

boston_housing

May 16, 2016

1 Machine Learning Engineer Nanodegree

1.1 Model Evaluation & Validation

1.2 Project 1: Predicting Boston Housing Prices

Welcome to the first project of the Machine Learning Engineer Nanodegree! In this notebook, some template code has already been written. You will need to implement additional functionality to successfully answer all of the questions for this project. Unless it is requested, do not modify any of the code that has already been included. In this template code, there are four sections which you must complete to successfully produce a prediction with your model. Each section where you will write code is preceded by a **STEP X** header with comments describing what must be done. Please read the instructions carefully!

In addition to implementing code, there will be questions that you must answer that relate to the project and your implementation. Each section where you will answer a question is preceded by a **QUESTION X** header. Be sure that you have carefully read each question and provide thorough answers in the text boxes that begin with “**Answer:**”. Your project submission will be evaluated based on your answers to each of the questions.

A description of the dataset can be found [here](#), which is provided by the **UCI Machine Learning Repository**.

2 Getting Started

To familiarize yourself with an iPython Notebook, **try double clicking on this cell**. You will notice that the text changes so that all the formatting is removed. This allows you to make edits to the block of text you see here. This block of text (and mostly anything that’s not code) is written using [Markdown](#), which is a way to format text using headers, links, italics, and many other options! Whether you’re editing a Markdown text block or a code block (like the one below), you can use the keyboard shortcut **Shift + Enter** or **Shift + Return** to execute the code or text block. In this case, it will show the formatted text.

Let’s start by setting up some code we will need to get the rest of the project up and running. Use the keyboard shortcut mentioned above on the following code block to execute it. Alternatively, depending on your iPython Notebook program, you can press the **Play** button in the hotbar. You’ll know the code block executes successfully if the message “*Boston Housing dataset loaded successfully!*” is printed.

```
In [1]: # Importing a few necessary libraries
import numpy as np
```

```

import matplotlib.pyplot as plt
from sklearn import datasets
from sklearn.tree import DecisionTreeRegressor

# Make matplotlib show our plots inline (nicely formatted in the notebook)
%matplotlib inline

# Create our client's feature set for which we will be predicting a selling
CLIENT_FEATURES = [[11.95, 0.00, 18.100, 0, 0.6590, 5.6090, 90.00, 1.385, 2

# Load the Boston Housing dataset into the city_data variable
city_data = datasets.load_boston()

# Initialize the housing prices and housing features
housing_prices = city_data.target
housing_features = city_data.data

print "Boston Housing dataset loaded successfully!"

/Users/daiwei/Library/Python/2.7/lib/python/site-packages/matplotlib/font_manager.py
warnings.warn('Matplotlib is building the font cache using fc-list. This may take

Boston Housing dataset loaded successfully!

```

3 Statistical Analysis and Data Exploration

In this first section of the project, you will quickly investigate a few basic statistics about the dataset you are working with. In addition, you'll look at the client's feature set in `CLIENT_FEATURES` and see how this particular sample relates to the features of the dataset. Familiarizing yourself with the data through an explorative process is a fundamental practice to help you better understand your results.

3.1 Step 1

In the code block below, use the imported `numpy` library to calculate the requested statistics. You will need to replace each `None` you find with the appropriate `numpy` coding for the proper statistic to be printed. Be sure to execute the code block each time to test if your implementation is working successfully. The print statements will show the statistics you calculate!

```

In [13]: # Number of houses in the dataset
total_houses = housing_prices.shape[0]

# Number of features in the dataset
total_features = housing_features.shape[1]

# Minimum housing value in the dataset

```

```

minimum_price = np.min(housing_prices)

# Maximum housing value in the dataset
maximum_price = np.max(housing_prices)

# Mean house value of the dataset
mean_price = np.mean(housing_prices)

# Median house value of the dataset
median_price = np.median(housing_prices)

# Standard deviation of housing values of the dataset
std_dev = np.std(housing_prices)

# Show the calculated statistics
print "Boston Housing dataset statistics (in $1000's):\n"
print "Total number of houses:", total_houses
print "Total number of features:", total_features
print "Minimum house price:", minimum_price
print "Maximum house price:", maximum_price
print "Mean house price: {0:.3f}".format(mean_price)
print "Median house price:", median_price
print "Standard deviation of house price: {0:.3f}".format(std_dev)

```

Boston Housing dataset statistics (in \$1000's):

```

Total number of houses: 506
Total number of features: 13
Minimum house price: 5.0
Maximum house price: 50.0
Mean house price: 22.533
Median house price: 21.2
Standard deviation of house price: 9.188

```

3.2 Question 1

As a reminder, you can view a description of the Boston Housing dataset [here](#), where you can find the different features under **Attribute Information**. The MEDV attribute relates to the values stored in our housing_prices variable, so we do not consider that a feature of the data.

Of the features available for each data point, choose three that you feel are significant and give a brief description for each of what they measure.

Remember, you can **double click the text box below** to add your answer!

Answer: I choose the DIS, B and LSTAT. The DIS measures the employment potential of this area. The B measures the safety to some extent and the LSTAT measures the average purchasing power and the level of prosperity of the town

3.3 Question 2

Using your client's feature set `CLIENT_FEATURES`, which values correspond with the features you've chosen above?

Hint: Run the code block below to see the client's data.

```
In [14]: print CLIENT_FEATURES

[[11.95, 0.0, 18.1, 0, 0.659, 5.609, 90.0, 1.385, 24, 680.0, 20.2, 332.09, 12.13]]
```

Answer: 1.385, 332.09, 12.13

4 Evaluating Model Performance

In this second section of the project, you will begin to develop the tools necessary for a model to make a prediction. Being able to accurately evaluate each model's performance through the use of these tools helps to greatly reinforce the confidence in your predictions.

4.1 Step 2

In the code block below, you will need to implement code so that the `shuffle_split_data` function does the following: - Randomly shuffle the input data `X` and target labels (housing values) `y`. - Split the data into training and testing subsets, holding 30% of the data for testing.

If you use any functions not already accessible from the imported libraries above, remember to include your import statement below as well!

Ensure that you have executed the code block once you are done. You'll know the `shuffle_split_data` function is working if the statement *"Successfully shuffled and split the data!"* is printed.

```
In [61]: # Put any import statements you need for this code block here
        from sklearn import cross_validation

        def shuffle_split_data(X, y):
            """ Shuffles and splits data into 70% training and 30% testing subsets
                then returns the training and testing subsets. """

            # Shuffle and split the data
            X_train = None
            y_train = None
            X_test = None
            y_test = None

            X_train, X_test, y_train, y_test = cross_validation.train_test_split(X, y)

            # Return the training and testing data subsets
            return X_train, y_train, X_test, y_test
```

```
# Test shuffle_split_data
try:
    X_train, y_train, X_test, y_test = shuffle_split_data(housing_features)
    print "Successfully shuffled and split the data!"
except:
    print "Something went wrong with shuffling and splitting the data."
```

Successfully shuffled and split the data!

4.2 Question 3

Why do we split the data into training and testing subsets for our model?

Answer: As we need the testing subsets to avoid overfitting or high variance when predicting

4.3 Step 3

In the code block below, you will need to implement code so that the `performance_metric` function does the following: - Perform a total error calculation between the true values of the `y` labels `y_true` and the predicted values of the `y` labels `y_predict`.

You will need to first choose an appropriate performance metric for this problem. See [the sklearn metrics documentation](#) to view a list of available metric functions. **Hint:** Look at the question below to see a list of the metrics that were covered in the supporting course for this project.

Once you have determined which metric you will use, remember to include the necessary import statement as well!

Ensure that you have executed the code block once you are done. You'll know the `performance_metric` function is working if the statement *"Successfully performed a metric calculation!"* is printed.

```
In [62]: # Put any import statements you need for this code block here
from sklearn.metrics import mean_squared_error
def performance_metric(y_true, y_predict):
    """ Calculates and returns the total error between true and predicted
        based on a performance metric chosen by the student. """

    #error = [precision_score(y_true,y_predict), recall_score(y_true,y_predict)]
    error = mean_squared_error(y_true,y_predict)
    return error

# Test performance_metric
try:
    total_error = performance_metric(y_train, y_train)
    print "Successfully performed a metric calculation!"
except:
    print "Something went wrong with performing a metric calculation."
```

Successfully performed a metric calculation!

4.4 Question 4

Which performance metric below did you find was most appropriate for predicting housing prices and analyzing the total error. Why? - Accuracy - Precision - Recall - F1 Score - Mean Squared Error (MSE) - Mean Absolute Error (MAE)

Answer: I think it's the MSE. Because the predict value is continuous, the accuracy, precision, recall and f1 score don't fit this matter. I think MSE is a little better than MAE as it's more 'soft'.

4.5 Step 4 (Final Step)

In the code block below, you will need to implement code so that the `fit_model` function does the following: - Create a scoring function using the same performance metric as in **Step 3**. See the [sklearn make_scorer documentation](#). - Build a GridSearchCV object using regressor, parameters, and scoring_function. See the [sklearn documentation on GridSearchCV](#).

When building the scoring function and GridSearchCV object, *be sure that you read the parameters documentation thoroughly*. It is not always the case that a default parameter for a function is the appropriate setting for the problem you are working on.

Since you are using sklearn functions, remember to include the necessary import statements below as well!

Ensure that you have executed the code block once you are done. You'll know the `fit_model` function is working if the statement *"Successfully fit a model to the data!"* is printed.

```
In [87]: # Put any import statements you need for this code block
        from sklearn.metrics import make_scorer, mean_squared_error
        from sklearn.grid_search import GridSearchCV

        def fit_model(X, y):
            """ Tunes a decision tree regressor model using GridSearchCV on the input
                and target labels y and returns this optimal model. """

            # Create a decision tree regressor object
            regressor = DecisionTreeRegressor()

            # Set up the parameters we wish to tune
            parameters = {'max_depth': (1, 2, 3, 4, 5, 6, 7, 8, 9, 10)}

            # Make an appropriate scoring function
            scoring_function = make_scorer(performance_metric, greater_is_better = False)

            # Make the GridSearchCV object
            reg = GridSearchCV(regressor, parameters, scoring = scoring_function)

            # Fit the learner to the data to obtain the optimal model with tuned parameters
            reg.fit(X, y)
```

```

        # Return the optimal model
        print reg.best_params_
        print reg.best_score_

    return reg.best_estimator_

# Test fit_model on entire dataset
try:
    reg = fit_model(housing_features, housing_prices)
    print "Successfully fit a model!"
except:
    print "Something went wrong with fitting a model."

{'max_depth': 4}
-36.05466437
Successfully fit a model!

```

4.6 Question 5

What is the grid search algorithm and when is it applicable?

Answer: 'Grid search algorithm do exhaustive search over specified parameter values for an estimator.', when we have chosen a specified model and want to tune the parameters of the model.

4.7 Question 6

What is cross-validation, and how is it performed on a model? Why would cross-validation be helpful when using grid search?

Answer: Cross-validation is a method which we cut the datasets into training and testing sets to validate the performance of our algorithm. It mainly reduces overfitting of the data. The cross-validation can avoid the grid search finds the best score which has high variance results.

5 Checkpoint!

You have now successfully completed your last code implementation section. Pat yourself on the back! All of your functions written above will be executed in the remaining sections below, and questions will be asked about various results for you to analyze. To prepare the **Analysis** and **Prediction** sections, you will need to initialize the two functions below. Remember, there's no need to implement any more code, so sit back and execute the code blocks! Some code comments are provided if you find yourself interested in the functionality.

```

In [27]: def learning_curves(X_train, y_train, X_test, y_test):
        """ Calculates the performance of several models with varying sizes of
            The learning and testing error rates for each model are then plotted

```

```

print "Creating learning curve graphs for max_depths of 1, 3, 6, and 10"

# Create the figure window
fig = plt.figure(figsize=(10,8))

# We will vary the training set size so that we have 50 different sizes
sizes = np.rint(np.linspace(1, len(X_train), 50)).astype(int)
train_err = np.zeros(len(sizes))
test_err = np.zeros(len(sizes))

# Create four different models based on max_depth
for k, depth in enumerate([1,3,6,10]):

    for i, s in enumerate(sizes):

        # Setup a decision tree regressor so that it learns a tree with depth
        regressor = DecisionTreeRegressor(max_depth = depth)

        # Fit the learner to the training data
        regressor.fit(X_train[:s], y_train[:s])

        # Find the performance on the training set
        train_err[i] = performance_metric(y_train[:s], regressor.predict(X_train[:s]))

        # Find the performance on the testing set
        test_err[i] = performance_metric(y_test, regressor.predict(X_train[:s]))

    # Subplot the learning curve graph
    ax = fig.add_subplot(2, 2, k+1)
    ax.plot(sizes, test_err, lw = 2, label = 'Testing Error')
    ax.plot(sizes, train_err, lw = 2, label = 'Training Error')
    ax.legend()
    ax.set_title('max_depth = %s'%(depth))
    ax.set_xlabel('Number of Data Points in Training Set')
    ax.set_ylabel('Total Error')
    ax.set_xlim([0, len(X_train)])

# Visual aesthetics
fig.suptitle('Decision Tree Regressor Learning Performances', fontsize=16)
fig.tight_layout()
fig.show()

In [28]: def model_complexity(X_train, y_train, X_test, y_test):
        """ Calculates the performance of the model as model complexity increases.
            The learning and testing errors rates are then plotted. """

        print "Creating a model complexity graph. . . "

```



```

# We will vary the max_depth of a decision tree model from 1 to 14
max_depth = np.arange(1, 14)
train_err = np.zeros(len(max_depth))
test_err = np.zeros(len(max_depth))

for i, d in enumerate(max_depth):
    # Setup a Decision Tree Regressor so that it learns a tree with depth d
    regressor = DecisionTreeRegressor(max_depth = d)

    # Fit the learner to the training data
    regressor.fit(X_train, y_train)

    # Find the performance on the training set
    train_err[i] = performance_metric(y_train, regressor.predict(X_train))

    # Find the performance on the testing set
    test_err[i] = performance_metric(y_test, regressor.predict(X_test))

# Plot the model complexity graph
plt.figure(figsize=(7, 5))
plt.title('Decision Tree Regressor Complexity Performance')
plt.plot(max_depth, test_err, lw=2, label = 'Testing Error')
plt.plot(max_depth, train_err, lw=2, label = 'Training Error')
plt.legend()
plt.xlabel('Maximum Depth')
plt.ylabel('Total Error')
plt.show()

```

6 Analyzing Model Performance

In this third section of the project, you'll take a look at several models' learning and testing error rates on various subsets of training data. Additionally, you'll investigate one particular algorithm with an increasing `max_depth` parameter on the full training set to observe how model complexity affects learning and testing errors. Graphing your model's performance based on varying criteria can be beneficial in the analysis process, such as visualizing behavior that may not have been apparent from the results alone.

In [29]: `learning_curves(X_train, y_train, X_test, y_test)`

```

Creating learning curve graphs for max_depths of 1, 3, 6, and 10. . .
0.0
141.596907895
2.82483333333
96.2802122807
14.9968888889
58.9663961988
17.344187291
58.9723506229

```

18.6570505952
56.0895596186
29.4001402027
48.3164332314
30.3992897727
48.7924722451
29.6228197035
48.1840818294
28.3863755136
47.9928423503
30.0583856749
47.9673974119
28.1261035631
48.1560535474
27.1294601716
48.2227185884
26.1006964033
48.1462586472
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48.2892324667
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29.0785387931
48.0242442434
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48.0271056759
28.7848174472
48.0650448792
30.4410371771
52.3063249229
31.6549073573
52.3731012323
32.4818150021
52.3614645453
34.0633519154
52.7195436996
33.9285905066
52.4989361937
33.0948731641
52.4299568146
33.2707189516
52.46329767
33.3459370312
52.4151439739
36.1316929902
52.2804233564

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52.3559563742
37.9646660552
62.545840603
37.4263543178
62.5394248111
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50.8743064869
41.6590726377
54.8167555483
41.5267086552
62.5354328062
40.9535529055
62.611014749
42.6807432735
50.9935109804
43.3643730917
51.0478611002
44.2894509518
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44.7336553938
52.268490199
44.4685492593
52.2645094288
44.9516432375
52.2772987182
45.1756551542
52.3360726045
45.2381794953
52.3560839192
45.7216570168
54.7043103109
45.7111090396
48.1764385959
45.4922219199
48.177394641
45.4560262702
51.1033072299
44.9208486367
51.0582649134
44.9726872904
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0.0
141.596907895
0.04
88.5482236842

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41.427185225
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36.1941670023
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3.36183838384
27.741687167
3.33366666667
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3.65113950456
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3.86513793396
26.6483618984
4.31163549318
25.1368448852
4.34303422619
25.6903879584
4.80010827487
24.0671415334
6.53061342985
32.647678146
6.28470545141
24.1029821189
6.10893933955
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6.00627148914
26.6554038723
6.60468662427
25.3385060003
6.98992113739
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11.9634975651
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11.9740865379
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11.0996863899
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27.0712077802
12.7612489392
27.0833492458
12.6954144603
27.0912827701
14.8060820483
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13.2118755828
27.0365966548
13.3131352477
27.1420256374
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17.1861294103
14.8642029292
24.6659851473
12.690436934
28.1091616034

0.0
141.596907895
0.0
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0.0
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42.6862828947
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0.172306306306
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0.139529220779
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30.9526204904
1.3974255262
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25.0617624142

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24.6146637435
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0.0216117021277
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0.0584523809524
29.4591081871
0.0495221674877
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0.0525724867725
26.0069224578
0.0896198156682
23.6554612939
0.163300324675
23.8001925507
0.218112631184
22.2899381783
0.250771161893
28.9725480402
0.366452800361
33.8310718303
0.391148820218
39.233137439
0.270479405888
16.6785840111
0.318346686895
14.9307284574
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0.349274317645
25.5901841644
0.331628373702
25.5177543545
0.364476270914
25.4468999612
0.453548010652
24.4513205077
0.445312225564
27.0725220839
0.377758586718
27.2059275818
0.609025811966
25.1075823825

```

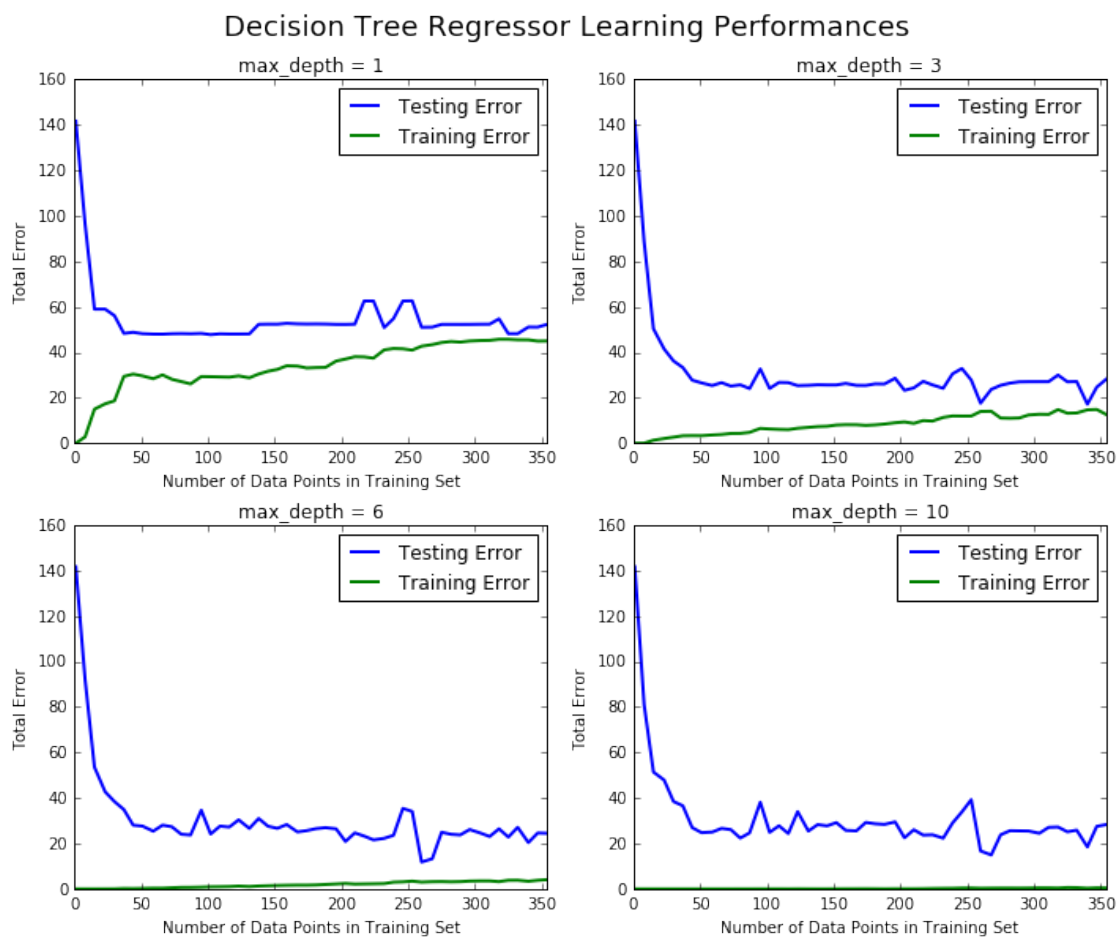
0.557571619813
25.8320439246
0.293397961842
18.4624461813
0.469976546472
27.4840550899
0.417463911716
28.2754034733

```

```

/Users/daiwei/Library/Python/2.7/lib/python/site-packages/matplotlib/figure.py:397:
"matplotlib is currently using a non-GUI backend, "

```



6.1 Question 7

Choose one of the learning curve graphs that are created above. What is the max depth for the chosen model? As the size of the training set increases, what happens to the training error? What happens to the testing error?

Answer: I choose the model with max depth 6. As the size of the training set increases, training error becomes a little bigger and become converged at the end and testing error reduces a lot at the begining and become converged at the end.

6.2 Question 8

Look at the learning curve graphs for the model with a max depth of 1 and a max depth of 10. When the model is using the full training set, does it suffer from high bias or high variance when the max depth is 1? What about when the max depth is 10?

Answer: it suffers from high bias when the max depth is 1, while suffers from high variance when the max depth is 10

```
In [30]: model_complexity(X_train, y_train, X_test, y_test)
```

```
Creating a model complexity graph. . .
```

```
44.9726872904
52.265274531
23.697567073
31.4246885545
12.690436934
28.1091616034
8.53315122323
25.2075663706
6.08283428208
24.0791033011
4.07990155031
23.5074023597
2.62738745508
27.5231351809
1.38433800626
25.8674768149
0.799187982725
30.4734712805
0.417463911716
25.4908514996
0.16510791633
27.9346215511
0.0551713319637
29.6996547752
0.00783400591875
27.6332891261
```



6.3 Question 9

From the model complexity graph above, describe the training and testing errors as the max depth increases. Based on your interpretation of the graph, which max depth results in a model that best generalizes the dataset? Why?

Answer: As the max depth increases, training error reduces fast at the beginning and converged to a small value near zero at the end while testing error reduces fast at the beginning and converged to a certatin error at about 6 in x-axis. I think the max depth 6 may best generalizes the datasets because at this point, the testing curve gets its lowest and the training error is lower than 10 and its really acceptable.

7 Model Prediction

In this final section of the project, you will make a prediction on the client's feature set using an optimized model from `fit_model`. When applying grid search along with cross-validation to optimize your model, it would typically be performed and validated on a training set and subsequently evaluated on a **dedicated test set**. In this project, the optimization below is performed on the *entire dataset* (as opposed to the training set you made above) due to the many outliers in the data. Using the entire dataset for training provides for a less volatile prediction at the expense of not testing your model's performance.

To answer the following questions, it is recommended that you run the code blocks several times and use the median or mean value of the results.

7.1 Question 10

Using grid search on the entire dataset, what is the optimal `max_depth` parameter for your model? How does this result compare to your initial intuition?

Hint: Run the code block below to see the max depth produced by your optimized model.

```
In [80]: print "Final model has an optimal max_depth parameter of", reg.get_params()

Final model has an optimal max_depth parameter of 7
```

Answer: The optimal `max_depth` parameter for my model is 4, it's a little smaller than my initial intuition.

7.2 Question 11

With your parameter-tuned model, what is the best selling price for your client's home? How does this selling price compare to the basic statistics you calculated on the dataset?

Hint: Run the code block below to have your parameter-tuned model make a prediction on the client's home.

```
In [88]: sale_price = reg.predict(CLIENT_FEATURES)
         print "Predicted value of client's home: {0:.3f}".format(sale_price[0])

Predicted value of client's home: 21.630
```

Answer: The best selling price for my client's home is 21.630. It's near the mean housing price and the median housing price.

7.3 Question 12 (Final Question):

In a few sentences, discuss whether you would use this model or not to predict the selling price of future clients' homes in the Greater Boston area.

Answer: I would use this model to predict the selling price of future clients. From learning curve its training error and testing error are acceptable. Additionally, I got different results between 4 and 8 when I ran the function `fit_model`. I tried 10 times and got 4 more often than others. And the predict answer with the parameter 4 got the answer near the median housing price so I think it's got a higher probability to be the best prediction.