CEE 498 Applied Machine Learning - HW4

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1 Problem 1

1.1 Part a

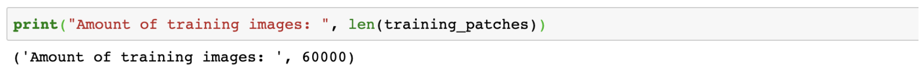
We followed the following steps for this part.

(a) Built a function for creating 10 x 10 patches and extracting these patches from a 4x4 grid of an image

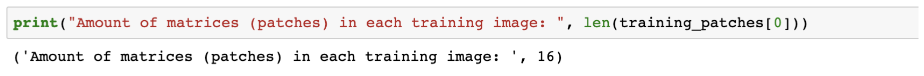
```
#Creating 4x4 grid of 10x10 patches
def patch_creation(image):
    patches = []
    x=[0,6,12,18]
    y=[0,6,12,18]
    for i in x:
        for j in y:
            patch = image[i:i+10,j:j+10].reshape(-1,100)
            patches.append(patch)
    return(patches)
```

(b) Created patches for all 60,000 training images.

```
#reshaping each 784 1-d array into 28x28 2-d array and creating patches for each image
training_patches=[]
for i in range(60000):
    image = train_set[0][i].reshape(28,28)
    training_patches.append(patch_creation(image))
```



```
print("Amount of training images: ", len(training_patches))
('Amount of training images: ', 60000)
```

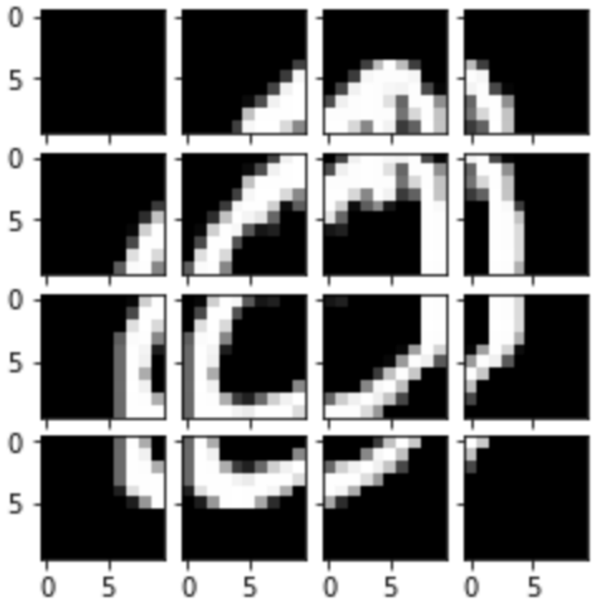


```
print("Amount of matrices (patches) in each training image: ", len(training_patches[0]))
('Amount of matrices (patches) in each training image: ', 16)
```

An example of the train image with the patches is as shown below.

```
test_image()
```

```
('Image shape: ', (28, 28))
('Num patches: ', 16)
```



(c) For each training image, one of these patches is chosen uniformly and at random. This dataset of 60,000 patches is sub-sampled uniformly and at random to produce a 6000 element dataset

```
#Choosing 1 patch from the 16 previously created for each
    image at random and appending to training list
train_cluster=[]
for i in range(60000):
    n = random.randint(0, 15)
    train_cluster.append(training_patches[i][n])
#creates a list of 6000 numbers where each is between 0 -
    59999
indices = random.sample(range(60000), 6000)
#appending randomly sampled patches using the previously
    created list of indices
train_cluster_sample=[]
for ind in indices:
    train_cluster_sample.append(train_cluster[ind])
```

```
print("Length of our randomly sampled patches: ", len(train_cluster_sample))
```

```
('Length of our randomly sampled patches: ', 6000)
```

(d) The above dataset is clustered to 50 centres.

```
#creating a 6000x100 matrix of zeros that where each row will
    be one of our samples
training_matrix = np.zeros((6000,100))
for i in range(6000):
    #making eacch row a random patch
    training_matrix[i,:] = train_cluster_sample[i][0]
# create kmeans object
kmeans = KMeans(n_clusters=50)
# fit kmeans object to data
kmeans.fit(training_matrix)
# save new clusters for chart
y_km = kmeans.predict(training_matrix)
```

(e) Assigned the closest cluster to all the patches of the 60,000 training images.

```
training_matrix_60k = np.zeros((60000,100))
for i in range(60000):
    training_matrix_60k[i,:] = train_cluster[i][0]
y_km_60k = kmeans.predict(training_matrix_60k)
```

(f) Subset datasets for each cluster centre and cluster them again to 50 clusters.

```
cluster_dict = {}
for i in range(50):
    key = str(i)
    subtrain_matrix = training_matrix_60k[y_km_60k==i,:]
    kmeans_sub = KMeans(n_clusters=50)
    kmeans_sub.fit(subtrain_matrix)
    cluster_dict[key] = kmeans_sub
    y_km_sub = kmeans_sub.predict(subtrain_matrix)
```

1.2 Part b

We followed the following steps for this part.

(a) Built a function for padding the images

```
def pad_with(vector, pad_width, iaxis, kwargs):
    pad_value = kwargs.get('padder', 0)
    vector[:pad_width[0]] = pad_value
    vector[-pad_width[1]:] = pad_value
```

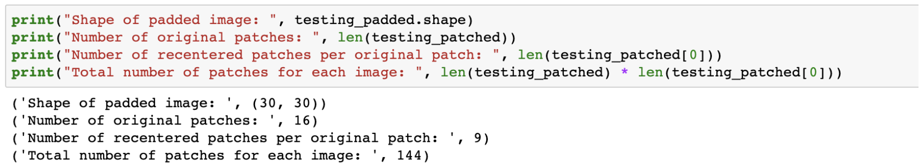
(b) Built a function for creating 9 sub-patches for each of the 10x10 patch in the 4x4 grid.

```
def patch_b(image):
    patches16 = []
    x_ = [0, 1, 2]
    y_ = [0, 1, 2]
    x=[0,6,12,18]
    y=[0,6,12,18]
    for i in x:
```

```python
        for j in y:
            patches9 = []
            for k in x_:
                for l in y_:
                    patch = image[i+k:i+k+10, j+l:j+l+10].reshape(-1,100)
                    patches9.append(patch)
            patches16.append(patches9)
    return patches16
```

(c) The sub patches were created for 10,000 testing images and 6,000 training images.

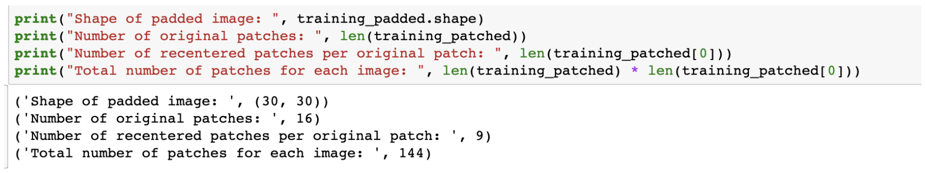
```python
testing_patches = []
testing_labels = []
for i in range(10000):
    testing_reshaped = test_set[0][i].reshape(28,28)
    testing_labels.append(test_set[1][i])
    testing_padded = np.pad(testing_reshaped, 1, pad_with)
    testing_patched = patch_b(testing_padded)
    testing_patches.append(testing_patched)
```



```python
print("Shape of padded image: ", testing_padded.shape)
print("Number of original patches: ", len(testing_patched))
print("Number of recentered patches per original patch: ", len(testing_patched[0]))
print("Total number of patches for each image: ", len(testing_patched) * len(testing_patched[0]))
```

```
('Shape of padded image: ', (30, 30))
('Number of original patches: ', 16)
('Number of recentered patches per original patch: ', 9)
('Total number of patches for each image: ', 144)
```

```python
training_patches = []
random_indices = random.sample(range(60000), 6000)
training_labels = []
for i in random_indices:
    training_reshaped = train_set[0][i].reshape(28,28)
    training_labels.append(train_set[1][i])
    training_padded = np.pad(training_reshaped, 1, pad_with)
    training_patched = patch_b(training_padded)
    training_patches.append(training_patched)
```



```python
print("Shape of padded image: ", training_padded.shape)
print("Number of original patches: ", len(training_patched))
print("Number of recentered patches per original patch: ", len(training_patched[0]))
print("Total number of patches for each image: ", len(training_patched) * len(training_patched[0]))
```

```
('Shape of padded image: ', (30, 30))
('Number of original patches: ', 16)
('Number of recentered patches per original patch: ', 9)
('Total number of patches for each image: ', 144)
```

(d) Then, we built a function for finding the cluster and sub cluster for each of the sub patches.

```python
def finding_cluster(data,num_images=10000,num_grids=16,num_patches=9):
    data_matrix_long = np.zeros((num_images*num_grids*num_patches,100))
    z=0
    for i in range(num_images):
        for j in range(num_grids):
            for k in range(num_patches):
                data_matrix_long[z,:] = data[i][j][k]
                z=z+1
    #Finding the main 50 clusters
    data_km_long = kmeans.predict(data_matrix_long)
    data_50clusters= np.zeros((num_images,num_grids,
    num_patches))
    z=0
    for i in range(num_images):
        for j in range(num_grids):
            for k in range(num_patches):
                data_50clusters[i,j,k] = data_km_long[z]
                z=z+1
    data_2500clusters= [[['000_000' for i in range(num_patches
    )] for j in range(num_grids)] for k in range(num_images)]
    subcluster_data_fit = np.zeros((1,100))
    z=1
    #Finding the subclusters of each patch
    for i in range(num_images):
        for j in range(num_grids):
            for k in range(num_patches):
                cluster = data_50clusters[i,j,k]
                subcluster_data_fit[0,:] = data[i][j][k]
                fitted_centre=cluster_dict[str(int(cluster))].
    predict(subcluster_data_fit)
                text=str(int(cluster))+'_'+str(fitted_centre
    [0])
                data_2500clusters[i][j][k]= text
                if z%10000==0 and z>=10000:
                    print(str(z*100/(num_images*num_grids*
    num_patches))+'% done')
                z=z+1
    return(data_2500clusters)
```

(e) We built a function for creating the histogram, i.e. we built the dataset of shape 10,000 x 2,500 for testing and 6,000 x 2,500 for training with each column giving the number of patches with a certain cluster_subcluster.

```
def histogram_patch_creation(data,num_images=10000,num_grids
    =16,num_patches=9):
    colnames=['image_num']
    for i in range(50):
        for j in range(50):
            colnames.append(str(i)+'_'+str(j))
    df=np.zeros((num_images,2501))
    hist_patches = pd.DataFrame(df,columns = colnames)
    hist_patches['image_num']=range(num_images)
    z=1
    for i in range(num_images):
        for j in range(16):
            for k in range(9):
                hist_patches.loc[i,data[i][j][k]]+=1
                if z%10000==0 and z>=10000:
                    print(str(z*100/(num_images*num_grids*
    num_patches))+'% done')
                z=z+1
    return(hist_patches)
```

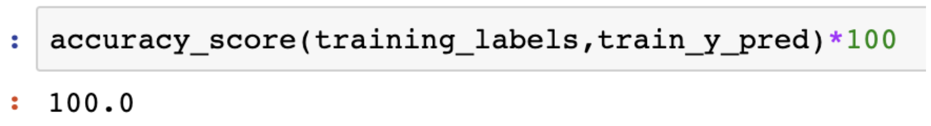
```
#Creating testing data of shape 10000x2500
test_hist_patches=histogram_patch_creation(test_2500clusters,10000,16,9)
#Creating training data of shape 6000x2500
train_2500clusters = finding_cluster(training_patches, 6000, 16, 9)
train_hist_patches=histogram_patch_creation(train_2500clusters,6000,16,9)
```

1.3 Part c

We built a random forest classifier using the training data created as above and tested it on the testing data. Number of trees is set to be 100 and there is no depth set.

```
from sklearn.ensemble import RandomForestClassifier
from sklearn.metrics import accuracy_score
from sklearn.metrics import confusion_matrix
rf = RandomForestClassifier(n_estimators=100, oob_score=True).fit(train_hist_patches,training_labels)
test_y_pred = rf.predict(test_hist_patches)
train_y_pred = rf.predict(train_hist_patches)
```

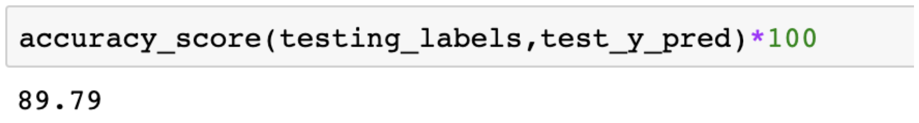
```
#Accuarcy on the training dataset
accuracy_score(training_labels,train_y_pred)*100
```



```
: accuracy_score(training_labels,train_y_pred)*100

: 100.0
```

```
#Accuarcy on the testing dataset
accuracy_score(testing_labels,test_y_pred)*100
```



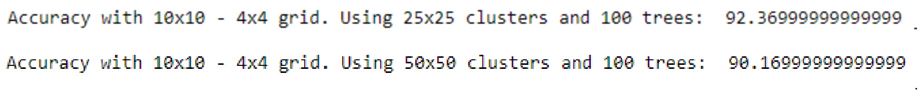
```
accuracy_score(testing_labels,test_y_pred)*100

89.79
```

We get a training accuracy of 100% and testing accuracy of 90%.

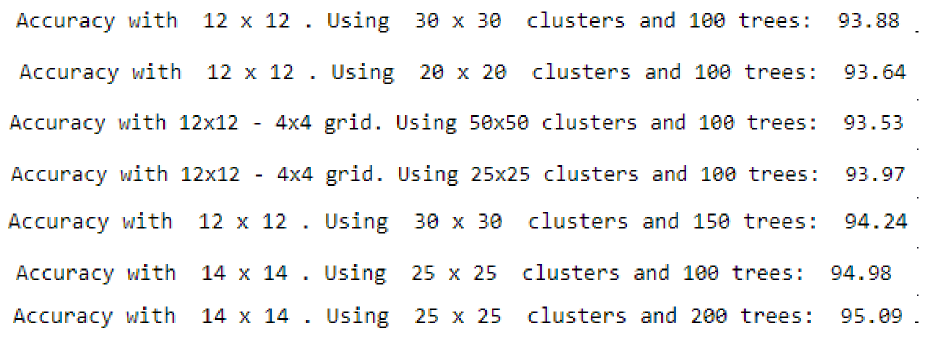
1.4 Part d

We changed the values of patch size (10x10, 12x12 and 14x14), number of trees in random forest (100,200) and the cluster size (main cluster x sub cluster = 20x20, 25x25, 30x30, 50x50). The test accuracies obtained are as shown below.



```
Accuracy with 10x10 - 4x4 grid. Using 25x25 clusters and 100 trees:  92.36999999999999

Accuracy with 10x10 - 4x4 grid. Using 50x50 clusters and 100 trees:  90.16999999999999
```



```
Accuracy with  12 x 12 . Using  30 x 30  clusters and 100 trees:  93.88
Accuracy with  12 x 12 . Using  20 x 20  clusters and 100 trees:  93.64
Accuracy with 12x12 - 4x4 grid. Using 50x50 clusters and 100 trees:  93.53
Accuracy with 12x12 - 4x4 grid. Using 25x25 clusters and 100 trees:  93.97
Accuracy with  12 x 12 . Using  30 x 30  clusters and 150 trees:  94.24
Accuracy with  14 x 14 . Using  25 x 25  clusters and 100 trees:  94.98
Accuracy with  14 x 14 . Using  25 x 25  clusters and 200 trees:  95.09
```

From the above, it is observed that if we use a patch size of 14x14 and cluster size of 25x25 and 200 trees in the decision forest, we can obtain a test accuracy as high as 95.1%.

1.5 Part e

Our best model (as obtained from part d with a testing accuracy of 95.1%) performs better than the linear classifiers, boosted stumps (Kegl et al., ICML 2009) and K-nearest-neighbors, Euclidean (L2)(LeCun et al. 1998). However, it does not perform as well as non-linear classifiers, SVMs, neural networks and convolutional nets.