Miles Benjamin CS 6140 Homework 1 ¶

Just start at the top and start running in order. If you want to go back start at the beginning of the section to make sure that the variables are initialized properly. Hope this works well for you!

In [1]:
```
import numpy as np
import math
import scipy as sp
import matplotlib.pyplot as plt
import scipy.io as scio

%matplotlib inline
```

Importing all the libraries

10 part 1

going to start by generating a dataset for which I know an approximate regression

In [89]:

```
X_trn = []
for i in range(20):
    X_trn.append([1,i])


    # Making a data set of approx  y = 1.5x to test the algorithm
sp.random.seed(123)
Y_trn = []
for i in range(len(X_trn)):
    Y_trn.append(X_trn[i][1] * (sp.rand(1) + 1))

X_tst = []
for i in range(100):
    X_tst.append([1,i - 50])

Y_tst = []
for i in range(len(X_tst)):
    Y_tst.append(X_tst[i][1] * (sp.rand(1) + 1))


plt.subplot(2,1,1)
plt.title('Y = 1.5X training')
plt.plot(X_trn, Y_trn)

plt.subplot(2,1,2)
plt.title('Y = 1.5X testing')
plt.plot(X_tst, Y_tst)
plt.tight_layout(pad=0.4, w_pad=0.5, h_pad=1.0)
```

In [90]:
```
def calcCFTheta(X,Y):
    inver = np.dot(X.T, X)
    xy = np.dot(X.T, Y)
    theta = np.dot(np.linalg.inv(inver), xy)


    return theta
```

In [91]:
```
def computeCost(X, Y, theta):

    cost = np.power(np.linalg.norm((X*theta - Y), 2))
    #print("cost: ", cost)
    return cost
```

In [92]:
```
def gradientDescent(X, Y, theta, lrnRate, ittr, batch):
    #print(X, Y, theta, lrnRate)
    m = len(Y)


    for i in range(ittr):
        miniX = []
        miniY = []
        for j in range(batch):
            batchIdx = math.floor((sp.rand(1) * m)[0])

            miniX.append(X.A[batchIdx])
            miniY.append(Y.A[batchIdx])

        miniX = np.mat(miniX)
        miniY = np.mat(miniY)


        theta = theta - (lrnRate/m) * (miniX.T * (miniX * theta - miniY)
        #print(theta)

    return theta
```

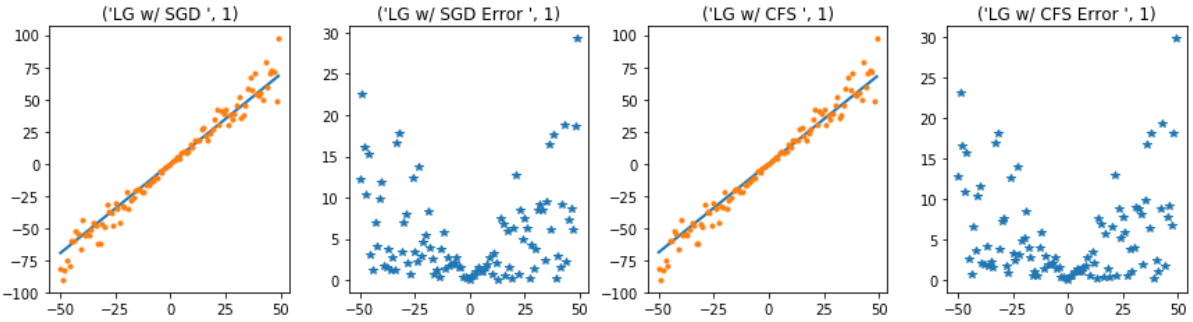
In [96]:
```
def outputRegression(theta1, theta2, X_tst, Y_tst, n):
    print('GD Theta: ', theta1, '\n CF Theta: ', theta2)

    plt.figure(figsize=(12, 3*n))

    for i in range(n):
        if (i != 0):
            # Get the right X feature column
            c = (i-1) *4

            X_test_Col = np.mat([np.array(X_tst)[:, i]])
            X_test_Col = X_test_Col.T


            # Plot Stochastic Gradient Descent
            plt.subplot(n,4,c+1)
            title = 'LG w/ SGD ', i
            plt.title(title)
            plt.plot(X_test_Col, X_test_Col * theta1[i], linewidth = 2)
            plt.plot(X_test_Col, Y_tst, '.')

            # Plot error for SGD
            plt.subplot(n,4,c+2)
            title = 'LG w/ SGD Error ', i
            plt.title(title)
            plt.plot(X_test_Col, abs(Y_tst - (X_test_Col * theta1[i])),

            # Plot Closed Form Solution
            plt.subplot(n,4,c+3)
            title = 'LG w/ CFS ', i
            plt.title(title)
            plt.plot(X_test_Col, X_test_Col * theta2[i], linewidth = 2)
            plt.plot(X_test_Col, Y_tst, '.')

            # Plot CFS Error
            plt.subplot(n,4,c+4)
            title = 'LG w/ CFS Error ', i
            plt.title(title)
            plt.plot(X_test_Col, abs(Y_tst - (X_test_Col * theta2[i])),

            plt.tight_layout(pad=0.4, w_pad=0.5, h_pad=1.0)
```

In [97]:
```
def linRegress(X_trn, Y_trn, X_tst, Y_tst, ittr, lrnRate, batch, n):
    m = len(X_trn)  # number of training samples (should be 20)

    X = np.mat(X_trn)
    Y = np.mat(Y_trn)
    theta1 = [0] * n

    theta1 = np.mat(theta1).T

    theta1 = gradientDescent(X, Y, theta1, lrnRate, ittr, batch)
    theta2 = calcCFTheta(X,Y)
    outputRegression(theta1, theta2, X_tst, Y_tst, n)
```

In [143]:
```
def nFeatureizeData(X, n):
    X_out = []

    for i in range(len(X)):
        temp = []
        for j in range(n + 1):
            temp.append(np.power(X[i][0],j))

        X_out.append(temp)


    return X_out;
```

In [98]:
```
batch = 4
ittr = 2000
lrnRate = 0.01
n = 2
linRegress(X_trn, Y_trn, X_tst, Y_tst, ittr, lrnRate, batch, n)
```

```
GD Theta:  [[ 0.46088082]
 [ 1.39017333]]
 CF Theta:  [[ 0.65462812]
 [ 1.37924891]]
```



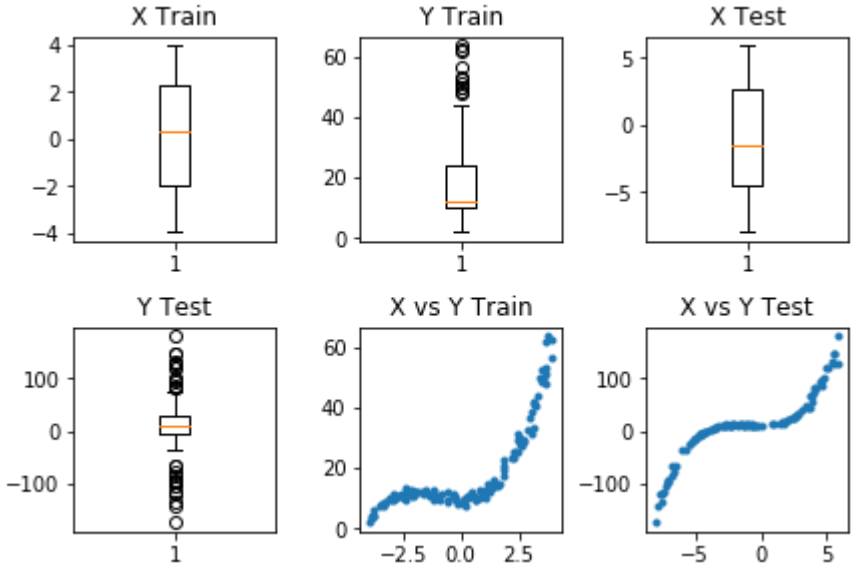
10 part 2

In [144]:
```
mat = scio.loadmat('HW1_Data/dataset1.mat')

X_trn = mat['X_trn']
Y_trn = mat['Y_trn']
X_tst = mat['X_tst']
Y_tst = mat['Y_tst']
data = [X_trn,Y_trn,X_tst,Y_tst]
```

In [100]:
```
print('shape of the X data is [%d, %d]' % X_trn.shape)
print('shape of the Y data is [%d, %d]' % Y_trn.shape)
```

```
shape of the X data is [120, 1]
shape of the Y data is [120, 1]
```

In [101]:
```
data_labels = ['X Train', 'Y Train', 'X Test', 'Y Test']

for x in range(4):
    plt.subplot(2,3,x +1)
    plt.boxplot(data[x])
    plt.title(data_labels[x])

plt.subplot(2,3,5)
plt.plot(X_trn, Y_trn, '.')
plt.title("X vs Y Train")

plt.subplot(2,3,6)
plt.plot(X_tst, Y_tst, '.')
plt.title("X vs Y Test")

plt.tight_layout(pad=0.4, w_pad=0.5, h_pad=1.0)
```

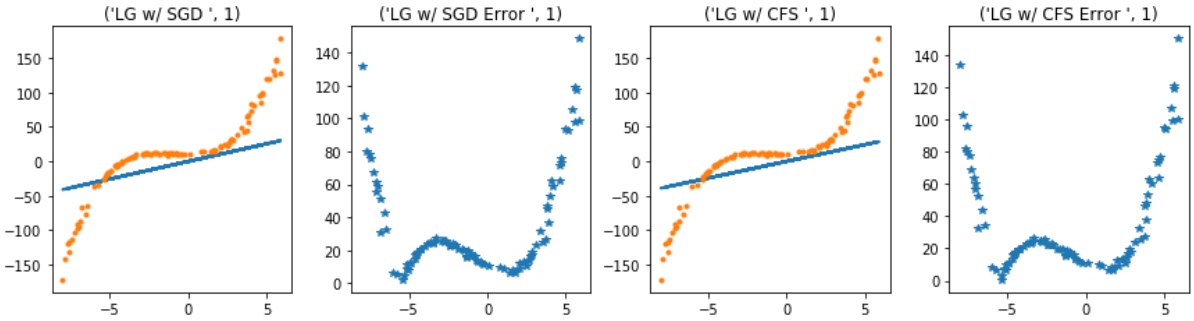


N = 1

I know I don't have to do this, but I was curious

In [145]:
```
n = 1
batch = 4
ittr = 2000
lrnRate = 0.01
features = n + 1
linRegress(nFeatureizeData(X_trn, n), Y_trn, nFeatureizeData(X_tst, n),
```

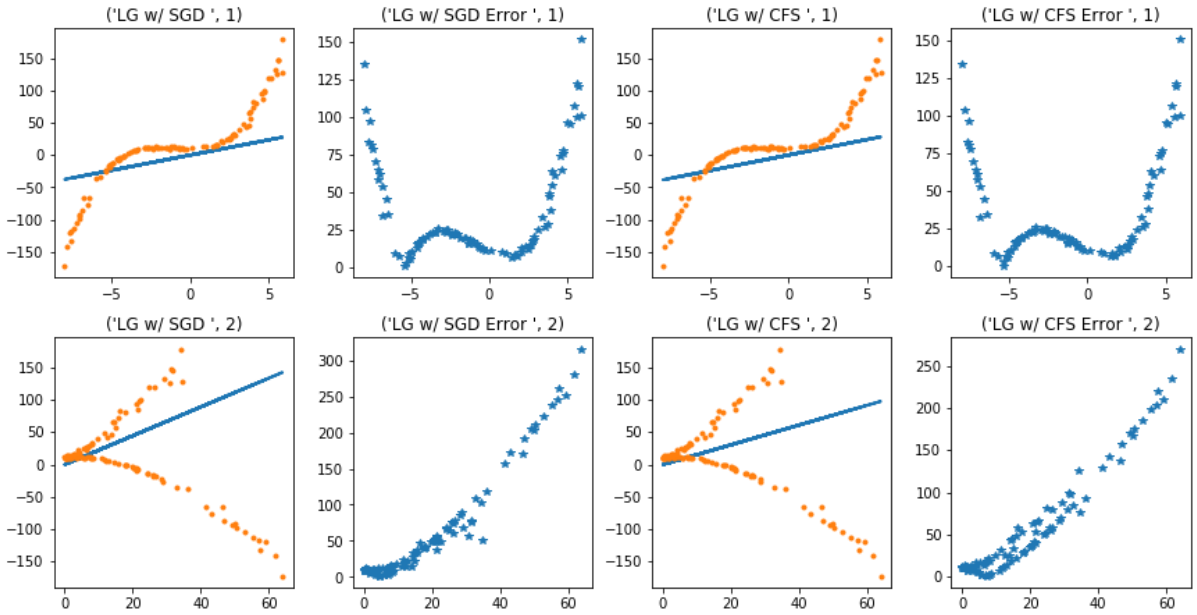
```
GD Theta:  [[ 8.76170969]
 [ 5.12283991]]
 CF Theta:  [[ 17.81209242]
 [  4.8607913 ]]
```



For N = 2

In [146]:
```
n = 2
batch = 4
ittr = 2000
lrnRate = 0.01
features = n + 1
linRegress(nFeatureizeData(X_trn, n), Y_trn, nFeatureizeData(X_tst, n), 
```

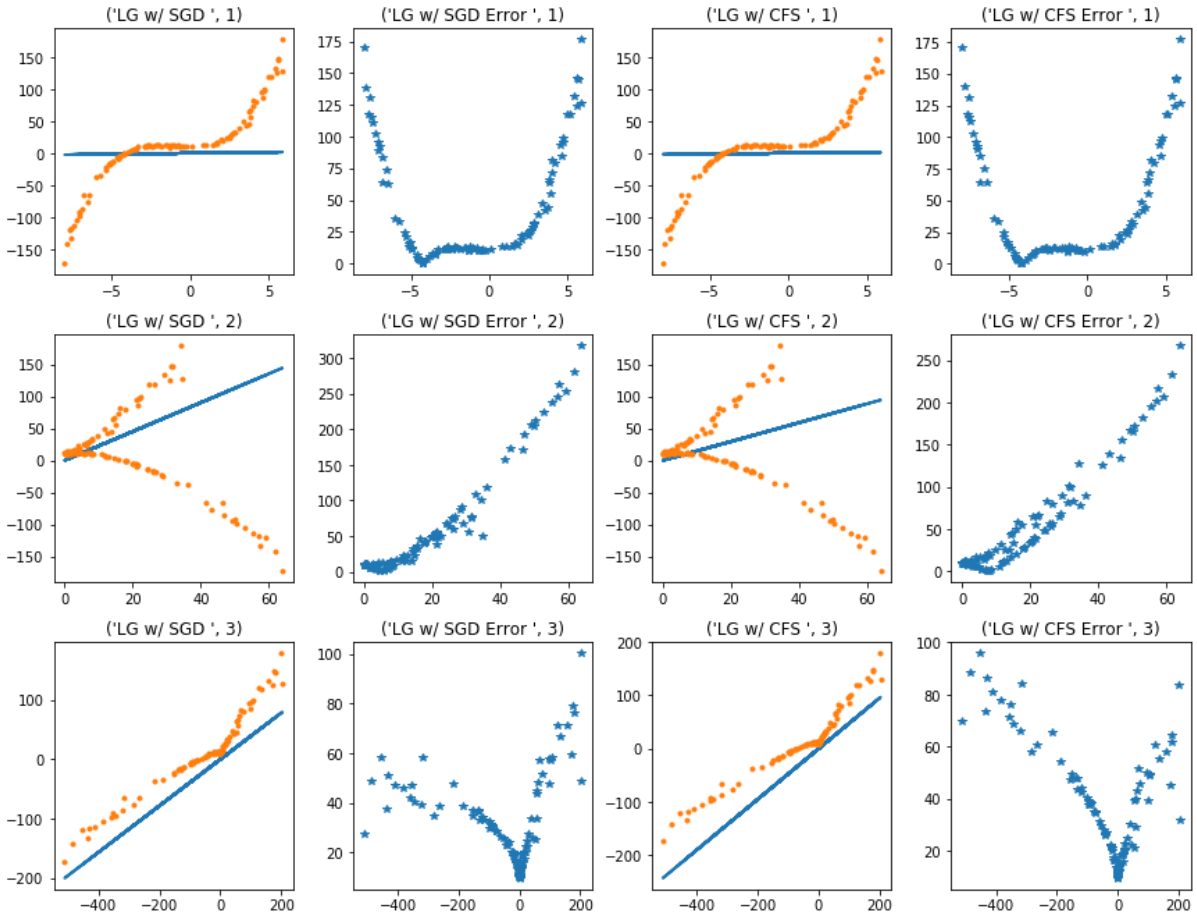
```
GD Theta:  [[ 2.60594924]
 [ 4.70017367]
 [ 2.22991393]]
 CF Theta:  [[ 9.49203678]
 [ 4.79191663]
 [ 1.52906587]]
```



For N = 3

In [147]:
```
n = 3
batch = 4
ittr = 2000
lrnRate = 0.01
features = n + 1
linRegress(nFeatureizeData(X_trn, n), Y_trn, nFeatureizeData(X_tst, n), 
```

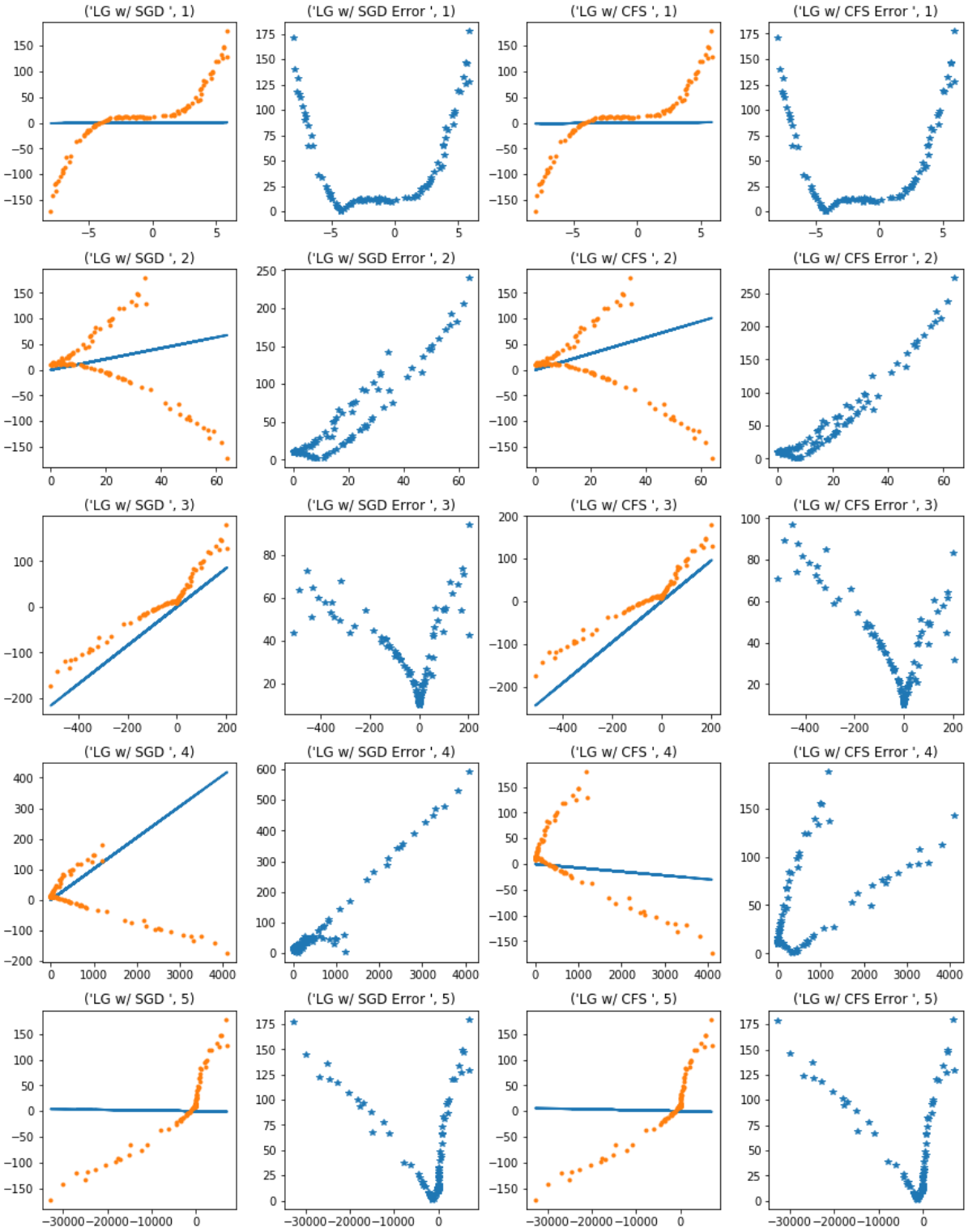
```
GD Theta:  [[ 2.70779825]
 [ 0.30743738]
 [ 2.25590356]
 [ 0.39081937]]
 CF Theta:  [[ 10.00815033]
 [  0.20418927]
 [  1.47413164]
 [  0.47320168]]
```



For N = 5

In [148]:
```
n = 5
batch = 4
ittr = 20000
lrnRate = 0.0001
features = n + 1
linRegress(nFeatureizeData(X_trn, n), Y_trn, nFeatureizeData(X_tst, n), Y

# I had to really tone down the learning rate and turn up the itterations
# it appears that there is a direct correlation between the size of n and
```

```
GD Theta:  [[  4.85328498e-01]
 [  1.35269865e-01]
 [  1.05553575e+00]
 [  4.21730646e-01]
 [  1.02181622e-01]
 [ -1.24677512e-04]]
 CF Theta:  [[  9.84545670e+00]
 [  2.03644970e-01]
 [  1.57564738e+00]
 [  4.75176601e-01]
 [ -7.40094164e-03]
 [ -1.77139419e-04]]
```


('LG w/ SGD ', 1)
('LG w/ SGD Error ', 1)
('LG w/ CFS ', 1)
('LG w/ CFS Error ', 1)
('LG w/ SGD ', 2)
('LG w/ SGD Error ', 2)
('LG w/ CFS ', 2)
('LG w/ CFS Error ', 2)
('LG w/ SGD ', 3)
('LG w/ SGD Error ', 3)
('LG w/ CFS ', 3)
('LG w/ CFS Error ', 3)
('LG w/ SGD ', 4)
('LG w/ SGD Error ', 4)
('LG w/ CFS ', 4)
('LG w/ CFS Error ', 4)
('LG w/ SGD ', 5)
('LG w/ SGD Error ', 5)
('LG w/ CFS ', 5)
('LG w/ CFS Error ', 5)

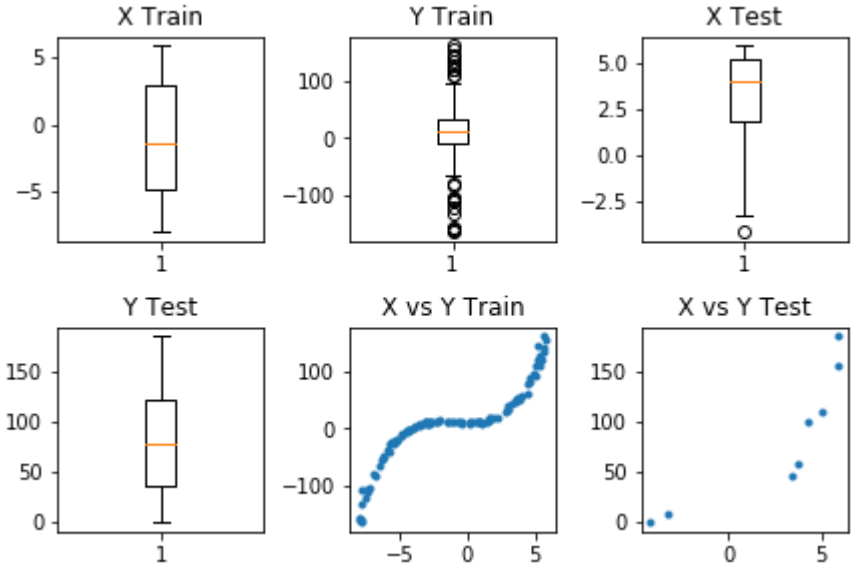
10.3

In [149]:
```
mat = scio.loadmat('HW1_Data/dataset2.mat')

X_trn = mat['X_trn']
Y_trn = mat['Y_trn']
X_tst = mat['X_tst']
Y_tst = mat['Y_tst']
data = [X_trn,Y_trn,X_tst,Y_tst]
```

In [150]:
```
print('shape of the X data is [%d, %d]' % X_trn.shape)
print('shape of the Y data is [%d, %d]' % Y_trn.shape)
```

```
shape of the X data is [100, 1]
shape of the Y data is [100, 1]
```

In [157]:
```
data_labels = ['X Train', 'Y Train', 'X Test', 'Y Test']

for x in range(4):
    plt.subplot(2,3,x +1)
    plt.boxplot(data[x])
    plt.title(data_labels[x])

plt.subplot(2,3,5)
plt.plot(X_trn, Y_trn, '.')
plt.title("X vs Y Train")

plt.subplot(2,3,6)
plt.plot(X_tst, Y_tst, '.')
plt.title("X vs Y Test")

plt.tight_layout(pad=0.4, w_pad=0.5, h_pad=1.0)
```



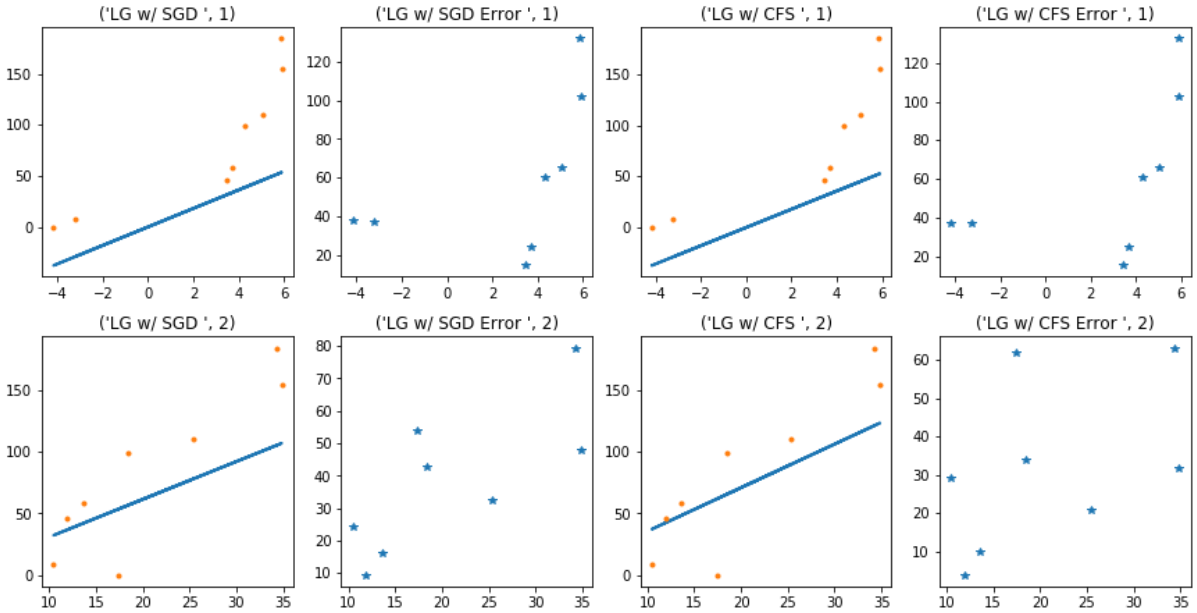
In [208]:
```
def calcCFRidge(X,Y,lam):
    #print(lam, X, Y)
    inver = np.dot(X.T, X) + (lam * np.identity(len(X[0])))
    xy = np.dot(X.T, Y)
    theta = np.dot(np.linalg.inv(inver), xy)

    return theta
```

In [292]:
```
def kCrossValid(X,Y,lams,c):
    # I just did K=N cross validation.  I didn't have time to generalize

    thetas = []
    holdOuts = []

    for i in range(len(lams)):
        X_test = []
        Y_test = []
        for j in range(len(X)):
            if (j != i):
                X_test.append(X[j])
                Y_test.append(Y[j])
        X_test = np.mat(X_test)
        Y_test = np.mat(Y_test)
        if (c == 1):
            thetas.append(calcCFRidge(X_test,Y_test,lams[i]))
        if (c == 0):
            dummytheta = [0] * len(X[0])
            dummytheta = np.mat(dummytheta).T
            #print(dummytheta)
            thetas.append(gradDescentRidge(X_test,Y_test,dummytheta, 0.0

        holdOuts.append(abs(Y[i] - X[i]*thetas[i]))
    holdOuts = np.asarray(holdOuts)
    #print(np.argmin(holdOuts))


    return lams[np.argmin(holdOuts)]
```

In [293]:
```
def gradDescentRidge(X, Y, theta, lrnRate, lams, ittr, batch):
    #print(X, Y, theta, lrnRate)
    m = len(Y)


    for i in range(ittr):
        miniX = []
        miniY = []
        for j in range(batch):
            batchIdx = math.floor((sp.rand(1) * m)[0])

            miniX.append(X.A[batchIdx])
            miniY.append(Y.A[batchIdx])

        miniX = np.mat(miniX)
        miniY = np.mat(miniY)

        #print("\ntheta: ", theta, "\nminiX: ", miniX, "\nminiY: ", mini
        theta = theta - (lrnRate/m) * ((miniX.T * (miniX * theta - miniY


    return theta
```

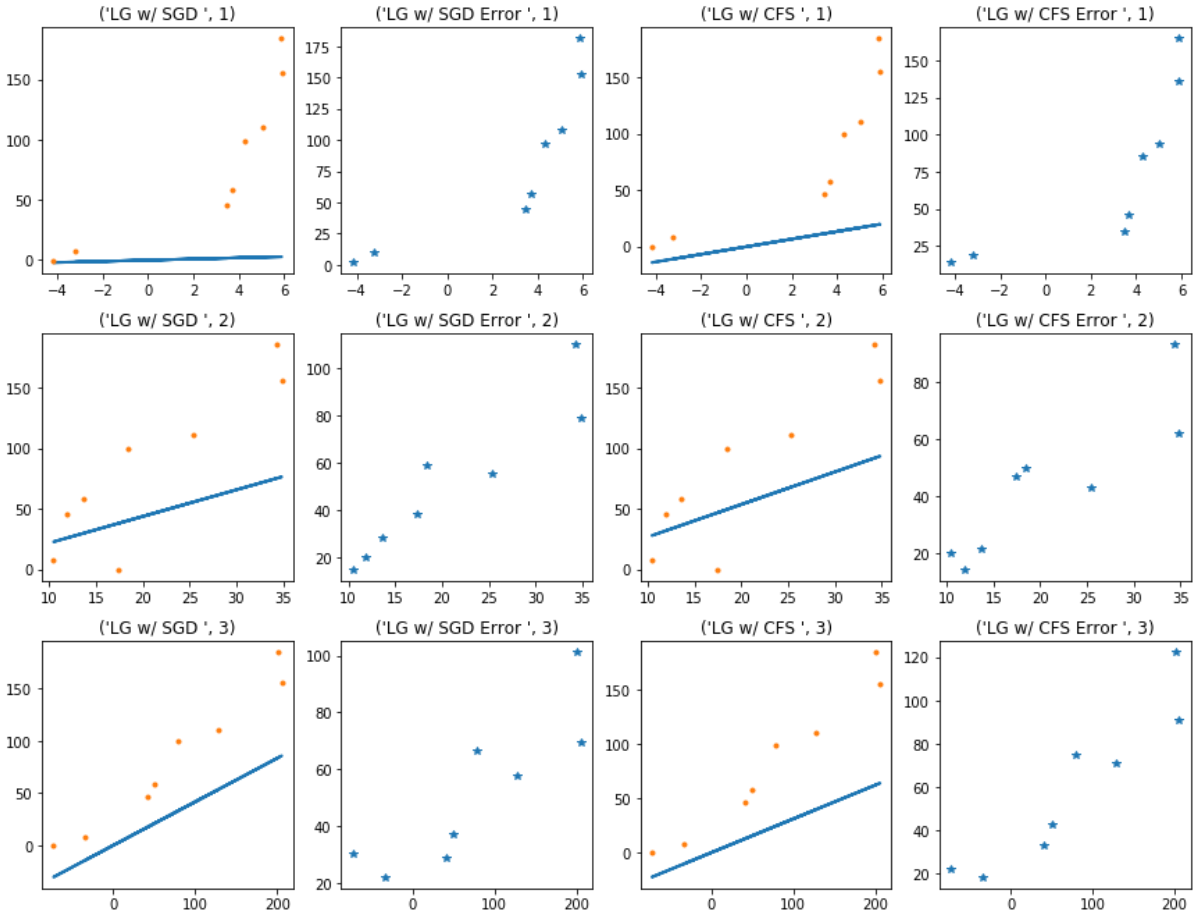
In [297]:
```
N = [2]

for k in range(len(N)):

    X_temp = nFeatureizeData(X_trn, N[k])

    sp.random.seed(123)
    lams = []
    for i in range(len(X_temp)):
        lams.append(sp.rand(1) * 10)


    lam2 = kCrossValid(X_temp, Y_trn, np.asarray(lams), 1)[0]
    lam1 = kCrossValid(X_temp, Y_trn, np.asarray(lams), 0)[0]


    X = nFeatureizeData(X_tst, N[k])

    theta1 = [0] * (N[k] +1)

    theta1 = np.mat(theta1).T

    theta1 = gradDescentRidge(np.mat(X), np.mat(Y_tst), np.mat(theta1), (
    print("Stocastic Grad Descent")
    print("lambda: ", lam1, " theta: ", theta1)

    theta2 = calcCFRidge(np.mat(X), np.mat(Y_tst), lam1)
    print("Closed Form Solution")
    print("lambda: ", lam2, " theta: ", theta2)


    outputRegression(theta1, theta2, X, Y_tst, N[k] + 1)
```

```
Stocastic Grad Descent
lambda:  42.6351306963  theta:  [[-2.83651949]
 [ 9.07501993]
 [ 3.07809323]]
Closed Form Solution
lambda:  1.6129206695  theta:  [[-12.76880157]
 [  8.932615  ]
 [  3.55154316]]
GD Theta:  [[-2.83651949]
 [ 9.07501993]
 [ 3.07809323]]
 CF Theta:  [[-12.76880157]
 [  8.932615  ]
 [  3.55154316]]
```


('LG w/ SGD ', 1)
('LG w/ SGD Error ', 1)
('LG w/ CFS ', 1)
('LG w/ CFS Error ', 1)
('LG w/ SGD ', 2)
('LG w/ SGD Error ', 2)
('LG w/ CFS ', 2)
('LG w/ CFS Error ', 2)

In [295]:
```
N = [3]

for k in range(len(N)):

    X_temp = nFeatureizeData(X_trn, N[k])

    sp.random.seed(123)
    lams = []
    for i in range(len(X_temp)):
        lams.append(sp.rand(1) * 10)


    lam2 = kCrossValid(X_temp, Y_trn, np.asarray(lams), 1)[0]
    lam1 = kCrossValid(X_temp, Y_trn, np.asarray(lams), 0)[0]


    X = nFeatureizeData(X_tst, N[k])

    theta1 = [0] * (N[k] +1)

    theta1 = np.mat(theta1).T

    theta1 = gradDescentRidge(np.mat(X), np.mat(Y_tst), np.mat(theta1), (
    print("Stocastic Grad Descent")
    print("lambda: ", lam1, " theta: ", theta1)

    theta2 = calcCFRidge(np.mat(X), np.mat(Y_tst), lam1)
    print("Closed Form Solution")
    print("lambda: ", lam2, " theta: ", theta2)


    outputRegression(theta1, theta2, X, Y_tst, N[k] + 1)
```

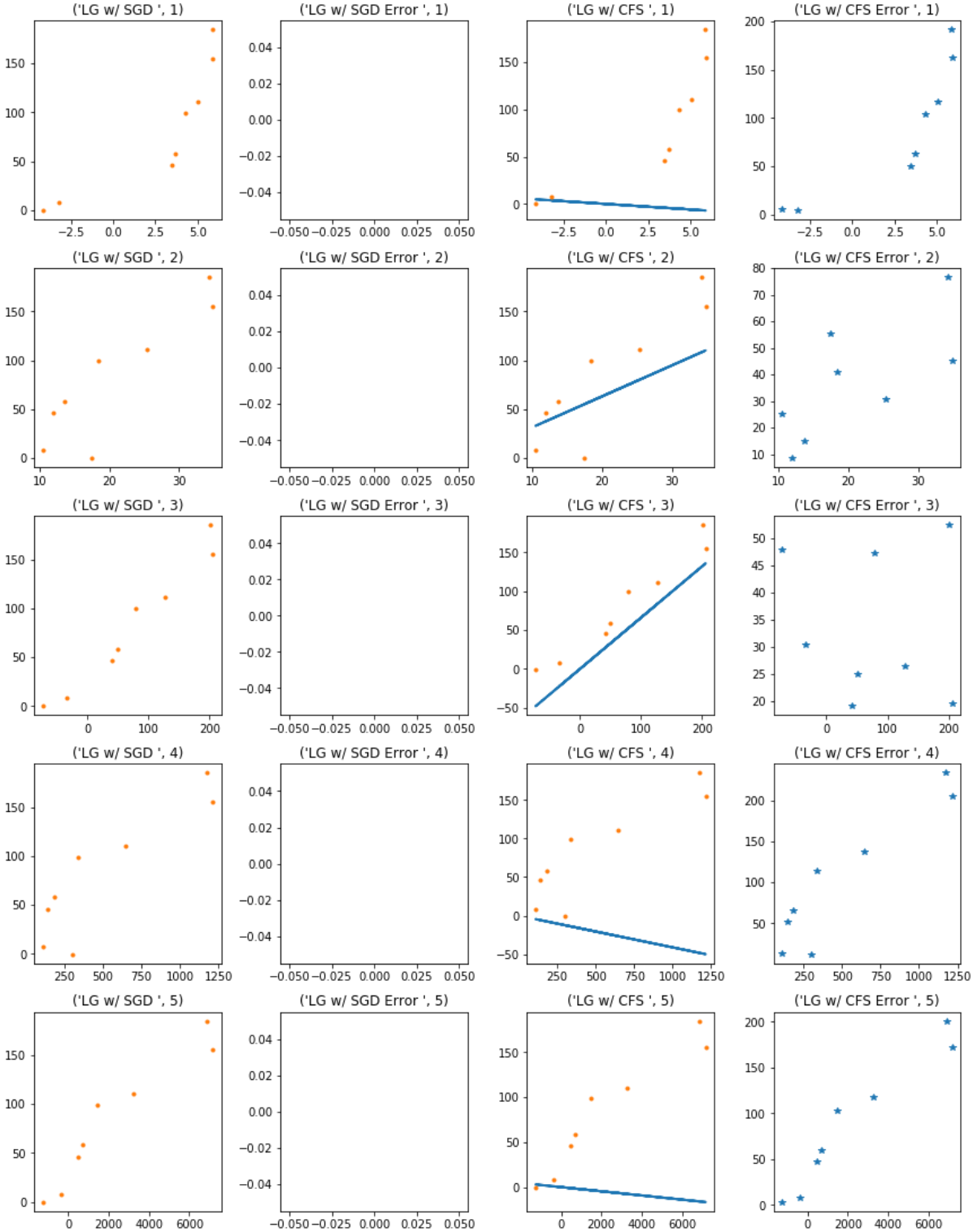
```
Stocastic Grad Descent
lambda:  5.94431879445  theta:  [[ 0.23262323]
 [ 0.48047131]
 [ 2.18935039]
 [ 0.41686872]]
Closed Form Solution
lambda:  2.8613933495  theta:  [[-5.53988052]
 [ 3.36237553]
 [ 2.67880489]
 [ 0.31145214]]
GD Theta:  [[ 0.23262323]
 [ 0.48047131]
 [ 2.18935039]
 [ 0.41686872]]
 CF Theta:  [[-5.53988052]
 [ 3.36237553]
 [ 2.67880489]
 [ 0.31145214]]
```


('LG w/ SGD ', 1)
('LG w/ SGD Error ', 1)
('LG w/ CFS ', 1)
('LG w/ CFS Error ', 1)
('LG w/ SGD ', 2)
('LG w/ SGD Error ', 2)
('LG w/ CFS ', 2)
('LG w/ CFS Error ', 2)
('LG w/ SGD ', 3)
('LG w/ SGD Error ', 3)
('LG w/ CFS ', 3)
('LG w/ CFS Error ', 3)

In [296]:
```
# This one won't run, I think it's too much for the kernel to handle!

N = [5]

for k in range(len(N)):

    X_temp = nFeatureizeData(X_trn, N[k])

    sp.random.seed(123)
    lams = []
    for i in range(len(X_temp)):
        lams.append(sp.rand(1) * 10)


    lam2 = kCrossValid(X_temp, Y_trn, np.asarray(lams), 1)[0]
    lam1 = kCrossValid(X_temp, Y_trn, np.asarray(lams), 0)[0]


    X = nFeatureizeData(X_tst, N[k])

    theta1 = [0] * (N[k] +1)

    theta1 = np.mat(theta1).T

    theta1 = gradDescentRidge(np.mat(X), np.mat(Y_tst), np.mat(theta1), (
    print("Stocastic Grad Descent")
    print("lambda: ", lam1, " theta: ", theta1)

    theta2 = calcCFRidge(np.mat(X), np.mat(Y_tst), lam1)
    print("Closed Form Solution")
    print("lambda: ", lam2, " theta: ", theta2)


    outputRegression(theta1, theta2, X, Y_tst, N[k] + 1)
```

```
/usr/local/lib/python3.5/dist-packages/ipykernel_launcher.py:19: Runtim
eWarning: invalid value encountered in subtract

Stocastic Grad Descent
lambda:  6.96469185598  theta:  [[ nan]
 [ nan]
 [ nan]
 [ nan]
 [ nan]
 [ nan]]
Closed Form Solution
lambda:  0.957125166124  theta:  [[ -2.69428026e+00]
 [ -1.17375436e+00]
 [  3.16040989e+00]
 [  6.60069335e-01]
 [ -4.10876507e-02]
 [ -2.32212241e-03]]
GD Theta:  [[ nan]
 [ nan]
 [ nan]
 [ nan]
```

```
[ nan]
[ nan]]
CF Theta:  [[ -2.69428026e+00]
[ -1.17375436e+00]
[  3.16040989e+00]
[  6.60069335e-01]
[ -4.10876507e-02]
[ -2.32212241e-03]]
```



In [ ]: