CS 178 HW 2

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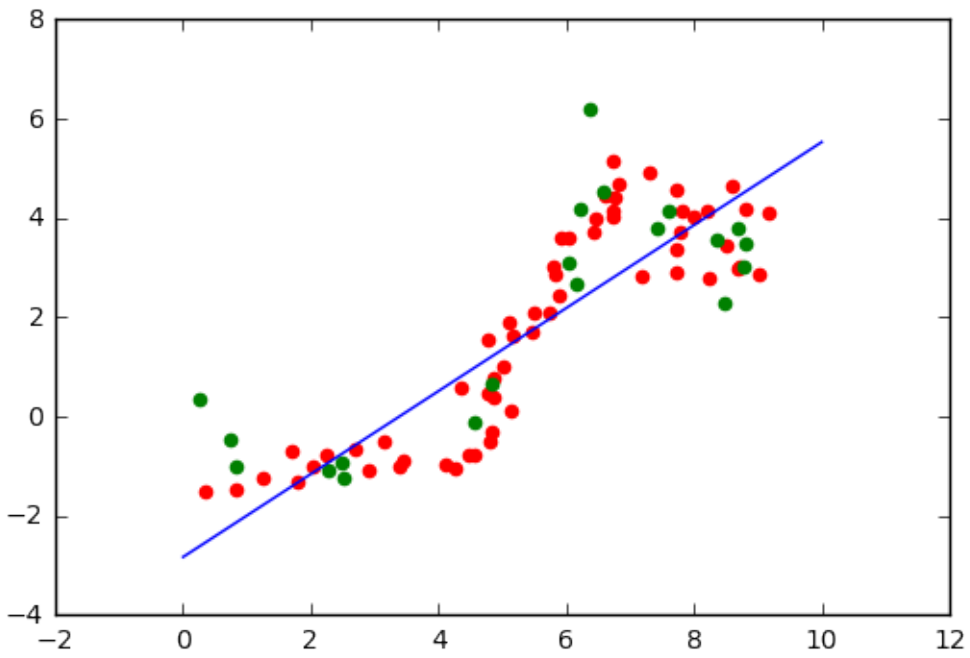
1.1 Problem 1: Linear Regression

In [1]:
```
import numpy as np
import matplotlib.pyplot as plt
import mltools as ml

# Problem 1: Linear Regression

# 1a
data = np.genfromtxt("data/curve80.txt",delimiter=None)

X = data[:,0]
X = X[:,np.newaxis]
Y = data[:,1]
Xtr,Xte,Ytr,Yte = ml.splitData(X,Y,0.75)

# 1b
lr = ml.linear.linearRegress(Xtr,Ytr)
xs = np.linspace(0,10,200)
xs = xs[:,np.newaxis]
ys = lr.predict(xs)

print("Green = Test Data, Red = Training Data")
plt.scatter(Xtr,Ytr,color = "red")
plt.scatter(Xte,Yte,color = "green")
plt.plot(xs,ys,)
ax = plt.axis()
plt.show()
print("Linear Regression Coefficients: "+str(lr.theta))
mseTe = lr.mse(Xte,Yte)
mseTr = lr.mse(Xtr,Ytr)

print("Mean Square Error of Test Data: "+str(mseTe))
print("Mean Square Error of Training Data: "+str(mseTr))
```

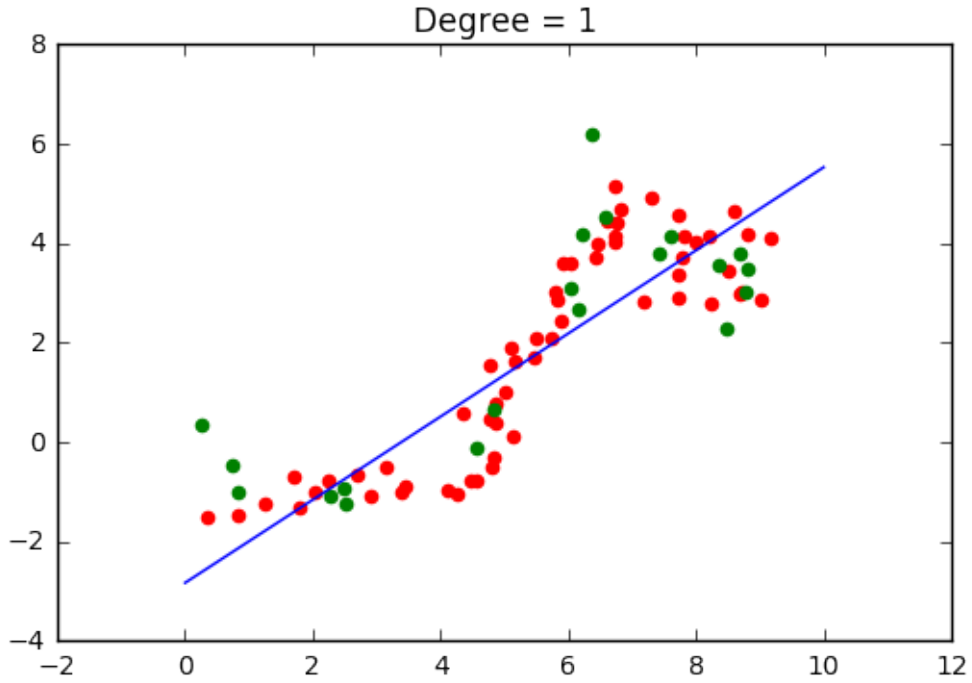
```
Green = Test Data, Red = Training Data
```

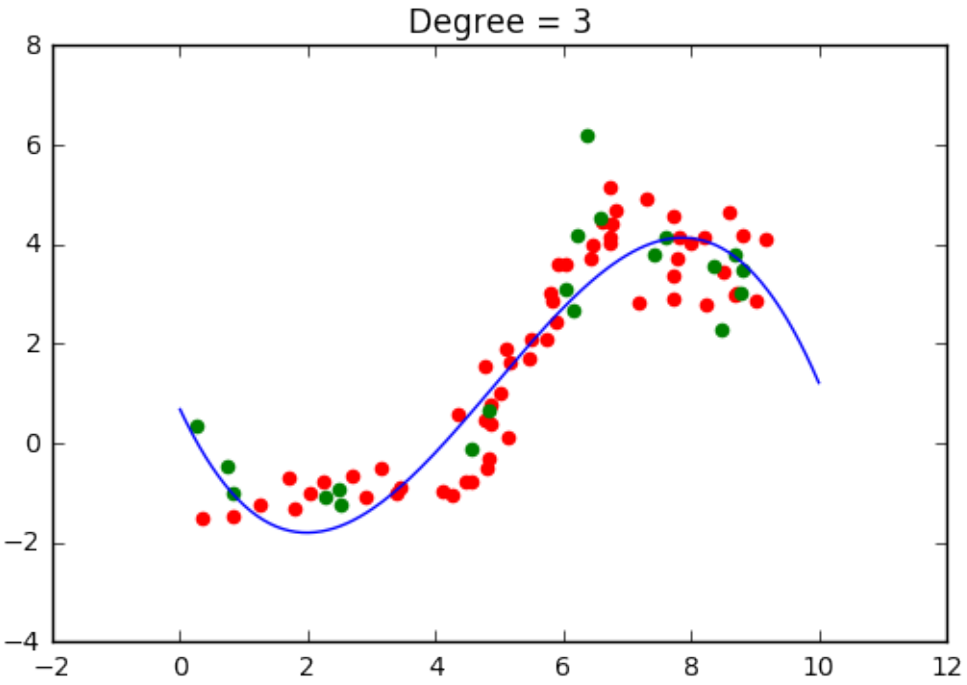


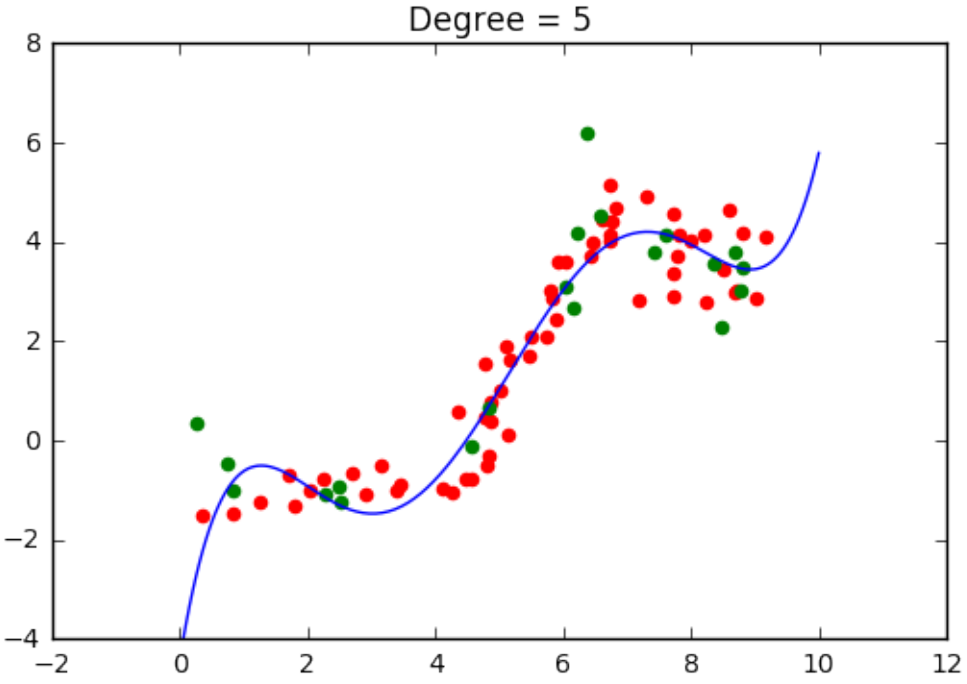

```
Linear Regression Coefficients: [[-2.82765049  0.83606916]]
Mean Square Error of Test Data: 2.24234920301
Mean Square Error of Training Data: 1.12771195561
```

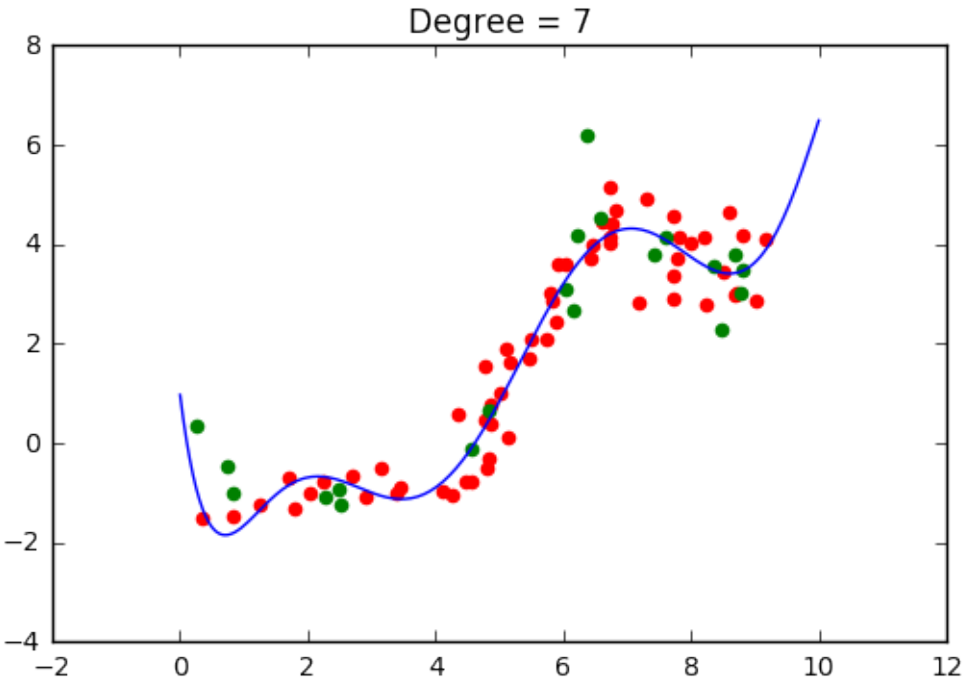
```
In [2]: # 1c
        degrees = [1,3,5,7,10,18]
        mseTeList = []
        mseTrList = []

        for degree in degrees:

            XtrP = ml.transforms.fpoly(Xtr,degree,bias=False)

            XtrP,params = ml.transforms.rescale(XtrP)

            lr = ml.linear.linearRegress(XtrP,Ytr)

            XteP,params = ml.transforms.rescale(ml.transforms.fpoly(Xte,degree,
                                                                    False),params)

            Phi = lambda X: ml.transforms.rescale(ml.transforms.fpoly(X,degree,
                                                                  False),params)[0]
```

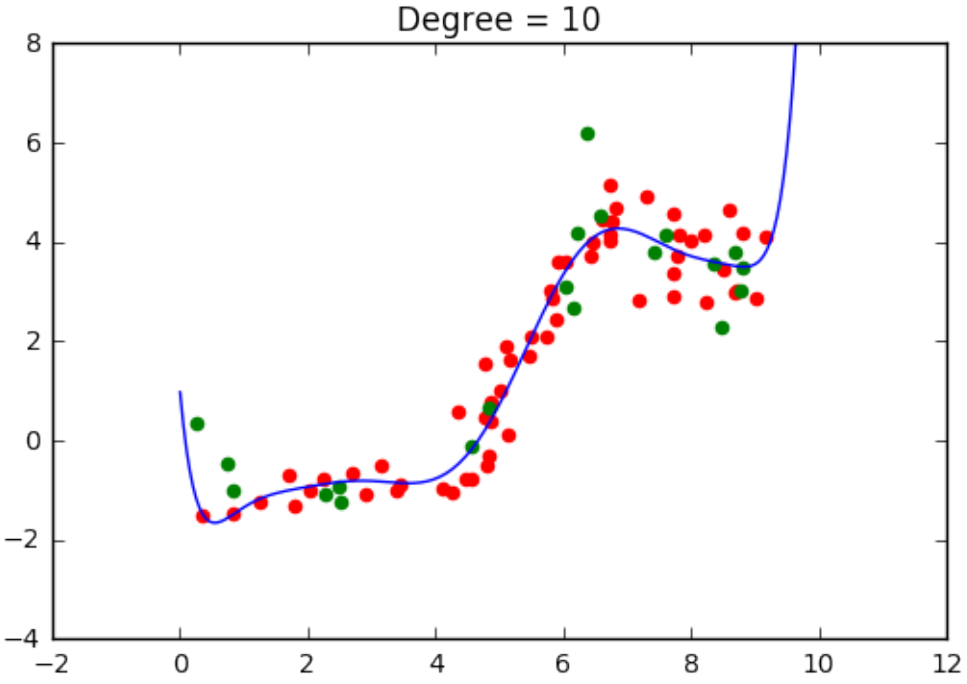
```
        YhatTrain = lr.predict(Phi(xs))
        YhatTest = lr.predict(Phi(Xte))

        plt.plot(xs,YhatTrain)
        plt.scatter(Xtr,Ytr,color = "red")
        plt.scatter(Xte,Yte,color = "green")
        plt.axis(ax)
        plt.title("Degree = "+str(degree))
        plt.show()

        mseTe = lr.mse(Phi(Xte),Yte)
        mseTr = lr.mse(Phi(Xtr),Ytr)

        mseTeList.append(mseTe)
        mseTrList.append(mseTr)

plt.title("Test MSE vs Training MSE")
plt.ylabel("MSE")
plt.xlabel("Degree")
plt.semilogy(degrees,mseTeList,'g-',degrees,mseTrList,'r-')
plt.show()
print("Green = Test Data, Red = Training Data")
```

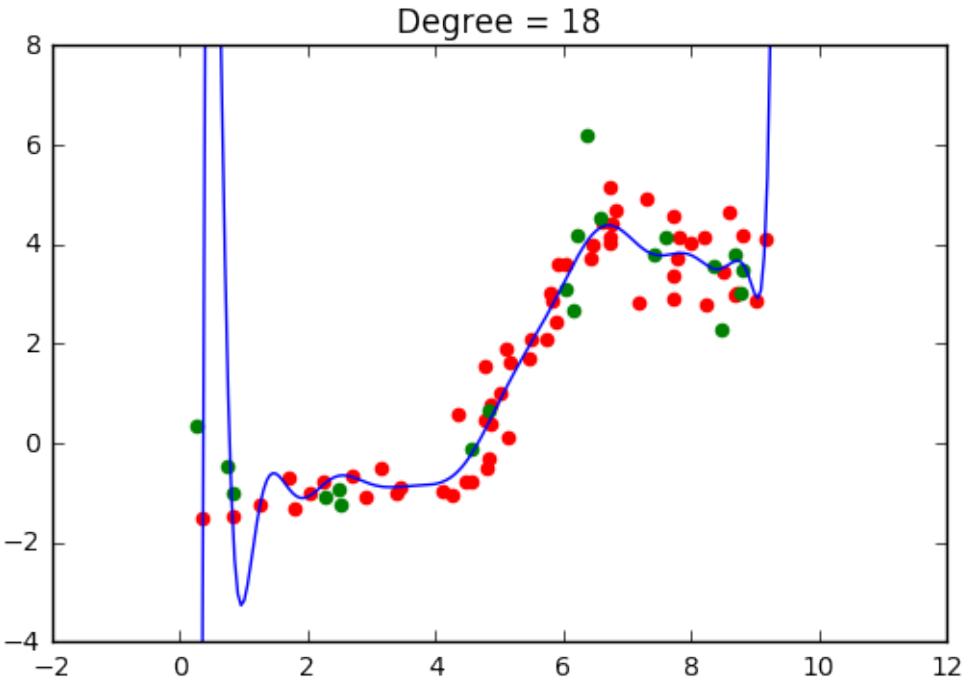


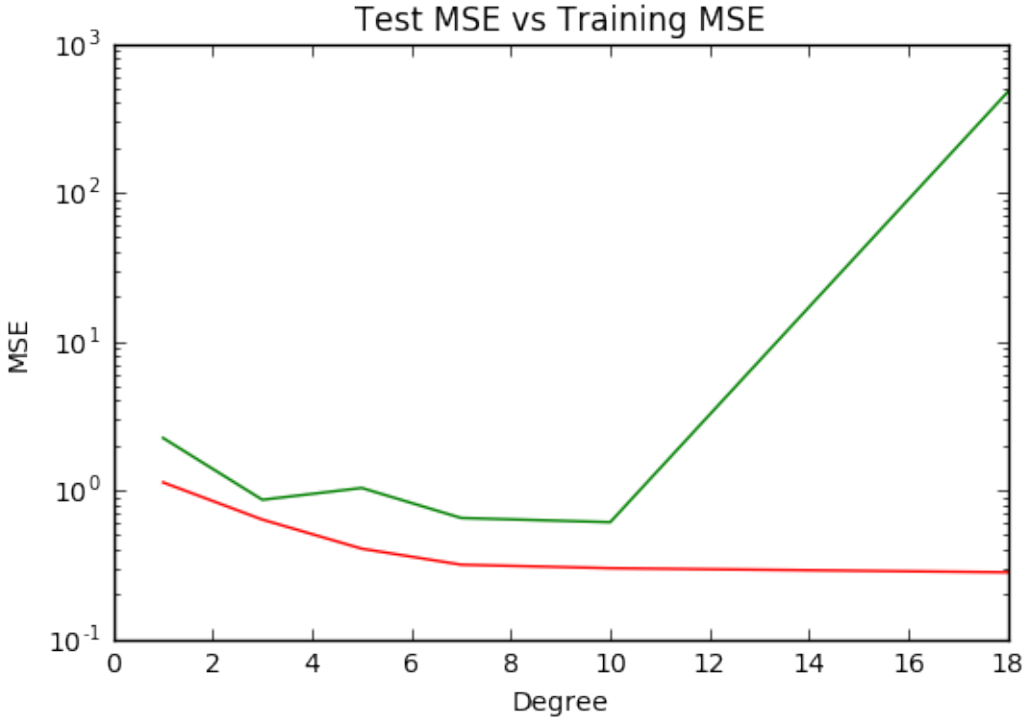

Degree = 3
8
6
4
2
0
−2
−4
−2
0
2
4
6
8
10
12


Degree = 5
8
6
4
2
0
−2
−4
−2
0
2
4
6
8
10
12


Degree = 7
8
6
4
2
0
−2
−4
−2
0
2
4
6
8
10
12


Degree = 10
8
6
4
2
0
−2
−4
−2
0
2
4
6
8
10
12

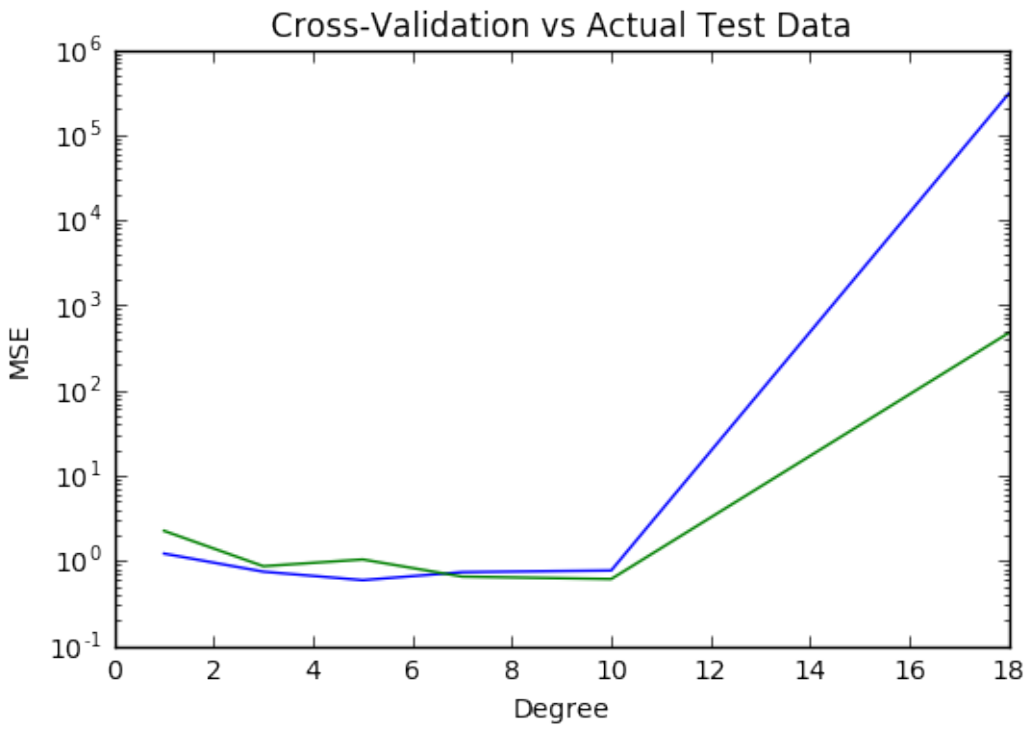

Degree = 18
8
6
4
2
0
−2
−4
−2
0
2
4
6
8
10
12


Test MSE vs Training MSE
MSE
10^3
10^2
10^1
10^0
10^{-1}
0
2
4
6
8
10
12
14
16
18
Degree

```
Green = Test Data, Red = Training Data
```

1.2 Problem 2: Cross-Validation

```
In [3]: #Problem 2: Cross-validation

        nFolds = 5;
        J = []

        for degree in degrees:

            temp = [0,0,0,0,0]
            for iFold in range(nFolds):
                Xti,Xvi,Yti,Yvi = ml.crossValidate(Xtr,Ytr,nFolds,iFold)

                XtiP = ml.transforms.fpoly(Xti,degree,bias=False)

                XtiP,params = ml.transforms.rescale(XtiP)

                XtiP,params = ml.transforms.rescale(ml.transforms.fpoly(Xti,degree,
                                                                        False),params)
                Phi = lambda X: ml.transforms.rescale(ml.transforms.fpoly(X,degree,
                                                                        False),params)[0]
                learner = ml.linear.linearRegress(XtiP,Yti)
                temp[iFold] = (learner.mse(Phi(Xvi),Yvi))
            J.append(np.mean(temp))

        plt.title("Cross-Validation vs Actual Test Data")
        plt.ylabel("MSE")
        plt.xlabel("Degree")
        plt.semilogy(degrees,J,'b-',degrees,mseTeList,'g-')
        plt.show()
        print("Blue = Cross-Validation, Green = Actual Test Data")

        '''
        According to the graph, degree 5 has the minimum cross-validation error.
        The MSE estimated from cross-validation is higher compared to the actual
        test data on higher degrees. Starting from around 10 degrees and
        higher the Cross-Validation data begins to have a much higher MSE
        and is overfitting earlier. This is why at lower degrees
        Cross-Validation has lower MSE but it quickly raises to high levels
        faster than the Test Data.
        '''
```



Blue = Cross-Validation, Green = Actual Test Data