

# Programming Assignment 3: Sentiment analysis

In this programming assignment, you will implement logistic regression to predict the sentiment of reviews that come from `imdb.com`, `amazon.com`, and `yelp.com`. Make sure the notebook is in the same folder that contains `full_set.txt`.

## 1. Load and preprocess data

```
In [1]: %matplotlib inline
import string
import numpy as np
import matplotlib
import matplotlib.pyplot as plt
matplotlib.rc('xtick', labels=14)
matplotlib.rc('ytick', labels=14)
```

The data set consists of 3000 sentences, each labeled '1' (if it came from a positive review) or '0' (if it came from a negative review). To be consistent with our notation from lecture, we will change the negative review label to '-1'.

```
In [2]: ## Read in the data set.
with open("full_set.txt") as f:
    content = f.readlines()

## Remove leading and trailing white space
content = [x.strip() for x in content]

## Separate the sentences from the labels
sentences = [x.split("\t")[0] for x in content]
labels = [x.split("\t")[1] for x in content]

## Transform the labels from '0 v.s. 1' to '-1 v.s. 1'
y = np.array(labels, dtype='int8')
y = 2*y - 1

for i in range(5):
    print ('Label: ', y[i], '; ', sentences[i])
```

Label: -1 ; So there is no way for me to plug it in here in the US unless I go by a converter.

Label: 1 ; Good case, Excellent value.

Label: 1 ; Great for the jawbone.

Label: -1 ; Tied to charger for conversations lasting more than 45 minutes.  
MAJOR PROBLEMS!!

Label: 1 ; The mic is great.

## Preprocessing the text data

To transform this prediction problem into one amenable to linear classification, we will first need to preprocess the text data. We will do four transformations:

1. Remove punctuation and numbers.
2. Transform all words to lower-case.
3. Remove *stop words*.
4. Convert the sentences into vectors, using a bag-of-words representation.

We begin with first two steps.

```
In [3]: ## full_remove takes a string x and a list of characters removal_list
## returns x with all the characters in removal_list replaced by ' '
def full_remove(x, removal_list):
    for w in removal_list:
        x = x.replace(w, ' ')
    return x

## Remove digits
digits = [str(x) for x in range(10)]
digit_less = [full_remove(x, digits) for x in sentences]

## Remove punctuation
punc_less = [full_remove(x, list(string.punctuation)) for x in digit_less]

## Make everything lower-case
sents_lower = [x.lower() for x in punc_less]
```

## Stop words

Stop words are words that are filtered out because they are believed to contain no useful information for the task at hand. These usually include articles such as 'a' and 'the', pronouns such as 'i' and 'they', and prepositions such as 'to' and 'from'. We have put together a very small list of stop words, but these are by no means comprehensive. Feel free to use something different; for instance, larger lists can easily be found on the web.

```
In [4]: ## Define our stop words
stop_set = set(['the', 'a', 'an', 'i', 'he', 'she', 'they', 'to', 'of', 'it',
                'from'])

## Remove stop words
sents_split = [x.split() for x in sents_lower]
sents_processed = [" ".join(list(filter(lambda a: a not in stop_set, x))) for
                   x in sents_split]
```

What do the sentences look like so far?

```
In [5]: sents_processed[0:10]
```

```
Out[5]: ['so there is no way for me plug in here in us unless go by converter',
        'good case excellent value',
        'great for jawbone',
        'tied charger for conversations lasting more than minutes major problems',
        'mic is great',
        'have jiggle plug get line up right get decent volume',
        'if you have several dozen or several hundred contacts then imagine fun send
        ing each them one by one',
        'if you are razr owner you must have this',
        'needless say wasted my money',
        'what waste money and time']
```

## Bag of words

In order to use linear classifiers on our data set, we need to transform our textual data into numeric data. The classical way to do this is known as the *bag of words* representation. In this representation, each word is thought of as corresponding to a number in  $\{1, 2, \dots, d\}$  where  $d$  is the size of our vocabulary. And each sentence is represented as a  $d$ -dimensional vector  $x$ , where  $x_i$  is the number of times that word  $i$  occurs in the sentence.

To do this transformation, we will make use of the `CountVectorizer` class in `scikit-learn` (Note that this is the only time you can call an external function from `scikit-learn`). We will cap the number of features at 4500, meaning a word will make it into our vocabulary only if it is one of the 4500 most common words in the corpus. This is often a useful step as it can weed out spelling mistakes and words which occur too infrequently to be useful.

**Task P1:** Once you get the bag-of-words representation, append a '1' to the beginning of each vector to allow our linear classifier to learn a bias term. What is the size of the resulting `data_mat` matrix?

```
In [6]: from sklearn.feature_extraction.text import CountVectorizer

        ## Transform to bag of words representation.
        vectorizer = CountVectorizer(analyzer = "word", tokenizer = None, preprocessor
        = None, stop_words = None, max_features = 4500)
        data_features = vectorizer.fit_transform(sents_processed)
        print ('The original size: ', data_features.shape)
```

```
The original size: (3000, 4500)
```

```
In [7]: ## STUDENT: YOUR CODE STARTS HERE
# Task: Append '1' to the beginning of each vector.
# Hint: You can use data_features.toarray() to transform data_features into a
# numpy array
# The output should be a numpy array named data_mat

data_mat = data_features.toarray()# please assign a numpy array to this
data_mat = np.insert(data_mat, 0, 1, axis = 1)

## STUDENT: CODE ENDS
print('The updated size: ',data_mat.shape)
print(data_mat)
```

```
The updated size: (3000, 4501)
[[1 0 0 ... 0 0 0]
 [1 0 0 ... 0 0 0]
 [1 0 0 ... 0 0 0]
 ...
 [1 0 0 ... 0 0 0]
 [1 0 0 ... 0 0 0]
 [1 0 0 ... 0 0 0]]
```

## Training / test split

Finally, we split the data into a training set of 2500 sentences and a test set of 500 sentences (of which 250 are positive and 250 negative).

```
In [8]: ## Split the data into testing and training sets
np.random.seed(0)
test_inds = np.append(np.random.choice((np.where(y==-1))[0], 250, replace=False),
np.random.choice((np.where(y==1))[0], 250, replace=False))
train_inds = list(set(range(len(labels))) - set(test_inds))

train_data = data_mat[train_inds,]
train_labels = y[train_inds]

test_data = data_mat[test_inds,]
test_labels = y[test_inds]

print("train data: ", train_data.shape)
print("test data: ", test_data.shape)

train data: (2500, 4501)
test data: (500, 4501)
```

## 2. Fitting a logistic regression model to the training data

In this section, we will implement our own logistic regression solver using gradient descent. As we have seen in the class, to learn the parameters of logistic regression, we need to perform the following optimization:

$$\tilde{\theta}_t = \underset{\tilde{\theta}}{\operatorname{argmin}} L_{\mathcal{D}}(\tilde{\theta}) = \underset{\tilde{\theta}}{\operatorname{argmin}} \sum_{i=1}^n \ln \left( 1 + e^{y_i \tilde{\theta}_t^T \tilde{x}_i} \right)$$

where  $y_i \in \{-1, +1\}$  is the label,  $\tilde{\theta}$  is the vector of coefficients:

$$\tilde{\theta} = [\theta_0 \quad \theta_1 \quad \dots \quad \theta_d]^T,$$

and  $\tilde{x}$  is the "augmented" feature vector (of  $d + 1$  dimensions), where we stick a 1 in the front of the original features:

$$\tilde{x} = [1 \quad x_1 \quad \dots \quad x_d]^T.$$

There is no nice, closed-form solution like with [least-squares linear regression](http://en.wikipedia.org/wiki/Moore%E2%80%93Penrose_pseudoinverse) ([http://en.wikipedia.org/wiki/Moore%E2%80%93Penrose\\_pseudoinverse](http://en.wikipedia.org/wiki/Moore%E2%80%93Penrose_pseudoinverse)) so we will use [gradient descent](http://en.wikipedia.org/wiki/Gradient_descent) ([http://en.wikipedia.org/wiki/Gradient\\_descent](http://en.wikipedia.org/wiki/Gradient_descent)) instead. Specifically we will use batch gradient descent which calculates the gradient from all data points in the data set. Luckily, the loss function  $L_{\mathcal{D}}(\tilde{\theta})$  we want to minimize is [convex](http://en.wikipedia.org/wiki/Convex_optimization) ([http://en.wikipedia.org/wiki/Convex\\_optimization](http://en.wikipedia.org/wiki/Convex_optimization)) so there is only one minimum. Thus the minimum we arrive at is the global minimum.

Gradient descent is a general method and requires twice differentiability for [smoothness](http://en.wikipedia.org/wiki/Smooth_function) ([http://en.wikipedia.org/wiki/Smooth\\_function](http://en.wikipedia.org/wiki/Smooth_function)). It updates the parameters using a first-order approximation of the error surface.

$$\tilde{\theta}_{t+1} = \tilde{\theta}_t + \nabla L_{\mathcal{D}}(\tilde{\theta}_t)$$

**Task P2:** Derive the gradient of the loss  $L_{\mathcal{D}}(\tilde{\theta})$  with respect to  $\tilde{\theta}$ , namely  $\nabla L_{\mathcal{D}}(\tilde{\theta}_t)$ . The answer should depend on data points  $(x_i, y_i)$  for  $i = 1, \dots, n$ , and the model parameter  $\tilde{\theta}$ . Make sure you get the sign correct. Also implement the function `weight_derivative`. Print the output of the code.

```
In [21]: def weight_derivative(weights, feature_matrix, labels):
# Input:
# weights: weight vector w, a numpy vector of dimension d
# feature_matrix: numpy array of size n by d, where n is the number of data points, and d is the feature dimension
# labels: true labels y, a numpy vector of dimension d, each with value -1 or +1
# Output:
# Derivative of the regression cost function with respect to the weight w, a numpy array of dimension d

## STUDENT: Start of code ###
y = labels
theta = weights
total = np.zeros(4501)

for i in range(train_labels.size):
    x = feature_matrix[i,]
    d = np.dot(x, theta)
    powr = -(y[i]*d)
    exp = np.exp(powr)
    du = -(y[i]*x)
    numerator = du * exp
    denominator = 1 + exp
    result = numerator / denominator
    total = np.add(total, result)

derivative = total

return derivative
# End of code ###
```

```
In [22]: # STUDENT: PRINT THE OUTPUT AND COPY IT TO THE SOLUTION FILE
my_weights = np.ones(data_mat.shape[1]) # a weight of all 1s
derivative = weight_derivative(my_weights, train_data, train_labels)

print (derivative[:10])
```

```
[ 1.23415330e+03 -4.13993755e-08  1.00000000e+00  9.9993856e-01
 1.99987630e+00  9.99859072e-01  9.52574127e-01  3.59772270e+01
 2.99996572e+00 -1.38879439e-11]
```

Now, we can just use the same gradient descent algorithm that we wrote in assignment 2 to solve it.

```
In [23]: def gradient_descent(feature_matrix, labels, initial_weights, step_size, tolerance):
    # Gradient descent algorithm for logistic regression problem

    # Input:
    # feature_matrix: numpy array of size n by d, where n is the number of data points, and d is the feature dimension
    # labels: true labels y, a numpy vector of dimension d
    # initial_weights: initial weight vector to start with, a numpy vector of dimension d
    # step_size: step size of update
    # tolerance: tolerance epsilon for stopping condition
    # Output:
    # Weights obtained after convergence

    converged = False
    weights = np.array(initial_weights) # current iterate
    i = 0
    while not converged:
        # implementation of what the gradient descent algorithm does in every iteration
        # Refer back to the update rule listed above: update the weight
        i += 1
        derivative = weight_derivative(weights, feature_matrix, labels)

        weights -= (step_size * derivative)

        # Compute the gradient magnitude:

        gradient_magnitude = np.sqrt(np.sum(derivative**2))

        # Check the stopping condition to decide whether you want to stop the iterations
        # print ("grad mag :", gradient_magnitude)
        # print ("tolerance:", tolerance)

        if gradient_magnitude < tolerance:
            converged = True

        print ("Iteration: ", i, "gradient_magnitude: ", gradient_magnitude) # for us to check about convergence

    return(weights)
```

**Task P3:** Specify the `initial_weights`, `step_size`, and `tolerance` for the function `gradient_descent`. Copy the outputs of the code to the solution file.

```
In [24]: #Initialize the weights, step size and tolerance
# Start of code
#STUDENT: Specify the initial_weights, step_size, and tolerance
initial_weights = np.zeros(data_mat.shape[1])
step_size = 2e-3
tolerance = 3
# end of code

# Use the regression_gradient_descent function to calculate the gradient descent and store it in the variable 'final_weights'
final_weights = gradient_descent(train_data,train_labels, initial_weights, step_size, tolerance)

# end of code
print ("Here are the final weights after convergence:")
print (final_weights)
```



```
Iteration: 1 gradient_magnitude: 209.21400526733385
Iteration: 2 gradient_magnitude: 178.58496774522143
Iteration: 3 gradient_magnitude: 159.8927105443988
Iteration: 4 gradient_magnitude: 146.5002270747251
Iteration: 5 gradient_magnitude: 135.9075180968014
Iteration: 6 gradient_magnitude: 127.0278241564014
Iteration: 7 gradient_magnitude: 119.3903556928941
Iteration: 8 gradient_magnitude: 112.78860450244265
Iteration: 9 gradient_magnitude: 107.07175483158811
Iteration: 10 gradient_magnitude: 102.14167671861115
Iteration: 11 gradient_magnitude: 97.88114002614333
Iteration: 12 gradient_magnitude: 94.1895353928877
Iteration: 13 gradient_magnitude: 90.96299842429494
Iteration: 14 gradient_magnitude: 88.11614643193525
Iteration: 15 gradient_magnitude: 85.57490653621652
Iteration: 16 gradient_magnitude: 83.28272066484196
Iteration: 17 gradient_magnitude: 81.19486432128949
Iteration: 18 gradient_magnitude: 79.2781651740734
Iteration: 19 gradient_magnitude: 77.5068440531695
Iteration: 20 gradient_magnitude: 75.86128152710081
Iteration: 21 gradient_magnitude: 74.32573473260932
Iteration: 22 gradient_magnitude: 72.88757000896885
Iteration: 23 gradient_magnitude: 71.53622301394935
Iteration: 24 gradient_magnitude: 70.26282546675397
Iteration: 25 gradient_magnitude: 69.05975263145561
Iteration: 26 gradient_magnitude: 67.92042877778394
Iteration: 27 gradient_magnitude: 66.83911146676603
Iteration: 28 gradient_magnitude: 65.81077145464059
Iteration: 29 gradient_magnitude: 64.83097278399507
Iteration: 30 gradient_magnitude: 63.89579051937642
Iteration: 31 gradient_magnitude: 63.001735202003765
Iteration: 32 gradient_magnitude: 62.14569446463415
Iteration: 33 gradient_magnitude: 61.32488179890004
Iteration: 34 gradient_magnitude: 60.53679458656995
Iteration: 35 gradient_magnitude: 59.77917790586217
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Iteration: 37 gradient_magnitude: 58.347396234222906
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Iteration: 44 gradient_magnitude: 54.04951614025237
Iteration: 45 gradient_magnitude: 53.50986834772166
Iteration: 46 gradient_magnitude: 52.9859098671223
Iteration: 47 gradient_magnitude: 52.47685335417881
Iteration: 48 gradient_magnitude: 51.98196776170777
Iteration: 49 gradient_magnitude: 51.500573166473785
Iteration: 50 gradient_magnitude: 51.032036167786536
Iteration: 51 gradient_magnitude: 50.575765785071006
Iteration: 52 gradient_magnitude: 50.131209792019
Iteration: 53 gradient_magnitude: 49.69785143366902
Iteration: 54 gradient_magnitude: 49.2752064801573
Iteration: 55 gradient_magnitude: 48.862820577156114
Iteration: 56 gradient_magnitude: 48.460266858351794
Iteration: 57 gradient_magnitude: 48.06714378986674
```

```
Iteration: 58 gradient_magnitude: 47.68307322042257
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Iteration: 60 gradient_magnitude: 46.94068344764869
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Iteration: 63 gradient_magnitude: 45.88669977857073
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Iteration: 68 gradient_magnitude: 44.27067763546955
Iteration: 69 gradient_magnitude: 43.966425251974634
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Iteration: 71 gradient_magnitude: 43.375217310988
Iteration: 72 gradient_magnitude: 43.087891122475625
Iteration: 73 gradient_magnitude: 42.80585043361201
Iteration: 74 gradient_magnitude: 42.52893027870457
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Iteration: 84 gradient_magnitude: 40.00978769107275
Iteration: 85 gradient_magnitude: 39.780126162183905
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Iteration: 88 gradient_magnitude: 39.11241183113269
Iteration: 89 gradient_magnitude: 38.89662273053782
Iteration: 90 gradient_magnitude: 38.684079396387844
Iteration: 91 gradient_magnitude: 38.47469932790948
Iteration: 92 gradient_magnitude: 38.26840297847667
Iteration: 93 gradient_magnitude: 38.06511361886047
Iteration: 94 gradient_magnitude: 37.86475720826144
Iteration: 95 gradient_magnitude: 37.66726227259883
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Iteration: 100 gradient_magnitude: 36.72037383024098
Iteration: 101 gradient_magnitude: 36.538676805810795
Iteration: 102 gradient_magnitude: 36.35940389843718
Iteration: 103 gradient_magnitude: 36.18250051294943
Iteration: 104 gradient_magnitude: 36.00791378305559
Iteration: 105 gradient_magnitude: 35.83559250076919
Iteration: 106 gradient_magnitude: 35.6654870493704
Iteration: 107 gradient_magnitude: 35.497549339691794
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Iteration: 109 gradient_magnitude: 35.167992066020524
Iteration: 110 gradient_magnitude: 35.00628343074764
Iteration: 111 gradient_magnitude: 34.846564287527286
Iteration: 112 gradient_magnitude: 34.688793332618246
Iteration: 113 gradient_magnitude: 34.53293046728098
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```

```
Iteration: 115 gradient_magnitude: 34.2267743659994
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Iteration: 117 gradient_magnitude: 33.92779762570862
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```

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Iteration: 172 gradient_magnitude: 27.723247451003207
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Iteration: 186 gradient_magnitude: 26.570725122803506
Iteration: 187 gradient_magnitude: 26.49303212700561
Iteration: 188 gradient_magnitude: 26.415915070213156
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Iteration: 194 gradient_magnitude: 25.964914136805543
Iteration: 195 gradient_magnitude: 25.891634529149936
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Iteration: 206 gradient_magnitude: 25.118680093507486
Iteration: 207 gradient_magnitude: 25.051273093476283
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Iteration: 213 gradient_magnitude: 24.656176769898682
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Iteration: 4201 gradient_magnitude: 3.0236305383828572
Iteration: 4202 gradient_magnitude: 3.02302946463163
Iteration: 4203 gradient_magnitude: 3.0224286447654807
Iteration: 4204 gradient_magnitude: 3.0218280786180065
Iteration: 4205 gradient_magnitude: 3.0212277660229483
Iteration: 4206 gradient_magnitude: 3.020627706814194
Iteration: 4207 gradient_magnitude: 3.020027900825775
Iteration: 4208 gradient_magnitude: 3.019428347891869
Iteration: 4209 gradient_magnitude: 3.0188290478467974
Iteration: 4210 gradient_magnitude: 3.018230000525026
Iteration: 4211 gradient_magnitude: 3.0176312057611674
Iteration: 4212 gradient_magnitude: 3.0170326633899758
Iteration: 4213 gradient_magnitude: 3.01643437324635
Iteration: 4214 gradient_magnitude: 3.0158363351653343
Iteration: 4215 gradient_magnitude: 3.015238548982116
Iteration: 4216 gradient_magnitude: 3.0146410145320255
Iteration: 4217 gradient_magnitude: 3.014043731650538
Iteration: 4218 gradient_magnitude: 3.013446700173271
```

```

Iteration: 4219 gradient_magnitude: 3.0128499199359853
Iteration: 4220 gradient_magnitude: 3.0122533907745854
Iteration: 4221 gradient_magnitude: 3.0116571125251186
Iteration: 4222 gradient_magnitude: 3.0110610850237745
Iteration: 4223 gradient_magnitude: 3.010465308106886
Iteration: 4224 gradient_magnitude: 3.009869781610928
Iteration: 4225 gradient_magnitude: 3.0092745053725176
Iteration: 4226 gradient_magnitude: 3.008679479228415
Iteration: 4227 gradient_magnitude: 3.0080847030155207
Iteration: 4228 gradient_magnitude: 3.007490176570879
Iteration: 4229 gradient_magnitude: 3.0068958997316737
Iteration: 4230 gradient_magnitude: 3.006301872335233
Iteration: 4231 gradient_magnitude: 3.005708094219024
Iteration: 4232 gradient_magnitude: 3.0051145652206563
Iteration: 4233 gradient_magnitude: 3.00452128517788
Iteration: 4234 gradient_magnitude: 3.003928253928587
Iteration: 4235 gradient_magnitude: 3.0033354713108094
Iteration: 4236 gradient_magnitude: 3.0027429371627194
Iteration: 4237 gradient_magnitude: 3.002150651322631
Iteration: 4238 gradient_magnitude: 3.0015586136289976
Iteration: 4239 gradient_magnitude: 3.0009668239204133
Iteration: 4240 gradient_magnitude: 3.0003752820356113
Iteration: 4241 gradient_magnitude: 2.9997839878134664
Here are the final weights after convergence:
[-0.26372878  0.1116505 -0.0744277 ... -2.97204879  0.
 -0.21972597]

```

**Task P4:** Write the code to extract the y-intercept  $\theta_0$  and the rest of the parameters  $\theta = [\theta_1 \dots \theta_d]^T$ . Copy the code and print the outputs.

```

In [25]: ## STUDENT: CODE STARTS HERE
## Pull out the parameters (theta_0, theta) of the logistic regression model
theta0 = final_weights[0]
theta = final_weights
## STUDENT: CODE ENDS HERE
print ('y intercept: ',theta0)
print ('theta1 and theta2: ',theta[1],theta[2])

```

```

y intercept: -0.26372877676156076
theta1 and theta2: 0.11165050235925947 -0.07442770496333988

```

Recall that the [logistic/sigmoid function](http://en.wikipedia.org/wiki/Logistic_function) ([http://en.wikipedia.org/wiki/Logistic\\_function](http://en.wikipedia.org/wiki/Logistic_function)) is given by

$$f(z) = \frac{1}{1 + e^{-z}}$$

Based on the logistic model, the posterior probability

$$P(y | \mathbf{x}) = f(y \tilde{\theta}^T \tilde{\mathbf{x}})$$

To make a prediction, we can simply choose the label  $y \in \{-1, +1\}$  with the higher posterior probability.

**Task P5:** Write the code to make the prediction for a given data matrix. Report the training error and test error.

```

In [40]: def model_predict(feature_matrix,weights):
# Prediction made by Logistic regression

# Input:
# feature_matrix: numpy array of size n by d+1, where n is the number of d
ata points, and d+1 is the feature dimension
# note we have included the dummy feature as the first col
umn of the feature_matrix
# weights: weight vector to start with, a numpy vector of dimension d+1
# Output:
# labels: predicted labels, a numpy vector of dimension n

## STUDENT: YOUR CODE HERE
result = np.zeros(feature_matrix.shape[0])
#print(feature_matrix.shape[0])
count = 0
for i in range(feature_matrix.shape[0]):

    positiveY = 1
    positiveY = 1 / (1 + np.exp(-(positiveY * (np.dot(weights, feature_mat
rix[i])))))
    negativeY = -1
    negativeY = 1 / (1 + np.exp(-(negativeY * (np.dot(weights, feature_ma
trix[i])))))

    if positiveY > negativeY:
        result[i] = 1
        count += 1
    else:
        result[i] = -1

return result
## STUDENT: CODE ENDS

```

```

In [41]: # STUDENT: copy the output of this section to the solution file

## Get predictions on training and test data
preds_train = model_predict(train_data,final_weights)
preds_test = model_predict(test_data,final_weights)

## Compute errors
errs_train = np.sum((preds_train > 0.0) != (train_labels > 0.0))
errs_test = np.sum((preds_test > 0.0) != (test_labels > 0.0))

print ("Training error: ", float(errs_train)/len(train_labels))
print ("Test error: ", float(errs_test)/len(test_labels))

```

```

Training error:  0.0028
Test error:  0.148

```

### 3. Analyzing the margin

As discussed in the lecture, the logistic regression model produces not just classifications but also conditional probability estimates.

We will say that  $x$  has **margin**  $\gamma$  if (according to the logistic regression model)  $\Pr(y=1|x) > (1/2)+\gamma$  or  $\Pr(y=1|x) < (1/2)-\gamma$ . For example, if  $\Pr(y=1|x)$  is 0.7 according to the logistic regression model, then the margin is 0.2. If  $\Pr(y=1|x)$  is 0.15 according to the logistic regression model, then the margin is 0.35.

**Task P6:** Implement the following function **margin\_counts** that takes as input the learned weights  $\tilde{\theta}$ , the feature matrix ( `feature_matrix` ), and a value of `gamma` , and computes how many points in the data have margin at least `gamma` . Copy the code and the output plot (i.e., visualization of the test set's distribution of margin values) to the solution file.

```
In [42]: def margin_counts(feature_matrix, weights, gamma):
  ## Return number of points for which Pr(y=1) lies in [0, 0.5 - gamma) or (0.5 + gamma, 1]

  # Input:
  # feature_matrix: numpy array of size n by d+1, where n is the number of data points, and d+1 is the feature dimension
  # note we have included the dummy feature as the first column of the feature_matrix
  # weights: weight vector to start with, a numpy vector of dimension d+1
  # gamma: the margin value
  # Output:
  # number of points for which Pr(y=1) lies in [0, 0.5 - gamma) or (0.5 + gamma, 1]

  ## STUDENT: YOUR CODE HERE
  counts = 0
  for i in range(feature_matrix.shape[0]):

      positive = 1
      positive = 1 / (1 + np.exp(-(positive * (np.dot(weights, feature_matrix[i])))))

      if 0 <= positive < 0.5 - gamma:
          counts+= 1

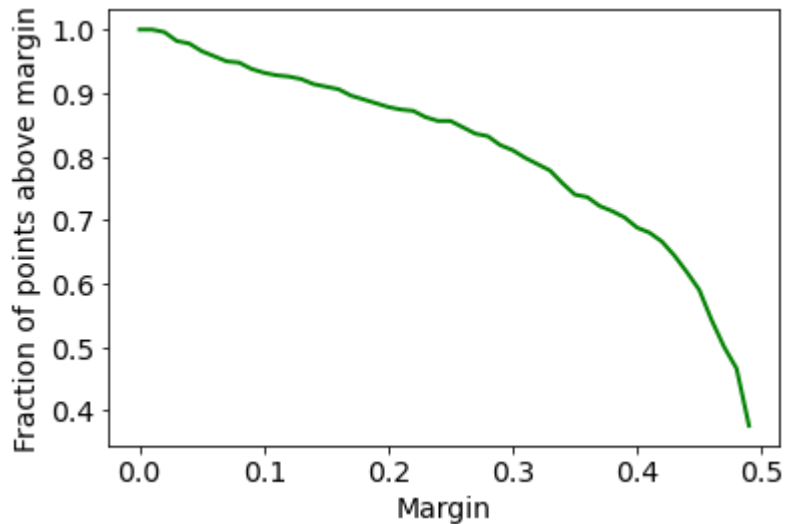
      elif 0.5 + gamma < positive <= 1:
          counts+= 1

  return counts

## STUDENT: CODE ENDS
```

We now visualize the test set's distribution of margin values.

```
In [43]: gammas = np.arange(0,0.5,0.01)
f = np.vectorize(lambda g: margin_counts(test_data, final_weights,g))
plt.plot(gammas, f(gammas)/500.0, linewidth=2, color='green')
plt.xlabel('Margin', fontsize=14)
plt.ylabel('Fraction of points above margin', fontsize=14)
plt.show()
```



Next, we investigate a natural question: Are points  $x$  with larger margin more likely to be classified correctly?

To address this, we define a function **margin\_errors** that computes the fraction of points with margin at least  $\gamma$  that are misclassified.

**Task P7:** Implement the function `margin_errors` that computes the fraction of points with margin at least  $\gamma$  that are misclassified. Copy the code and the output plot (i.e., visualization of the relationship between margin and error rate) to the solution file. What do you observe from the plot?

```

In [46]: def margin_errors(feature_matrix, labels, weights, gamma):
    ## Return error of predictions that lie in intervals [0, 0.5 - gamma) and (0.5 + gamma, 1]

    # Input:
    # feature_matrix: numpy array of size n by d+1, where n is the number of data points, and d+1 is the feature dimension
    # note we have included the dummy feature as the first column of the feature_matrix
    # labels: true labels y, a numpy vector of dimension n
    # weights: weight vector to start with, a numpy vector of dimension d+1
    # gamma: the margin value
    # Output:
    # error of predictions that lie in intervals [0, 0.5 - gamma) and (0.5 + gamma, 1]

    ## STUDENT: YOUR CODE HERE
    withinGamma = 0
    Wrong = 0

    for x in range(feature_matrix.shape[0]):
        n = feature_matrix[x]

        probPos = 1 / (1 + np.exp(-(1 * (np.dot(weights, n)))))
        probNeg = 1 / (1 + np.exp(-(-1 * (np.dot(weights, n)))))

        pred = 0
        if probPos > probNeg:
            pred = 1
        else:
            pred = -1

        prob = max(probPos, probNeg)

        if ((1 >= prob > gamma + 0.5) or (0 <= prob < gamma - 0.5)):
            withinGamma += 1

        if pred != labels[x]:
            Wrong += 1
    return Wrong / withinGamma

## STUDENT: YOUR CODE ENDS

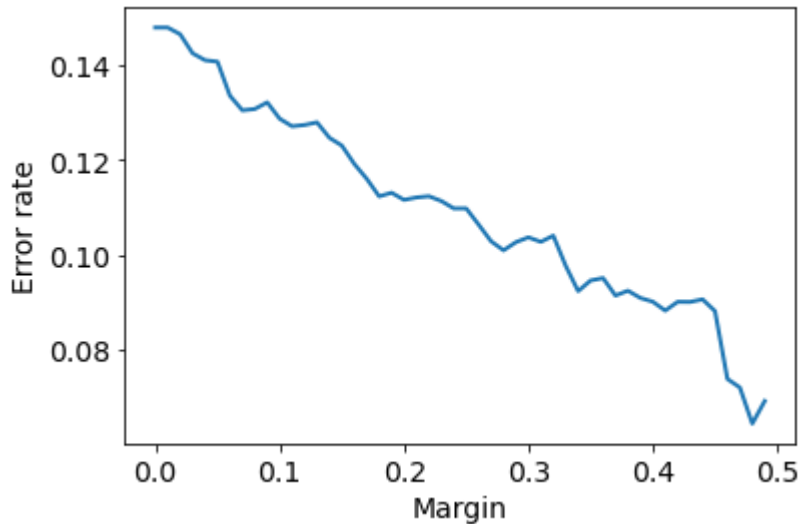
```

We now visualize the relationship between margin and error rate.

```
In [47]: ## Create grid of gamma values
gammas = np.arange(0, 0.5, 0.01)

## Compute margin_errors on test data for each value of g
f = np.vectorize(lambda g: margin_errors(test_data, test_labels, final_weights,
g))

## Plot the result
plt.plot(gammas, f(gammas), linewidth=2)
plt.ylabel('Error rate', fontsize=14)
plt.xlabel('Margin', fontsize=14)
plt.show()
```



## 4. Words with large influence

Finally, we attempt to partially **interpret** the logistic regression model.

Which words are most important in deciding whether a sentence is positive? As a first approximation to this, we simply take the words whose coefficients in  $\theta$  have the largest positive values.

Likewise, we look at the words whose coefficients in  $\theta$  have the most negative values, and we think of these as influential in negative predictions.

**Task P8:** Report the top 10 positive words (i.e., words with the largest positive coefficients of  $\theta$ ) and the top 10 negative words (i.e., words with the most negative coefficients of  $\theta$ ).



```

In [49]: ## Convert vocabulary into a list:
## This is a list where the i-th entry corresponds to the

vocab = np.array([z[0] for z in sorted(vectorizer.vocabulary_.items(), key=lambda x:x[1])])
print(vocab)

## STUDENT: YOUR CODE HERE
sortedList = final_weights.argsort()

pos = list()
neg = list()

for i in range(10):
    pos.append(vocab[sortedList[-(i + 1)]]))
    neg.append(vocab[sortedList[i]])

print('Positive words are:\t' + str(pos))
print('Negative words are:\t' + str(neg))

## STUDENT: CODE ENDS

['aailiyah' 'abandoned' 'abhor' ... 'zero' 'zillion' 'zombie']
Positive words are:      ['scratch', 'perfected', 'function', 'greatest', 'loved', 'awful', 'likes', 'nicest', 'lovely', 'deliciously']
Negative words are:      ['disappointment', 'poorly', 'wasted', 'sucker', 'arepas', 'disappointment', 'worth', 'dog', 'aversion', 'waste']

```

## 5. (Bonus question) Classifiers that can abstain

Suppose you are building a classifier, and can tolerate an error rate of at most some value  $\epsilon$ . Unfortunately, every classifier you try has a higher error than this.

Therefore, you decide that the classifier is allowed to occasionally **abstain**: that is, to say *"don't know"*. When it actually makes a prediction, it must have error rate at most  $\epsilon$ . And subject to this constraint, it should abstain as infrequently as possible.

How would you build an abstaining classifier of this kind, starting from a logistic regression model? To get the bonus score, you need to show the following:

- A general description of the method
- Your code implementation
- A case study to show how you can use it in practice (including necessary plots)

```

In [ ]: ## STUDENT: YOUR CODE HERE

```

```

## STUDENT: CODE ENDS

```