 0s 23us/step - loss: 0.0120 - mean_absolute_error
Epoch 148/300
10113/10113 [==============================] - 0s 23us/step - loss: 0.0117 - mean_absolute_error
Epoch 149/300
10113/10113 [==============================] - 0s 23us/step - loss: 0.0120 - mean_absolute_error
Epoch 150/300
```

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10113/10113 [==============================] - 0s 23us/step - loss: 0.0121 - mean_absolute_error
Epoch 151/300
10113/10113 [==============================] - 0s 23us/step - loss: 0.0122 - mean_absolute_error
Epoch 152/300
10113/10113 [==============================] - 0s 23us/step - loss: 0.0121 - mean_absolute_error
Epoch 153/300
10113/10113 [==============================] - 0s 23us/step - loss: 0.0120 - mean_absolute_error
Epoch 154/300
10113/10113 [==============================] - 0s 23us/step - loss: 0.0116 - mean_absolute_error
Epoch 155/300
10113/10113 [==============================] - 0s 23us/step - loss: 0.0118 - mean_absolute_error
Epoch 156/300
10113/10113 [==============================] - 0s 24us/step - loss: 0.0118 - mean_absolute_error
Epoch 157/300
10113/10113 [==============================] - 0s 22us/step - loss: 0.0117 - mean_absolute_error
Epoch 158/300
10113/10113 [==============================] - 0s 22us/step - loss: 0.0117 - mean_absolute_error
Epoch 159/300
10113/10113 [==============================] - 0s 22us/step - loss: 0.0115 - mean_absolute_error
Epoch 160/300
10113/10113 [==============================] - 0s 23us/step - loss: 0.0118 - mean_absolute_error
Epoch 161/300
10113/10113 [==============================] - 0s 23us/step - loss: 0.0116 - mean_absolute_error
Epoch 162/300
10113/10113 [==============================] - 0s 22us/step - loss: 0.0116 - mean_absolute_error
Epoch 163/300
10113/10113 [==============================] - 0s 23us/step - loss: 0.0116 - mean_absolute_error
Epoch 164/300
10113/10113 [==============================] - 0s 22us/step - loss: 0.0118 - mean_absolute_error
Epoch 165/300
10113/10113 [==============================] - 0s 26us/step - loss: 0.0115 - mean_absolute_error
Epoch 166/300
10113/10113 [==============================] - 0s 22us/step - loss: 0.0118 - mean_absolute_error
Epoch 167/300
10113/10113 [==============================] - 0s 22us/step - loss: 0.0117 - mean_absolute_error
Epoch 168/300
10113/10113 [==============================] - 0s 23us/step - loss: 0.0116 - mean_absolute_error
Epoch 169/300
10113/10113 [==============================] - 0s 27us/step - loss: 0.0117 - mean_absolute_error
Epoch 170/300
10113/10113 [==============================] - 0s 24us/step - loss: 0.0118 - mean_absolute_error
Epoch 171/300
10113/10113 [==============================] - 0s 23us/step - loss: 0.0119 - mean_absolute_error
Epoch 172/300
10113/10113 [==============================] - 0s 23us/step - loss: 0.0116 - mean_absolute_error
Epoch 173/300
10113/10113 [==============================] - 0s 22us/step - loss: 0.0115 - mean_absolute_error
Epoch 174/300
```

```
10113/10113 [==============================] - 0s 19us/step - loss: 0.0115 - mean_absolute_error
Epoch 175/300
10113/10113 [==============================] - 0s 20us/step - loss: 0.0116 - mean_absolute_error
Epoch 176/300
10113/10113 [==============================] - 0s 20us/step - loss: 0.0117 - mean_absolute_error
Epoch 177/300
10113/10113 [==============================] - 0s 19us/step - loss: 0.0114 - mean_absolute_error
Epoch 178/300
10113/10113 [==============================] - 0s 20us/step - loss: 0.0115 - mean_absolute_error
Epoch 179/300
10113/10113 [==============================] - 0s 20us/step - loss: 0.0115 - mean_absolute_error
Epoch 180/300
10113/10113 [==============================] - 0s 19us/step - loss: 0.0114 - mean_absolute_error
Epoch 181/300
10113/10113 [==============================] - 0s 19us/step - loss: 0.0115 - mean_absolute_error
Epoch 182/300
10113/10113 [==============================] - 0s 20us/step - loss: 0.0117 - mean_absolute_error
Epoch 183/300
10113/10113 [==============================] - 0s 19us/step - loss: 0.0117 - mean_absolute_error
Epoch 184/300
10113/10113 [==============================] - 0s 20us/step - loss: 0.0114 - mean_absolute_error
Epoch 185/300
10113/10113 [==============================] - 0s 19us/step - loss: 0.0116 - mean_absolute_error
Epoch 186/300
10113/10113 [==============================] - 0s 20us/step - loss: 0.0112 - mean_absolute_error
Epoch 187/300
10113/10113 [==============================] - 0s 20us/step - loss: 0.0115 - mean_absolute_error
Epoch 188/300
10113/10113 [==============================] - 0s 19us/step - loss: 0.0113 - mean_absolute_error
Epoch 189/300
10113/10113 [==============================] - 0s 19us/step - loss: 0.0109 - mean_absolute_error
Epoch 190/300
10113/10113 [==============================] - 0s 20us/step - loss: 0.0111 - mean_absolute_error
Epoch 191/300
10113/10113 [==============================] - 0s 20us/step - loss: 0.0115 - mean_absolute_error
Epoch 192/300
10113/10113 [==============================] - 0s 20us/step - loss: 0.0114 - mean_absolute_error
Epoch 193/300
10113/10113 [==============================] - 0s 20us/step - loss: 0.0115 - mean_absolute_error
Epoch 194/300
10113/10113 [==============================] - 0s 20us/step - loss: 0.0112 - mean_absolute_error
Epoch 195/300
10113/10113 [==============================] - 0s 21us/step - loss: 0.0113 - mean_absolute_error
Epoch 196/300
10113/10113 [==============================] - 0s 20us/step - loss: 0.0117 - mean_absolute_error
Epoch 197/300
10113/10113 [==============================] - 0s 20us/step - loss: 0.0111 - mean_absolute_error
Epoch 198/300
```

```
10113/10113 [==============================] - 0s 21us/step - loss: 0.0110 - mean_absolute_error
Epoch 199/300
10113/10113 [==============================] - 0s 20us/step - loss: 0.0113 - mean_absolute_error
Epoch 200/300
10113/10113 [==============================] - 0s 20us/step - loss: 0.0110 - mean_absolute_error
Epoch 201/300
10113/10113 [==============================] - 0s 20us/step - loss: 0.0112 - mean_absolute_error
Epoch 202/300
10113/10113 [==============================] - 0s 20us/step - loss: 0.0114 - mean_absolute_error
Epoch 203/300
10113/10113 [==============================] - 0s 21us/step - loss: 0.0116 - mean_absolute_error
Epoch 204/300
10113/10113 [==============================] - 0s 20us/step - loss: 0.0111 - mean_absolute_error
Epoch 205/300
10113/10113 [==============================] - 0s 20us/step - loss: 0.0110 - mean_absolute_error
Epoch 206/300
10113/10113 [==============================] - 0s 21us/step - loss: 0.0111 - mean_absolute_error
Epoch 207/300
10113/10113 [==============================] - 0s 21us/step - loss: 0.0112 - mean_absolute_error
Epoch 208/300
10113/10113 [==============================] - 0s 19us/step - loss: 0.0110 - mean_absolute_error
Epoch 209/300
10113/10113 [==============================] - 0s 18us/step - loss: 0.0111 - mean_absolute_error
Epoch 210/300
10113/10113 [==============================] - 0s 18us/step - loss: 0.0112 - mean_absolute_error
Epoch 211/300
10113/10113 [==============================] - 0s 18us/step - loss: 0.0111 - mean_absolute_error
Epoch 212/300
10113/10113 [==============================] - 0s 18us/step - loss: 0.0112 - mean_absolute_error
Epoch 213/300
10113/10113 [==============================] - 0s 19us/step - loss: 0.0114 - mean_absolute_error
Epoch 214/300
10113/10113 [==============================] - 0s 18us/step - loss: 0.0114 - mean_absolute_error
Epoch 215/300
10113/10113 [==============================] - 0s 18us/step - loss: 0.0111 - mean_absolute_error
Epoch 216/300
10113/10113 [==============================] - 0s 18us/step - loss: 0.0110 - mean_absolute_error
Epoch 217/300
10113/10113 [==============================] - 0s 18us/step - loss: 0.0106 - mean_absolute_error
Epoch 218/300
10113/10113 [==============================] - 0s 19us/step - loss: 0.0110 - mean_absolute_error
Epoch 219/300
10113/10113 [==============================] - 0s 18us/step - loss: 0.0111 - mean_absolute_error
Epoch 220/300
10113/10113 [==============================] - 0s 18us/step - loss: 0.0113 - mean_absolute_error
Epoch 221/300
10113/10113 [==============================] - 0s 18us/step - loss: 0.0113 - mean_absolute_error
Epoch 222/300
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10113/10113 [==============================] - 0s 17us/step - loss: 0.0109 - mean_absolute_error
Epoch 223/300
10113/10113 [==============================] - 0s 18us/step - loss: 0.0110 - mean_absolute_error
Epoch 224/300
10113/10113 [==============================] - 0s 19us/step - loss: 0.0109 - mean_absolute_error
Epoch 225/300
10113/10113 [==============================] - 0s 19us/step - loss: 0.0111 - mean_absolute_error
Epoch 226/300
10113/10113 [==============================] - 0s 19us/step - loss: 0.0113 - mean_absolute_error
Epoch 227/300
10113/10113 [==============================] - 0s 20us/step - loss: 0.0110 - mean_absolute_error
Epoch 228/300
10113/10113 [==============================] - 0s 20us/step - loss: 0.0107 - mean_absolute_error
Epoch 229/300
10113/10113 [==============================] - 0s 20us/step - loss: 0.0108 - mean_absolute_error
Epoch 230/300
10113/10113 [==============================] - 0s 21us/step - loss: 0.0108 - mean_absolute_error
Epoch 231/300
10113/10113 [==============================] - 0s 20us/step - loss: 0.0110 - mean_absolute_error
Epoch 232/300
10113/10113 [==============================] - 0s 21us/step - loss: 0.0109 - mean_absolute_error
Epoch 233/300
10113/10113 [==============================] - 0s 21us/step - loss: 0.0109 - mean_absolute_error
Epoch 234/300
10113/10113 [==============================] - 0s 21us/step - loss: 0.0110 - mean_absolute_error
Epoch 235/300
10113/10113 [==============================] - 0s 20us/step - loss: 0.0109 - mean_absolute_error
Epoch 236/300
10113/10113 [==============================] - 0s 20us/step - loss: 0.0111 - mean_absolute_error
Epoch 237/300
10113/10113 [==============================] - 0s 20us/step - loss: 0.0110 - mean_absolute_error
Epoch 238/300
10113/10113 [==============================] - 0s 20us/step - loss: 0.0110 - mean_absolute_error
Epoch 239/300
10113/10113 [==============================] - 0s 20us/step - loss: 0.0108 - mean_absolute_error
Epoch 240/300
10113/10113 [==============================] - 0s 21us/step - loss: 0.0109 - mean_absolute_error
Epoch 241/300
10113/10113 [==============================] - 0s 21us/step - loss: 0.0107 - mean_absolute_error
Epoch 242/300
10113/10113 [==============================] - 0s 21us/step - loss: 0.0109 - mean_absolute_error
Epoch 243/300
10113/10113 [==============================] - 0s 24us/step - loss: 0.0111 - mean_absolute_error
Epoch 244/300
10113/10113 [==============================] - 0s 27us/step - loss: 0.0110 - mean_absolute_error
Epoch 245/300
10113/10113 [==============================] - 0s 28us/step - loss: 0.0109 - mean_absolute_error
Epoch 246/300
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10113/10113 [==============================] - 0s 28us/step - loss: 0.0109 - mean_absolute_error
Epoch 247/300
10113/10113 [==============================] - 0s 27us/step - loss: 0.0109 - mean_absolute_error
Epoch 248/300
10113/10113 [==============================] - 0s 27us/step - loss: 0.0111 - mean_absolute_error
Epoch 249/300
10113/10113 [==============================] - 0s 28us/step - loss: 0.0107 - mean_absolute_error
Epoch 250/300
10113/10113 [==============================] - 0s 27us/step - loss: 0.0108 - mean_absolute_error
Epoch 251/300
10113/10113 [==============================] - 0s 28us/step - loss: 0.0107 - mean_absolute_error
Epoch 252/300
10113/10113 [==============================] - 0s 27us/step - loss: 0.0108 - mean_absolute_error
Epoch 253/300
10113/10113 [==============================] - 0s 28us/step - loss: 0.0110 - mean_absolute_error
Epoch 254/300
10113/10113 [==============================] - 0s 27us/step - loss: 0.0108 - mean_absolute_error
Epoch 255/300
10113/10113 [==============================] - 0s 28us/step - loss: 0.0109 - mean_absolute_error
Epoch 256/300
10113/10113 [==============================] - 0s 27us/step - loss: 0.0107 - mean_absolute_error
Epoch 257/300
10113/10113 [==============================] - 0s 28us/step - loss: 0.0107 - mean_absolute_error
Epoch 258/300
10113/10113 [==============================] - 0s 28us/step - loss: 0.0108 - mean_absolute_error
Epoch 259/300
10113/10113 [==============================] - 0s 28us/step - loss: 0.0106 - mean_absolute_error
Epoch 260/300
10113/10113 [==============================] - 0s 28us/step - loss: 0.0105 - mean_absolute_error
Epoch 261/300
10113/10113 [==============================] - 0s 28us/step - loss: 0.0107 - mean_absolute_error
Epoch 262/300
10113/10113 [==============================] - 0s 28us/step - loss: 0.0110 - mean_absolute_error
Epoch 263/300
10113/10113 [==============================] - 0s 28us/step - loss: 0.0110 - mean_absolute_error
Epoch 264/300
10113/10113 [==============================] - 0s 28us/step - loss: 0.0108 - mean_absolute_error
Epoch 265/300
10113/10113 [==============================] - 0s 28us/step - loss: 0.0107 - mean_absolute_error
Epoch 266/300
10113/10113 [==============================] - 0s 28us/step - loss: 0.0107 - mean_absolute_error
Epoch 267/300
10113/10113 [==============================] - 0s 27us/step - loss: 0.0108 - mean_absolute_error
Epoch 268/300
10113/10113 [==============================] - 0s 24us/step - loss: 0.0105 - mean_absolute_error
Epoch 269/300
10113/10113 [==============================] - 0s 22us/step - loss: 0.0107 - mean_absolute_error
Epoch 270/300
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10113/10113 [==============================] - 0s 23us/step - loss: 0.0105 - mean_absolute_error
Epoch 271/300
10113/10113 [==============================] - 0s 22us/step - loss: 0.0106 - mean_absolute_error
Epoch 272/300
10113/10113 [==============================] - 0s 23us/step - loss: 0.0108 - mean_absolute_error
Epoch 273/300
10113/10113 [==============================] - 0s 24us/step - loss: 0.0105 - mean_absolute_error
Epoch 274/300
10113/10113 [==============================] - 0s 22us/step - loss: 0.0107 - mean_absolute_error
Epoch 275/300
10113/10113 [==============================] - 0s 22us/step - loss: 0.0105 - mean_absolute_error
Epoch 276/300
10113/10113 [==============================] - 0s 22us/step - loss: 0.0106 - mean_absolute_error
Epoch 277/300
10113/10113 [==============================] - 0s 23us/step - loss: 0.0106 - mean_absolute_error
Epoch 278/300
10113/10113 [==============================] - 0s 23us/step - loss: 0.0105 - mean_absolute_error
Epoch 279/300
10113/10113 [==============================] - 0s 22us/step - loss: 0.0106 - mean_absolute_error
Epoch 280/300
10113/10113 [==============================] - 0s 23us/step - loss: 0.0104 - mean_absolute_error
Epoch 281/300
10113/10113 [==============================] - 0s 23us/step - loss: 0.0105 - mean_absolute_error
Epoch 282/300
10113/10113 [==============================] - 0s 23us/step - loss: 0.0106 - mean_absolute_error
Epoch 283/300
10113/10113 [==============================] - 0s 23us/step - loss: 0.0105 - mean_absolute_error
Epoch 284/300
10113/10113 [==============================] - 0s 23us/step - loss: 0.0107 - mean_absolute_error
Epoch 285/300
10113/10113 [==============================] - 0s 23us/step - loss: 0.0108 - mean_absolute_error
Epoch 286/300
10113/10113 [==============================] - 0s 23us/step - loss: 0.0106 - mean_absolute_error
Epoch 287/300
10113/10113 [==============================] - 0s 23us/step - loss: 0.0106 - mean_absolute_error
Epoch 288/300
10113/10113 [==============================] - 0s 24us/step - loss: 0.0107 - mean_absolute_error
Epoch 289/300
10113/10113 [==============================] - 0s 23us/step - loss: 0.0106 - mean_absolute_error
Epoch 290/300
10113/10113 [==============================] - 0s 23us/step - loss: 0.0106 - mean_absolute_error
Epoch 291/300
10113/10113 [==============================] - 0s 23us/step - loss: 0.0104 - mean_absolute_error
Epoch 292/300
10113/10113 [==============================] - 0s 23us/step - loss: 0.0105 - mean_absolute_error
Epoch 293/300
10113/10113 [==============================] - 0s 23us/step - loss: 0.0107 - mean_absolute_error
Epoch 294/300
```
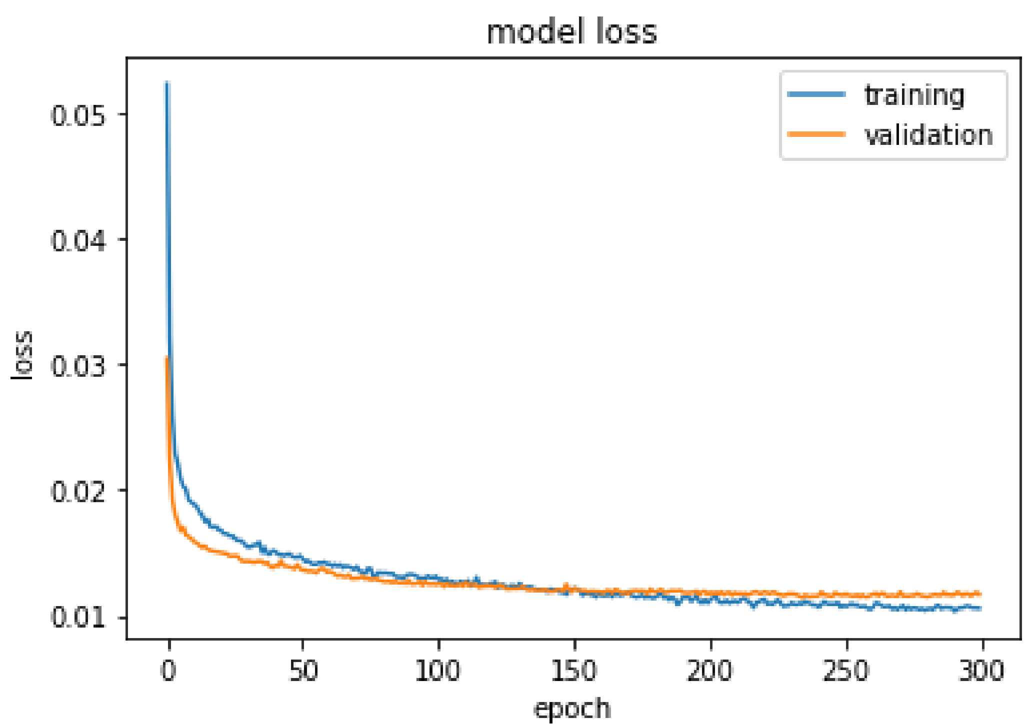

```
10113/10113 [==============================] - 0s 23us/step - loss: 0.0106 - mean_absolute_error
Epoch 295/300
10113/10113 [==============================] - 0s 23us/step - loss: 0.0108 - mean_absolute_error
Epoch 296/300
10113/10113 [==============================] - 0s 23us/step - loss: 0.0108 - mean_absolute_error
Epoch 297/300
10113/10113 [==============================] - 0s 22us/step - loss: 0.0107 - mean_absolute_error
Epoch 298/300
10113/10113 [==============================] - 0s 20us/step - loss: 0.0106 - mean_absolute_error
Epoch 299/300
10113/10113 [==============================] - 0s 20us/step - loss: 0.0106 - mean_absolute_error
Epoch 300/300
10113/10113 [==============================] - 0s 20us/step - loss: 0.0106 - mean_absolute_error
```

In [62]:
```
# summarize history for loss
plt.plot(history.history['loss'])
plt.plot(history.history['val_loss'])
plt.title('model loss')
plt.ylabel('loss')
plt.xlabel('epoch')
plt.legend(['training', 'validation'], loc='upper right')
plt.show()
```



You have to treat this result with care: The training loss is evaluated after each batch, where nodes are dropped, while the validation loss is calculated after one epoch, where all nodes are included.

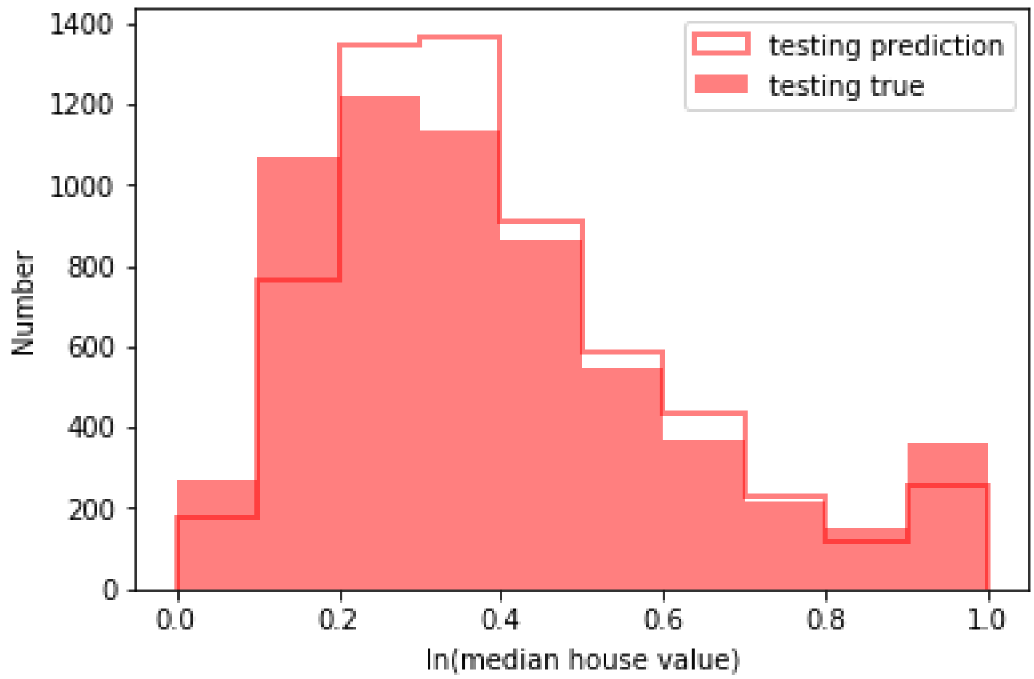
```
In [63]: loss_and_metrics = model.evaluate(X_test, y_test, batch_size=256)
         print loss_and_metrics
         y_pred = model.predict(X_test, verbose = True, batch_size=256)
```

```
6192/6192 [==============================] - 0s 5us/step
[0.01133931456109658, 0.070766112678118762]
6192/6192 [==============================] - 0s 20us/step
```

```
In [64]: # Explained variance score: 1 is perfect prediction
         print('Coefficient of determination: %.2f' % r2_score(y_test, y_pred))
         # The mean squared error
         print("Mean squared error: %.2f" % mean_squared_error(y_test, y_pred))
         # The mean squared error
         print("Mean absolute error: %.2f" % mean_absolute_error(y_test, y_pred))
```

```
Coefficient of determination: 0.80
Mean squared error: 0.01
Mean absolute error: 0.07
```

```
In [65]: # predictions
         y_pred.reshape(-1)

         plt.hist(y_test, alpha=0.5, color='red', range=[0, 1], bins=10)
         plt.hist(y_pred, alpha=0.5, color='red', range=[0, 1], bins=10, histtype='step', linewi
         plt.xlabel('ln(median house value)')
         plt.ylabel('Number')
         plt.legend(['testing prediction', 'testing true'], loc='upper right')

Out[65]: <matplotlib.legend.Legend at 0x7fa6d2d09790>
```



6.3 Task 4 (Bonus) - Playtime

- What do you need to change in the DNN if you don't scale the target vector?
- How does the result change if you use a quantile transformer with uniform output?
- How does the L1 regularizer perform?
- What happens if you change the L2 regularizer strength?
- What happens if you change the drop out percentage?
- How does the result change if you use only the 3 most important features?