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CMPE 258
Assignmnt - 3
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In [1]:
```
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
from numpy.random import uniform, seed
```

1. (40pts) Define functions

Please define the following functions. One-hot encoding Sigmoid Forward propagation Backward propagation Gradient descent Softmax

In [2]:
```
def sigmoid(z):
    return 1/(1 + np.exp(-z))
```

In [3]:
```
def sigmoid_derivative(a):
    return a * (1-a)
```

In [4]:
```
def softmax(z):
    ez = np.exp(z)
    return (ez/np.sum(ez,axis=1).reshape(-1,1))
```

In [5]:
```
def forward_pass(X_mat):

    global neural_dict
    W1 = neural_dict['W1']
    W2 = neural_dict['W2']
    B1 = neural_dict['B1']
    B2 = neural_dict['B2']

    z1 = np.dot(X_mat,W1.T).T + B1
    a1 = sigmoid(z1)
    z2 = (np.dot(W2, a1)+ B2)
    a2 = sigmoid(z2).T
    neural_dict['a1'] = a1
    neural_dict['a2'] = a2
```

In [6]:
```
def one_hot_encoding(mat):
    list_of_list = []
    for i in range(0,len(mat)):
        small_list = np.zeros(np.max(mat)+1)
        small_list[mat[i]] = 1
        list_of_list.append(small_list)
    result = np.array(list_of_list)
    return result
```

In [7]:
```
def backward_pass():
    m = X_train.shape[0]
    y = Y_train_onehot
    W1 = neural_dict['W1']
    W2 = neural_dict['W2']
    B1 = neural_dict['B1']
    B2 = neural_dict['B2']
    a1 = neural_dict['a1']
    a2 = neural_dict['a2']

    dl_dz2 = a2-y
    dl_dw2 = np.dot(dl_dz2.T, a1.T)/m
    dl_db2 = np.sum(dl_dz2.T, axis=1, keepdims=True)/m
    dl_da1 = np.dot(dl_dz2, W2)
    dl_dz1 = np.multiply(dl_da1.T,sigmoid_derivative(a1))
    dl_dw1 = np.dot(dl_dz1, X_train)/m
    dl_db1 = np.sum(dl_dz1, axis=1, keepdims=True)/m

    return dl_dw1, dl_dw2, dl_db1, dl_db2
```

In [8]:
```
def calculate_loss():
    a = neural_dict['a2']
    y = Y_train_onehot
    return (np.multiply(y,np.log(a)) + np.multiply((1-y),np.log(1-a)))
```

In [9]:
```
def calculate_cost():
    m = X_train.shape[0]
    cost = -np.sum(calculate_loss())
    return cost/m
```

In [10]:
```
def gradient_descent(X_train,learning_rate,iterations=1000):

    global plot_object
    global neural_dict

    neural_dict['W1'] = W1
    neural_dict['W2'] = W2
    neural_dict['B1'] = B1
    neural_dict['B2'] = B2

    all_costs = []
    count = 0
    forward_pass(X_train)
    new_cost = calculate_cost()
    current_cost = float("inf")
    while new_cost <= current_cost and count < iterations:
        all_costs.append(new_cost)
        count += 1
        dl_dw1, dl_dw2, dl_db1, dl_db2 = backward_pass()


        neural_dict['W1'] = neural_dict['W1'] - (learning_rate * dl_dw1)
        neural_dict['W2'] = neural_dict['W2'] - (learning_rate * dl_dw2)
        neural_dict['B1'] = neural_dict['B1'] - (learning_rate * dl_db1)
        neural_dict['B2'] = neural_dict['B2'] - (learning_rate * dl_db2)

        current_cost = new_cost
        forward_pass(X_train)
        new_cost = calculate_cost()
        count +=1
    plot_object[learning_rate] = all_costs
    print "Final cost : ",
    print new_cost
    print "Iternations : %d" % count
```

In [11]:
```
"""
Predicting results by performing Softmax on the result of forward pass o
n the testing data
"""

def predict(X_mat):
    global neural_dict

    W1 = neural_dict['W1']
    W2 = neural_dict['W2']
    B1 = neural_dict['B1']
    B2 = neural_dict['B2']

    z1 = np.dot(X_mat,W1.T).T + B1
    a1 = sigmoid(z1)
    z2 = (np.dot(W2, a1)+ B2)
    a2 = softmax(z2).T
    prediction = []
    for i in a2:
        prediction.append(np.argmax(i))
    return prediction
```

In [12]:
```
def calculate_accuracy(actual,predicted):
    count = 0.0
    for i in range(0,len(actual)):
        if predicted[i] == actual[i]:
            count+= 1
    return count/len(actual)
```

In [13]:
```
plot_object = {}
```

2. (5pts) Split data

Please split each data (Train & Test) set as input (x) and output (y) set. Input set is the columns starting 0 to 399. Output set is the column of 'y'.

In [14]:
```
train_data = pd.read_csv("./ex3_train.csv")
test_data = pd.read_csv("./ex3_test.csv")

X_train = train_data.iloc[:,:(train_data.shape[1] -1 )]
X_test =  test_data.iloc[:,:(test_data.shape[1] -1 )]

Y_train = train_data['y']
Y_test =test_data['y']
Y_train_onehot = one_hot_encoding(Y_train)
Y_test_onehot = one_hot_encoding(Y_test)

Y_train = Y_train.tolist()
Y_test = Y_test.tolist()
```

3. (5pts) Initialize parameters

Please use np.random.seed(1) when weight coefficients is initialized. Please set as zeros for bias terms.

In [15]:
```
hidden_neurons = 25
output_neurons = 10
np.random.seed(1)

W1 = []
for i in range(0,hidden_neurons):
    sampl = np.random.uniform(low=-1, high=1, size=(X_train.shape[1]))
    W1.append(sampl)
W2 = []
for i in range(0,output_neurons):
    sampl = np.random.uniform(low=-1, high=1, size=(hidden_neurons))
    W2.append(sampl)
B1 = []
for i in range(0,hidden_neurons):
    B1.append([0])
B2 = []
for i in range(0,output_neurons):
    B2.append([0])

W1 = np.array(W1)
W2 = np.array(W2)
B1 = np.array(B1)
B2 = np.array(B2)
```

4. (20pts) Neural Network model with 1 hidden layer

Please build neural network model using input layer (400 neurons), 1 hidden layer (25 neurons), and output layer (10 neurons) using training data set.

In [16]:
```
neural_dict = {}
```

In [17]:
```
learning_rates = [0.01,0.1,0.5,0.7,1]
plot_object = {}
for rate in learning_rates:
    gradient_descent(X_train,rate,500)
    Y_pred = np.array(np.argmax(neural_dict['a2'], axis=1))
    print "Learning rate : %f" % rate
    print "Training accuracy : %f " % calculate_accuracy(Y_train,Y_pred)
    print
    print "************"
    print
```

```
Final cost :  3.32102945016
Iternations : 500
Learning rate : 0.010000
Training accuracy : 0.140857

************

Final cost :  2.18525907906
Iternations : 500
Learning rate : 0.100000
Training accuracy : 0.619429

************

Final cost :  1.09508005459
Iternations : 500
Learning rate : 0.500000
Training accuracy : 0.836857

************

Final cost :  0.917439042255
Iternations : 500
Learning rate : 0.700000
Training accuracy : 0.866000

************

Final cost :  0.766041218141
Iternations : 500
Learning rate : 1.000000
Training accuracy : 0.897143

************
```

5. (10pts) Predictions

Please predict digit using softmax function. Please calculate accuracy for the prediction using training data set and testing data set.

In [18]:
```
'''Would take about 2 Minutes'''

gradient_descent(X_train,1,8000)
Y_pred_train = np.array(np.argmax(neural_dict['a2'], axis=1))
Y_pred_test = predict(X_test)
print "Training accuracy : %f " % calculate_accuracy(Y_train,Y_pred_trai
n)
print "Testing accuracy : %f " % calculate_accuracy(Y_test,Y_pred_test)
```

```
Final cost :  0.107004221111
Iternations : 8000
Training accuracy : 0.993429
Testing accuracy : 0.910667
```

6. (20pts) Optimization

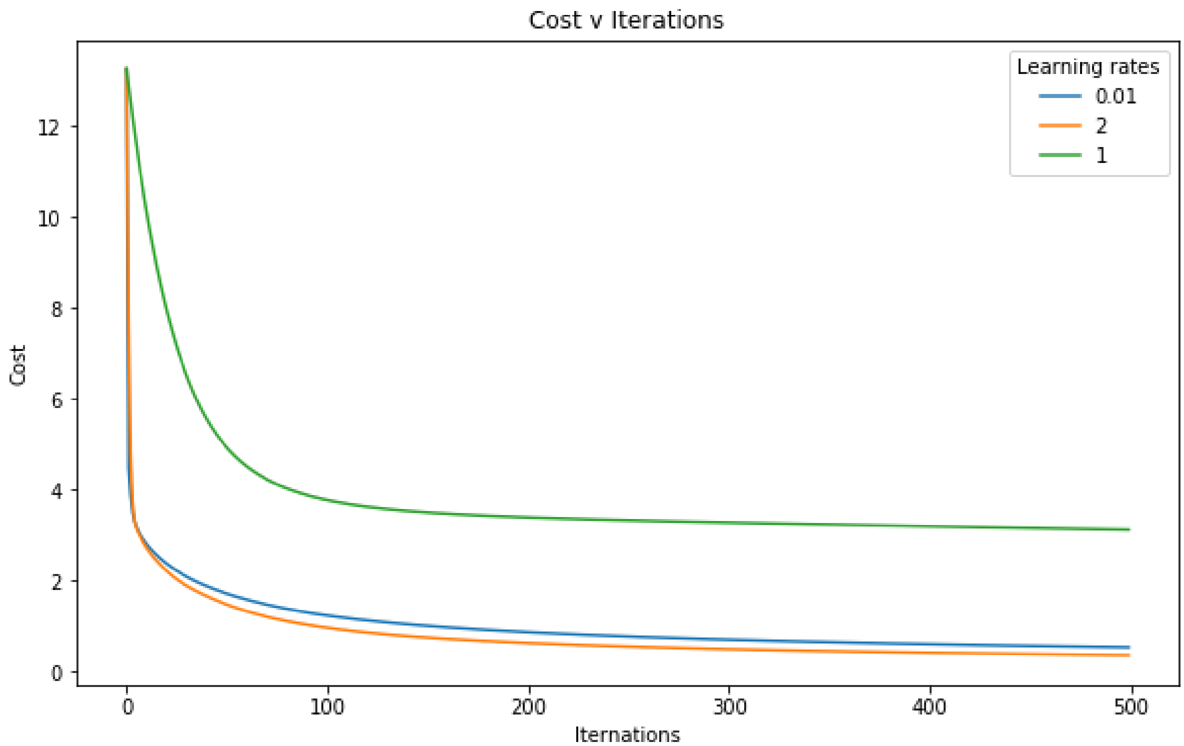
Please optimize your model using various learning rate and number of iteration. Please plot cost versus number of iteration with different learning rate for training data set. Please print out the optimized accuracy for testing data set.

In [19]:
```
learning_rates = [0.01,2,1]
plot_object = {}
# iterations = [500,700,1000,5000]
train_results = []
test_results = []
for rate in learning_rates:
#     for it in iterations:
    gradient_descent(X_train,rate,1000)   #,it)
    Y_pred_train = np.array(np.argmax(neural_dict['a2'], axis=1))
    Y_pred_test = predict(X_test)
    train_results.append(calculate_accuracy(Y_train,Y_pred_train))
    test_results.append(calculate_accuracy(Y_test,Y_pred_test))
    print "Learning rate : %f" % rate
    print "Training accuracy : %f " % train_results[-1]
    print "Testing accuracy : %f " % test_results[-1]
    print
    print "************"
    print
```

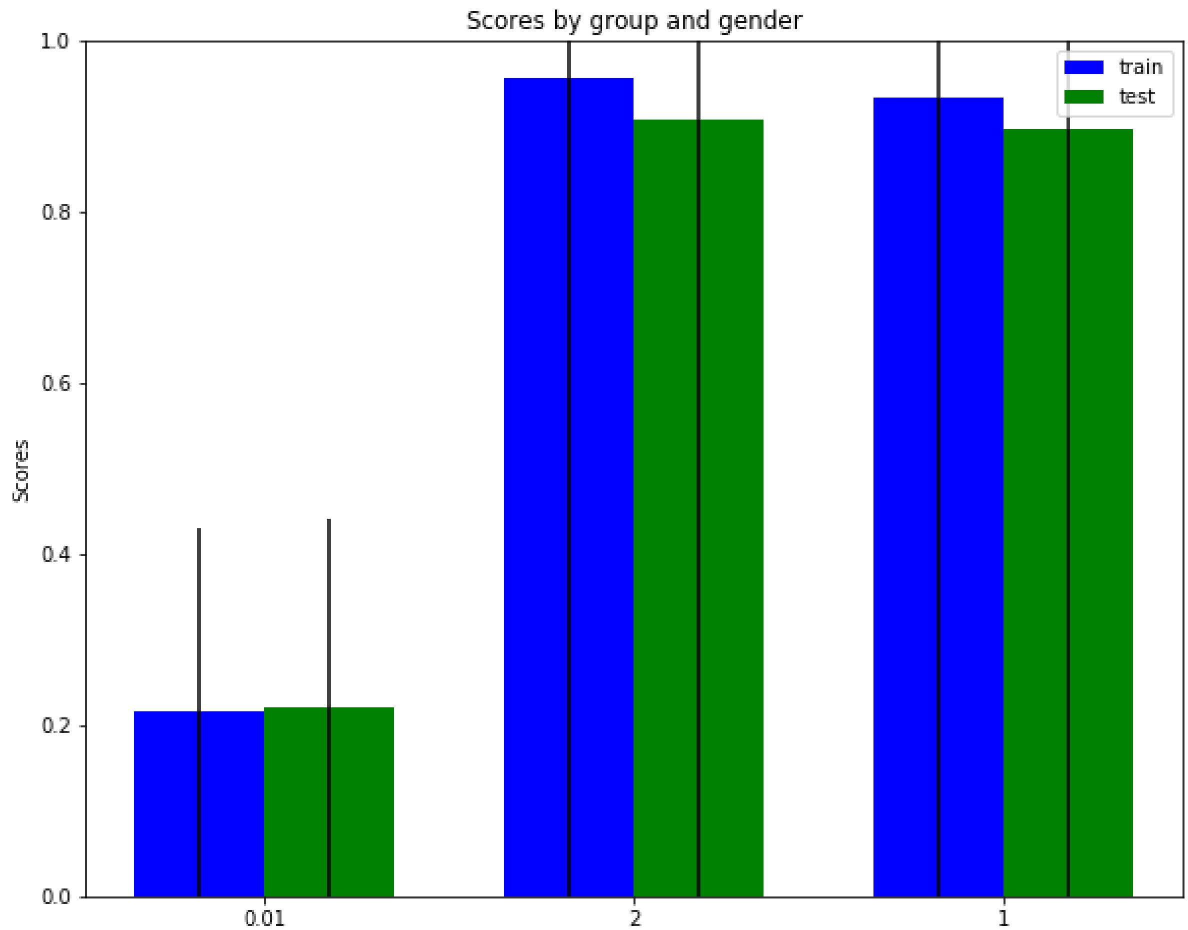
```
Final cost :  3.11273973701
Iternations : 1000
Learning rate : 0.010000
Training accuracy : 0.215143
Testing accuracy : 0.220000

************

Final cost :  0.354720557248
Iternations : 1000
Learning rate : 2.000000
Training accuracy : 0.955143
Testing accuracy : 0.907333

************

Final cost :  0.529825934313
Iternations : 1000
Learning rate : 1.000000
Training accuracy : 0.934000
Testing accuracy : 0.896667

************
```

In [20]:
```
plt.figure(figsize=(10,6))
plt.xlabel('Iternations')
plt.ylabel('Cost')
plt.title("Cost v Iterations")
for key, value in plot_object.items():
    plt.plot(range(0,len(value)),sorted(value,reverse=True),label='Learn
ing rate' + str(key))
plt.legend(learning_rates,title="Learning rates")
```

Out[20]: `<matplotlib.legend.Legend at 0x106609b90>`



In [21]:
```
N = len(learning_rates)


ind = np.arange(N)  # the x locations for the groups
width = 0.35       # the width of the bars


fig, ax = plt.subplots()
rects1 = ax.bar(ind, train_results, width, color='b', yerr=train_results
)

rects2 = ax.bar(ind + width, test_results, width, color='g', yerr=test_r
esults)


fig.set_figheight(8)
fig.set_figwidth(10)

# add some text for labels, title and axes ticks
ax.set_ylabel('Scores')
ax.set_title('Scores by group and gender')
ax.set_xticks(ind + width / 2)
ax.set_xticklabels((learning_rates))
ax.set_ylim([0,1])

ax.legend((rects1[0], rects2[0]), ('train', 'test'))

plt.show()
```



Best accuracy achieved with rate 1 and Iterations 8000

Final cost : 0.107004221111
Iternations : 8000
Learning rate : 1
Training accuracy : 0.993429
Testing accuracy : 0.910667

Quick second Best accuracy achieved with rate 2 and Iterations 1200

Final cost : 0.3136009954
Iternations : 1200
Learning rate : 2
Training accuracy : 0.961714
Testing accuracy : 0.908000