CS289A_HW03_Prob6ab

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First, I load modules to be used in the execution of the problem:

```
In [1]: %load_ext autoreload

In [2]: %autoreload 2

In [3]: import math
        import HW03_utils as ut
        import numpy as np
        from matplotlib import pyplot as plt
```

Then, I define custom functions to be used in the program (the last two are used to calculate the mean and covariance matrix):

```
In [4]: def normalize_images(image_vectors):
        # Function to normalize pixel contrast of images

                magnitudes = np.linalg.norm(image_vectors,axis=1)
                normalized_ims = image_vectors/magnitudes[:,None]
                return normalized_ims

In [5]: def get_class_bounds(classid,labels):
        # Function to extract index bounds of the specified class from the dataset

            for i in range(len(labels)):
                if labels[i] == classid:
                    startindex = i
                    break
            stopindex = len(labels)
            for i in range(i,len(labels)):
                if labels[i] != classid:
                    stopindex = i
                    break

            return startindex,stopindex

In [6]: def get_class_from_data(classid,data,labels):
        # Find the start (inclusive) and end (exclusive) of a class within the data
```

```
        startindex,stopindex = get_class_bounds(classid,labels)

        # Separate the specified class
        class_data = data[startindex:stopindex]

        return class_data
```

```
In [7]: def mean_of_class(classid,data,labels):
        # Calculate the mean value when the class is fit to a normal distribution

            class_data = get_class_from_data(classid,data,labels)
            # Calculate the mean of the class data
            class_mu = np.mean(class_data,axis=0)

            return class_mu
```

```
In [8]: def cov_of_class(classid,data,labels):
        # Calcualte the covariance matrix when the class is fit to a normal distrib

            class_data = get_class_from_data(classid,data,labels)
            # Calculate the covariance matrix from the class data
            class_Sigma = np.cov(class_data,rowvar=False)

            return class_Sigma
```

Now comes the program execution. To start, I specify local paths to the data and then load it into memory.

```
In [9]: CS_DIR = r"/Users/mitch/Documents/Cal/2 - 2017 Spring/COMPSCI 289A - Intro
```

```
In [10]: # Load MNIST data
         data_array = ut.loaddata("hw3_mnist_dist/hw3_mnist_dist/train.mat",CS_DIR+
```

Immediately after loading the data, I shuffle it and then separate it into data and labels.

```
In [11]: # Shuffle data and set aside validation set
         np.random.shuffle(data_array)

         trainarray = data_array[:-10000]
         valarray = data_array[-10000:]

         # Organize array by digit
         trainarray_byclass = trainarray[trainarray[:,-1].argsort()]
         valarray_byclass = valarray[valarray[:,-1].argsort()]
```

```
In [12]: train_data = trainarray_byclass[:,:-1]
         train_labels = trainarray_byclass[:,-1]

         val_data = valarray_byclass[:,:-1]
         val_labels = valarray_byclass[:,-1]
```

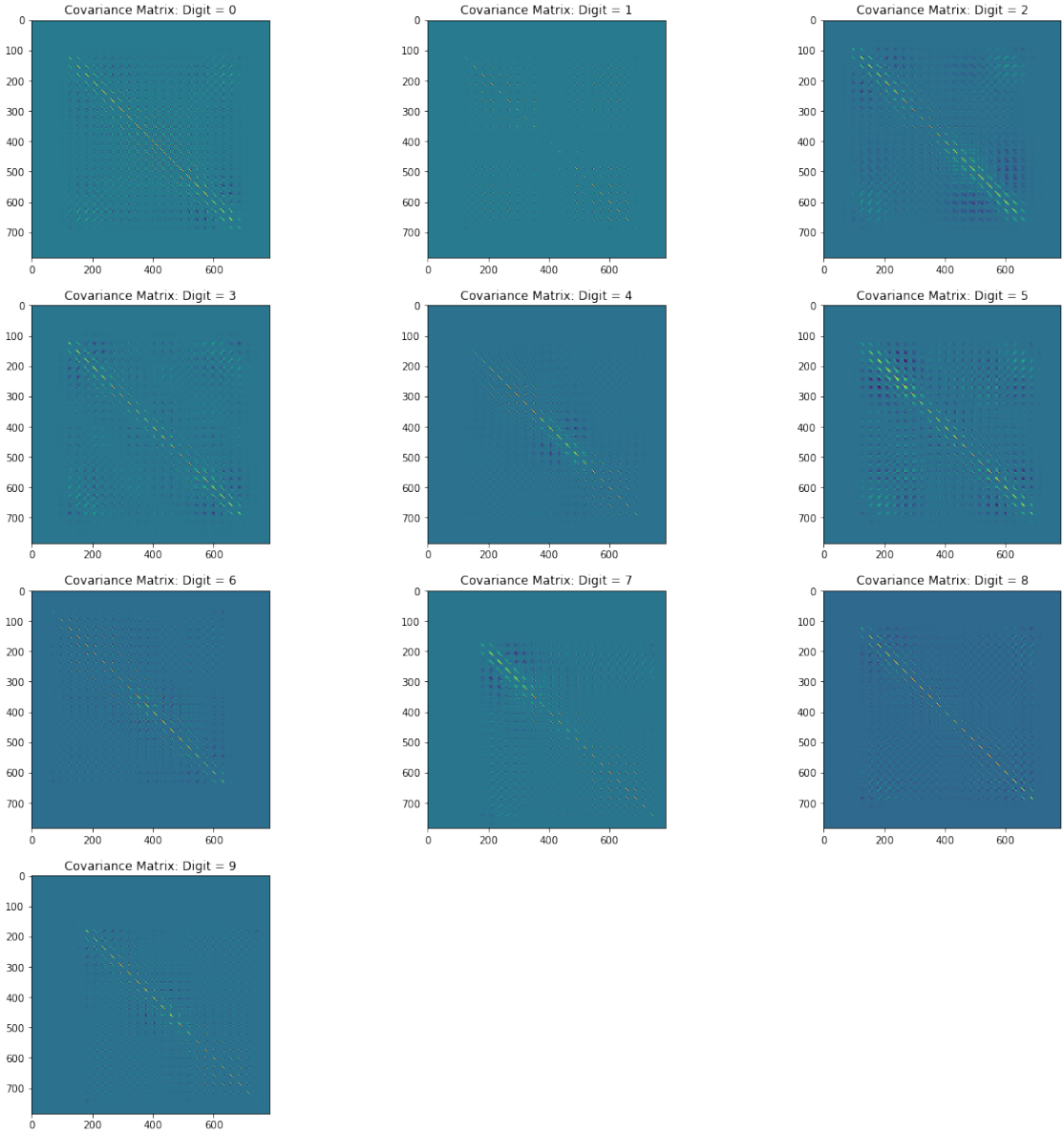
To maintain consistency between calculations, I normalize all the images using a custom defined function (given above).

```
In [13]: normalized_traindata = normalize_images(train_data)
         normalized_valdata = normalize_images(val_data)
```

For each digit, I calculate the mean and covariance matrix and then plot both.

```
In [14]: fig = plt.figure(figsize=(20,20))
         for i in range(10):
             mu_i = mean_of_class(i,normalized_traindata,train_labels)
             Sigma_i = cov_of_class(i,normalized_traindata,train_labels)

             plt.subplot(4,3,i+1)
             plt.imshow(Sigma_i)
             plt.title('Covariance Matrix: Digit = %i' %i)
         plt.savefig('VisualCovMatrices.jpg')
         plt.show()
```


Covariance Matrix: Digit = 0
Covariance Matrix: Digit = 1
Covariance Matrix: Digit = 2
Covariance Matrix: Digit = 3
Covariance Matrix: Digit = 4
Covariance Matrix: Digit = 5
Covariance Matrix: Digit = 6
Covariance Matrix: Digit = 7
Covariance Matrix: Digit = 8
Covariance Matrix: Digit = 9