HW1 Writeup
Name: Yujia Luo
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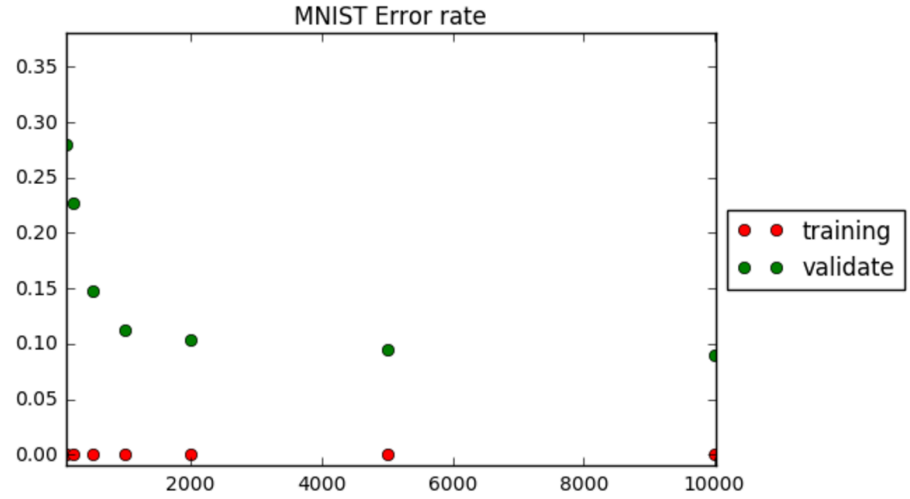
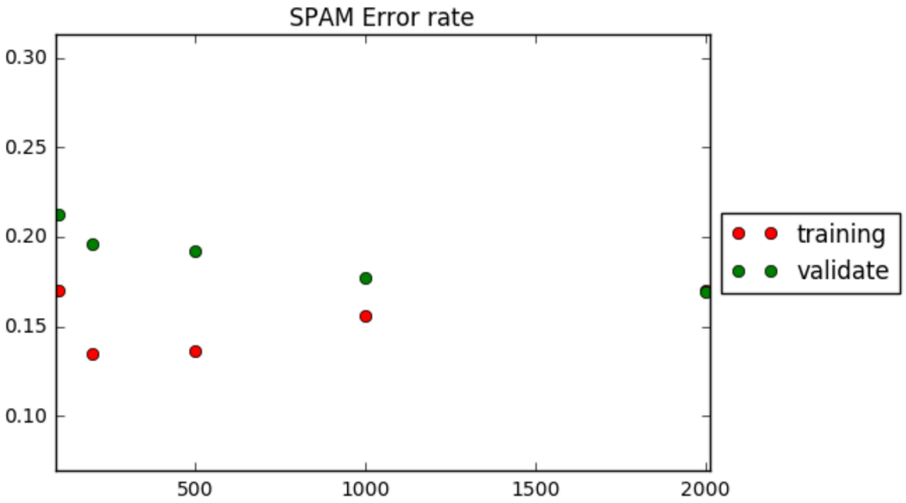
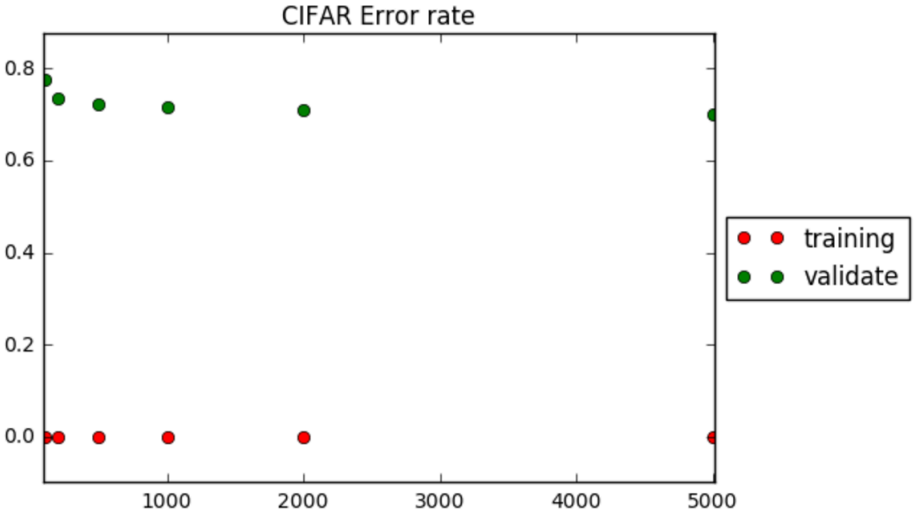
Q2. Training v.s Validation Error Rate Plotting







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Q3. Tune MNIST

For C tuning, I used the standard narrowing-down method. I found that positive C values have similar error rates, but it starts going down as C decreases until C reaches around 10^(-6). So I focused on the 10^(-8) ~ 10^(-5) range and narrowed down my optimal C to 1.5*10^(-6).

```
C:  1e-05   error:  0.082
C:  0.0001   error:  0.0871
C:  0.001   error:  0.0871
C:  0.01   error:  0.0871
C:  0.1   error:  0.0871
C:  1   error:  0.0871
C:  10   error:  0.0871
C:  100   error:  0.0871
C:  1000   error:  0.0871
C:  10000   error:  0.0871
C:  1e-06   error:  0.0699
C:  2.575e-05   error:  0.0856
C:  5.05e-05   error:  0.0865
C:  7.525e-05   error:  0.0869
C:  0.0001   error:  0.0871
C:  2e-08   error:  0.0942
C:  1.8765e-05   error:  0.0847
C:  3.751e-05   error:  0.0864
C:  5.6255e-05   error:  0.0868
C:  7.5e-05   error:  0.0869
C:  2e-07   error:  0.0725
C:  4.65e-06   error:  0.0763
C:  9.1e-06   error:  0.0813
C:  1.355e-05   error:  0.0832
C:  1.8e-05   error:  0.0844
C:  1e-07   error:  0.0762
C:  4.5e-07   error:  0.0727
C:  8e-07   error:  0.0706
C:  1.15e-06   error:  0.0703
C:  1.5e-06   error:  0.0695
C:  1.15e-06   error:  0.0703
C:  1.1125e-06   error:  0.0699
C:  1.075e-06   error:  0.0699
C:  1.0375e-06   error:  0.0701
C:  1e-06   error:  0.0699

* Optimal C: 1.5*10^(-6)
```

Q4. Tune SPAM

For feature adding, I used "A List of Common Spam Words" (https://emailmarketing.comm100.com/email-marketing-ebook/spam-words.aspx) as a reference to manually select words that appear most offen and intuitively make sense and added them to featurize.py file. For C tuning, the procedure is the same as that of MNIST. And I found that my validation accuracy

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rate increases as C increases until it reaches around 200. So I picked 200 as my final optimal C value.

```
C:  1e-05   accuracy:  0.709976733103
C:  0.0001   accuracy:  0.715777011559
C:  0.001   accuracy:  0.749416832525
C:  0.01   accuracy:  0.776679655015
C:  0.1   accuracy:  0.792725590783
C:  1   accuracy:  0.799106140031
C:  10   accuracy:  0.801040002243
C:  100   accuracy:  0.800846017997
C:  10.0   accuracy:  0.801040002243
C:  32.5   accuracy:  0.80142628879
C:  55.0   accuracy:  0.801039441594
C:  77.5   accuracy:  0.800652594399
C:  100.0   accuracy:  0.800846017997
C:  100.0   accuracy:  0.800846017997
C:  144.444444444   accuracy:  0.800846017997
C:  188.888888889   accuracy:  0.800846017997
C:  233.333333333   accuracy:  0.801232865192
C:  277.777777778   accuracy:  0.801232865192
C:  322.222222222   accuracy:  0.801232865192
C:  366.666666667   accuracy:  0.801232865192
C:  411.111111111   accuracy:  0.801232865192
C:  455.555555556   accuracy:  0.801232865192
C:  500.0   accuracy:  0.801232865192
C:  10.0   accuracy:  0.801040002243
C:  21.25   accuracy:  0.800846578645
C:  32.5   accuracy:  0.80142628879
C:  43.75   accuracy:  0.80142628879
C:  55.0   accuracy:  0.801039441594

* Optimal C: 200
```

Q5. Kaggle Score

* MNIST: 0.94720
* SPAM: 0.87978

In [2]:
```
import pandas as pd
import math
import numpy as np
import scipy.io as sio
from sklearn import svm, metrics, cross_validation
from sklearn.model_selection import KFold, cross_val_score
import matplotlib.pyplot as plt
%matplotlib inline
```

```
/Users/yikaluo/applications/anaconda3/lib/python3.5/site-packages/sk
learn/cross_validation.py:44: DeprecationWarning: This module was de
precated in version 0.18 in favor of the model_selection module into
which all the refactored classes and functions are moved. Also note
that the interface of the new CV iterators are different from that o
f this module. This module will be removed in 0.20.
  "This module will be removed in 0.20.", DeprecationWarning)
```

1. Data Partitioning

In [3]:
```
## MNIST
mnist_df = sio.loadmat("./hw01_data/mnist/train.mat")['trainX']
np.random.shuffle(mnist_df)
mnist_validate = mnist_df[:10000, :]
mnist_train = mnist_df[10000:, :]
```

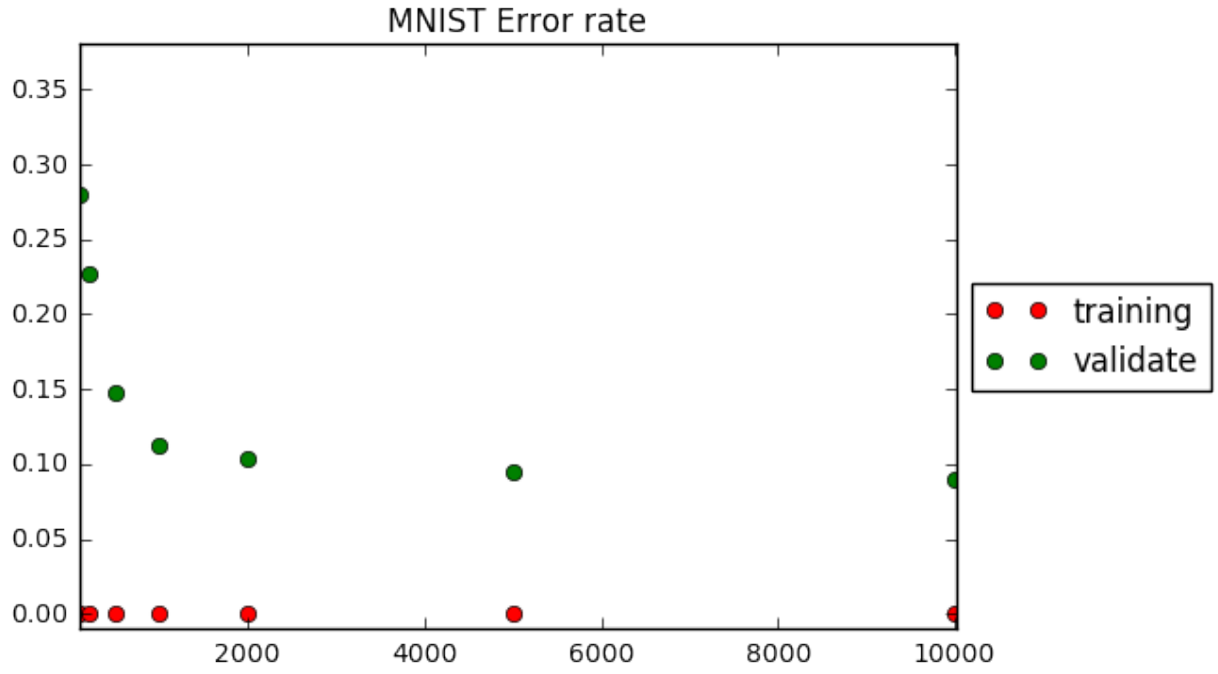
In [4]:
```
## cifar
cifar_df = sio.loadmat("./hw01_data/cifar/train.mat")['trainX']
np.random.shuffle(cifar_df)
cifar_validate = cifar_df[:5000, :]
cifar_train = cifar_df[5000:, :]
```

In [5]:
```
## Spam
spam_train_data = sio.loadmat("./hw01_data/spam/spam_data.mat")['train
ing_data']
spam_train_label = sio.loadmat("./hw01_data/spam/spam_data.mat")['trai
ning_labels']
spam_train_label = spam_train_label.reshape((len(spam_train_data), 1))
spam_df = np.concatenate((spam_train_data, spam_train_label), axis = 1
)
np.random.shuffle(spam_df)
spam_validate = spam_df[:int((len(spam_df) * 0.2)), :]
spam_train = spam_df[(int(len(spam_df) * 0.2)):, :]
```

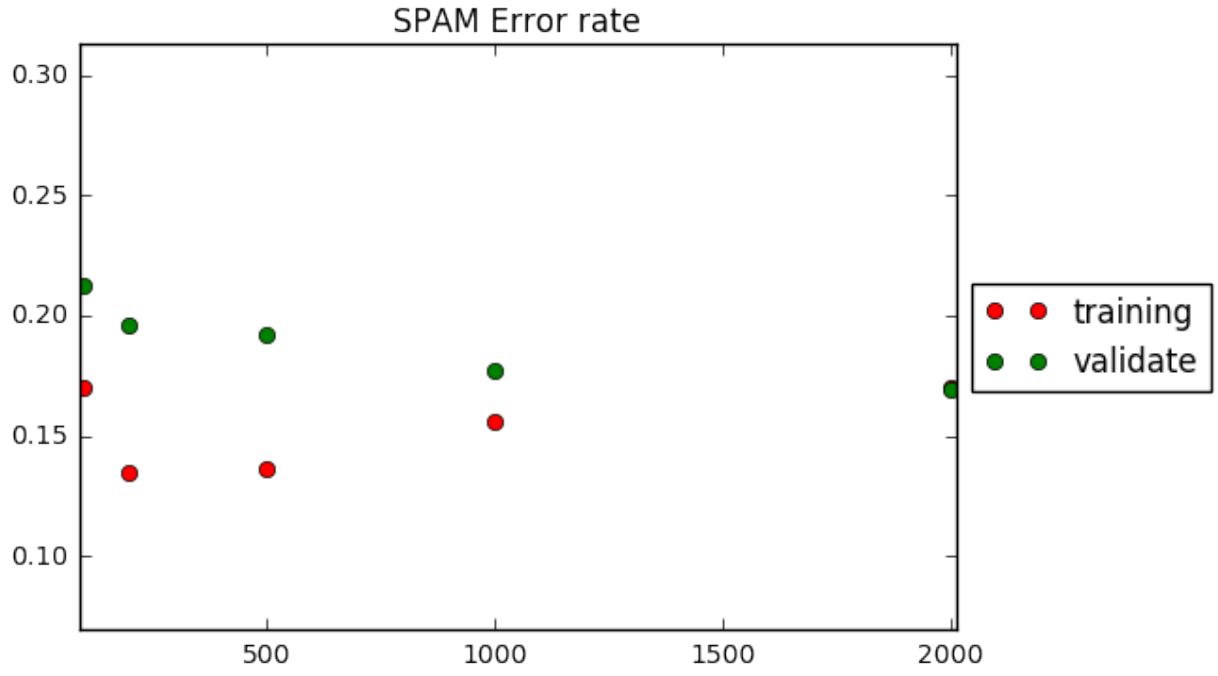
2. Support Vector Machines

In [11]:
```
def train_and_error(train_data, validate_data, categories):

    errors, v_errors = [], []
    x = train_data[:, :-1]
    y = train_data[:, -1:].reshape(1, len(x))[0]
    v_x = validate_data[:, :-1]
    v_y = validate_data[:, -1:].reshape(1, len(v_x))[0]

    for size in categories:
        clf = svm.SVC(kernel = "linear")
        x_fit = x[:size, :]
        y_fit = y[:size]
        clf.fit(x_fit, y_fit)
        v_y_hat = clf.predict(v_x)
        y_hat = clf.predict(x_fit)
        # Error rate
        err = 1 - metrics.accuracy_score(y_fit, y_hat)
        v_err = 1 - metrics.accuracy_score(v_y, v_y_hat)
        errors.append(err)
        v_errors.append(v_err)

    plt.plot(categories, errors, 'ro', label = "training")
    plt.plot(categories, v_errors, 'go', label = "validate")
    plt.axis([min(categories)-10, max(categories)+10, -0.1, max(v_erro
rs)+0.1])
    plt.legend(loc='center left', bbox_to_anchor=(1, 0.5))
    plt.title("CIFAR Error rate")
```

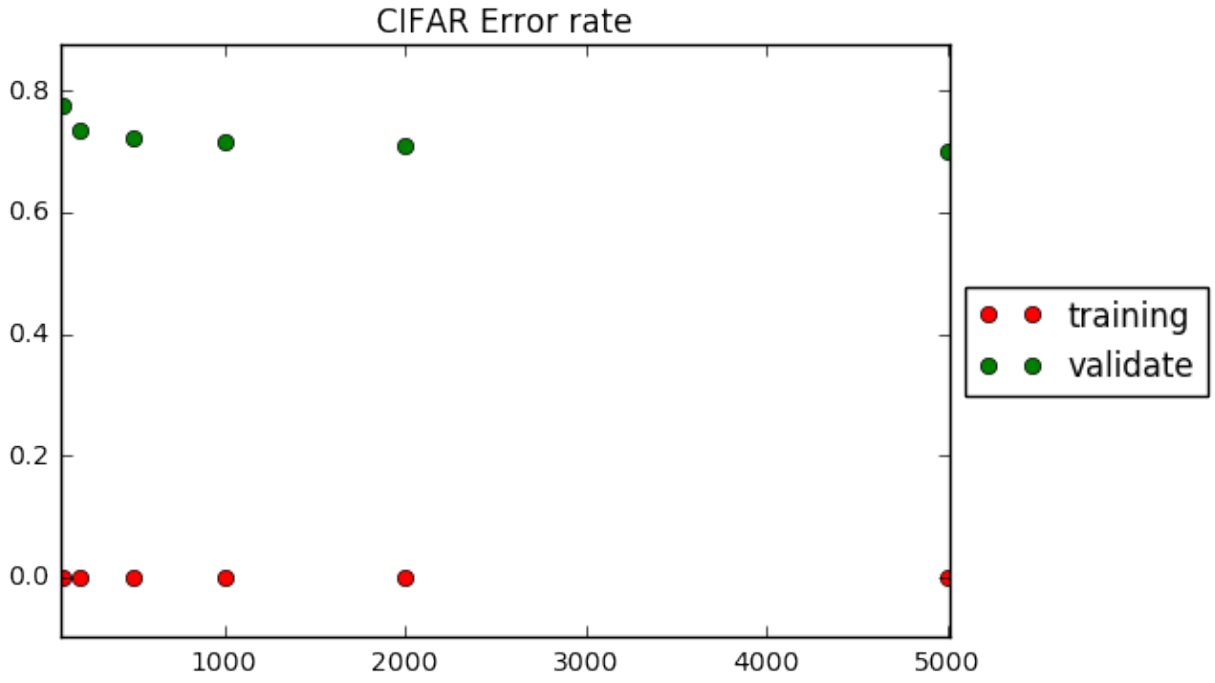
In [8]:
```
## MNIST
categories = [100, 200, 500, 1000, 2000, 5000, 10000]
train_and_error(mnist_train, mnist_validate, categories)
```



In [6]:
```
## SPAM
categories = [100, 200, 500, 1000, 2000]
train_and_error(spam_train, spam_validate, categories)
```



In [12]:
```
## cifar
categories = [100, 200, 500, 1000, 2000, 5000]
train_and_error(cifar_train, cifar_validate, categories)
```



3. Hyperparameter Tuning

In [11]:
```
def tune(train_data, validate_data, c_vals):
    train_size = 10000
    errors = []
    x = train_data[:, :-1][:train_size, :]
    y = train_data[:, -1:][:train_size].reshape(1, train_size)[0]
    v_x = validate_data[:, :-1]
    v_y = validate_data[:, -1:].reshape(1, len(v_x))[0]

    for c_val in c_vals:
        clf = svm.SVC(kernel = "linear", C = c_val)
        clf.fit(x, y)
        v_y_hat = clf.predict(v_x)
        # Error rate
        err = 1 - metrics.accuracy_score(v_y, v_y_hat)
        errors.append(err)
        print("C: ", c_val, "  error: ", err)

#     plt.plot([math.log(x) for x in c_vals], errors, 'ro-')
#     plt.axis([math.log(min(c_vals)) - 0.00001, math.log(max(c_vals))
+ 0.00001, min(errors) - 0.001, max(errors) + 0.001])
#     plt.title("Error Rate V.S. C Values")

    return errors
```

In [12]:
```
# First Round
c = [10**i for i in range(-5, 5)]
errors = tune(mnist_train, mnist_validate, c)
print("Lowest Error Rate in first round: ", min(errors))
```

```
C:  1e-05   error:  0.082
C:  0.0001   error:  0.0871
C:  0.001   error:  0.0871
C:  0.01   error:  0.0871
C:  0.1   error:  0.0871
C:  1   error:  0.0871
C:  10   error:  0.0871
C:  100   error:  0.0871
C:  1000   error:  0.0871
C:  10000   error:  0.0871
Lowest Error Rate in first round:  0.082
```

In [13]:
```
# Second Round
c = np.linspace(10**(-6), 10**(-4), 5)
errors = tune(mnist_train, mnist_validate, c)
print("Lowest Error Rate in second round: ", min(errors))
```

```
C:  1e-06   error:  0.0699
C:  2.575e-05   error:  0.0856
C:  5.05e-05   error:  0.0865
C:  7.525e-05   error:  0.0869
C:  0.0001   error:  0.0871
Lowest Error Rate in second round:  0.0699
```

In [14]:
```
# Third Round
c = np.linspace(2*10**(-8), 7.5*10**(-5), 5)
errors = tune(mnist_train, mnist_validate, c)
print("Lowest Error Rate in third round: ", min(errors))
```

```
C:  2e-08   error:  0.0942
C:  1.8765e-05   error:  0.0847
C:  3.751e-05   error:  0.0864
C:  5.6255e-05   error:  0.0868
C:  7.5e-05   error:  0.0869
Lowest Error Rate in third round:  0.0847
```

In [15]:
```
# Fourth Round
c = np.linspace(2*10**(-7), 1.8*10**(-5), 5)
errors = tune(mnist_train, mnist_validate, c)
print("Lowest Error Rate in fourth round: ", min(errors))
```

```
C:  2e-07   error:  0.0725
C:  4.65e-06   error:  0.0763
C:  9.1e-06   error:  0.0813
C:  1.355e-05   error:  0.0832
C:  1.8e-05   error:  0.0844
Lowest Error Rate in fourth round:  0.0725
```

In [16]:
```
# Fifth Round
c = np.linspace(10**(-7), 1.5*10**(-6), 5)
errors = tune(mnist_train, mnist_validate, c)
print("Lowest Error Rate in fifth round: ", min(errors))
```

```
C:  1e-07   error:  0.0762
C:  4.5e-07   error:  0.0727
C:  8e-07   error:  0.0706
C:  1.15e-06   error:  0.0703
C:  1.5e-06   error:  0.0695
Lowest Error Rate in fifth round:  0.0695
```

In [17]:
```
# Sixth Round
c = np.linspace(1.15*10**(-6), 1*10**(-6), 5)
errors = tune(mnist_train, mnist_validate, c)
print("Lowest Error Rate in sixth round: ", min(errors))
```

```
C:  1.15e-06   error:  0.0703
C:  1.1125e-06   error:  0.0699
C:  1.075e-06   error:  0.0699
C:  1.0375e-06   error:  0.0701
C:  1e-06   error:  0.0699
Lowest Error Rate in sixth round:  0.0699
```

*** Best C for MNIST: 1.5 x 10^(-6)**

*** Kaggle Score: 0.94720**

4. K-Fold Cross-Validation

In [7]:
```
def cross_validate(x, y, c_val):
    clf = svm.SVC(kernel='linear', C=c_val)
    scores = cross_val_score(clf, x, y, cv=5)
    accuracy = scores.mean()
    print("C: ", c_val, "  accuracy: ", accuracy)

    return accuracy
```

In [ ]:
```
spam_train_label = spam_train_label.reshape(1,len(spam_train_label))[0
]
# Find best C - first round
c = [10**i for i in range(-5, 2)]
accuracies = []
for val in c:
    acc = cross_validate(spam_train_data, spam_train_label, val)
    accuracies.append(acc)

print("Highest accuracy in first round: ", max(accuracies))
```

```
C:  1e-05   accuracy:  0.709976733103
C:  0.0001   accuracy:  0.715777011559
C:  0.001   accuracy:  0.749416832525
C:  0.01   accuracy:  0.776679655015
C:  0.1   accuracy:  0.792725590783
C:  1   accuracy:  0.799106140031
C:  10   accuracy:  0.801040002243
C:  100   accuracy:  0.800846017997
```

In [8]:
```
# Find best C - Second round
c = np.linspace(10, 100, 5)
accuracies = []
for val in c:
    acc = cross_validate(spam_train_data, spam_train_label, val)
    accuracies.append(acc)

print("Highest accuracy in second round: ", max(accuracies))
```

```
C:  10.0   accuracy:  0.801040002243
C:  32.5   accuracy:  0.80142628879
C:  55.0   accuracy:  0.801039441594
C:  77.5   accuracy:  0.800652594399
C:  100.0   accuracy:  0.800846017997
Highest accuracy in second round:  0.80142628879
```

In [8]:
```
spam_train_label = spam_train_label.reshape(1,len(spam_train_label))[0
]
# Find best C - first round
c = np.linspace(100, 500, 10)
accuracies = []
for val in c:
    acc = cross_validate(spam_train_data, spam_train_label, val)
    accuracies.append(acc)

print("Highest accuracy in third round: ", max(accuracies))
```

```
C:  100.0   accuracy:  0.800846017997
C:  144.444444444   accuracy:  0.800846017997
C:  188.888888889   accuracy:  0.800846017997
C:  233.333333333   accuracy:  0.801232865192
C:  277.777777778   accuracy:  0.801232865192
C:  322.222222222   accuracy:  0.801232865192
C:  366.666666667   accuracy:  0.801232865192
C:  411.111111111   accuracy:  0.801232865192
C:  455.555555556   accuracy:  0.801232865192
C:  500.0   accuracy:  0.801232865192
Highest accuracy in third round:  0.801232865192
```

In [7]:
```
# Find best C - Third round
spam_train_label = spam_train_label.reshape(1,len(spam_train_label))[0
]
c = np.linspace(10, 55, 5)
accuracies = []
for val in c:
    acc = cross_validate(spam_train_data, spam_train_label, val)
    accuracies.append(acc)

print("Highest accuracy in second round: ", max(accuracies))
```

```
C:  10.0   accuracy:  0.801040002243
C:  21.25   accuracy:  0.800846578645
C:  32.5   accuracy:  0.80142628879
C:  43.75   accuracy:  0.80142628879
C:  55.0   accuracy:  0.801039441594
Highest accuracy in second round:  0.80142628879
```

Best C for Spam: 200

Kaggle score: 0.87978

5. Kaggle

In [18]:
```
## Mnist
mnist_test = sio.loadmat("./hw01_data/mnist/test.mat")["testX"]
clf = svm.SVC(kernel="linear", C=1.5*10**(-6))
size = 10000
x = mnist_df[:, :-1]
y = [mnist_df[row][-1] for row in range(0, len(mnist_df))]
clf.fit(x, y)
y_hat = clf.predict(mnist_test)
df = pd.DataFrame(data = y_hat, columns=["Id", "Category"])
df.to_csv("./hw01_data/mnist/prediction.csv")
```

In [3]:
```
## Spam
spam_test = sio.loadmat("./hw01_data/spam/spam_data.mat")["test_data"]
clf = svm.SVC(kernel = "linear", C=200)
clf.fit(spam_train_data, spam_train_label)
y_hat = clf.predict(spam_test)
df = pd.DataFrame(data = y_hat)
df.to_csv("./hw01_data/spam/prediction.csv")
```

```
/Users/yikaluo/applications/anaconda3/lib/python3.5/site-packages/sk
learn/utils/validation.py:526: DataConversionWarning: A column-vecto
r y was passed when a 1d array was expected. Please change the shape
of y to (n_samples, ), for example using ravel().
  y = column_or_1d(y, warn=True)
```

In [ ]:
```

```