Q2

May 10, 2024

0.1 Mahdi Anvari 610700002 Homework 2 of Machine Learning Question 2

[100]:

```
# importing libraries
import numpy as np
import pandas as pd
import tensorflow as tf
from sklearn.decomposition import PCA
from sklearn.preprocessing import StandardScaler
import matplotlib.pyplot as plt
```

Dataset: • Load MNIST dataset (could be accessed using from keras.datasets in python) • Separate them by label into 10 smaller sets

[116]:

```
mnist_path = 'c:/Users/M/Downloads/mnist.npz'
with np.load(mnist_path, allow_pickle=True) as f:
    X_train, Y_train = f['x_train'], f['y_train']
    X_test, Y_test = f['x_test'], f['y_test']

X_all = np.concatenate((X_train, X_test), axis=0)
Y_all = np.concatenate((Y_train, Y_test), axis=0)
print((X_all.shape))
print((Y_all.shape))

Sets = [[] for _ in range(10)]
Sets2 = [[] for _ in range(10)]
for i in range(len(X_all)):
    label = Y_all[i]
    Sets[label].append(X_all[i])
    Sets2[label].append(X_all[i])

for i in range(10):
    print(f"Length of label {i} is: ",len(Sets[i]))
```

```
(70000, 28, 28)
(70000,)
Length of label 0 is:  6903
Length of label 1 is:  7877
Length of label 2 is:  6990
Length of label 3 is:  7141
Length of label 4 is:  6824
Length of label 5 is:  6313
Length of label 6 is:  6876
Length of label 7 is:  7293
Length of label 8 is:  6825
Length of label 9 is:  6958
```

a. Flatten the pictures and apply PCA

[117]:

```
for i in range(10):
    Sets[i] = np.array(Sets[i])
    Sets2[i] = np.array(Sets[i])
print(Sets[0].shape)
for i in range(10):
    Sets[i] = (Sets[i]).reshape(Sets[i].shape[0],-1)
print(Sets[0].shape)
```

```
(6903, 28, 28)
(6903, 784)
```

[103]:

```
NormalizedSets = [[] for _ in range(10)]
for i in range(10):
    scaler = StandardScaler()
    NormalizedSets[i] = scaler.fit_transform(Sets[i])
print(NormalizedSets[0].shape)
```

```
(6903, 784)
```

[104]:

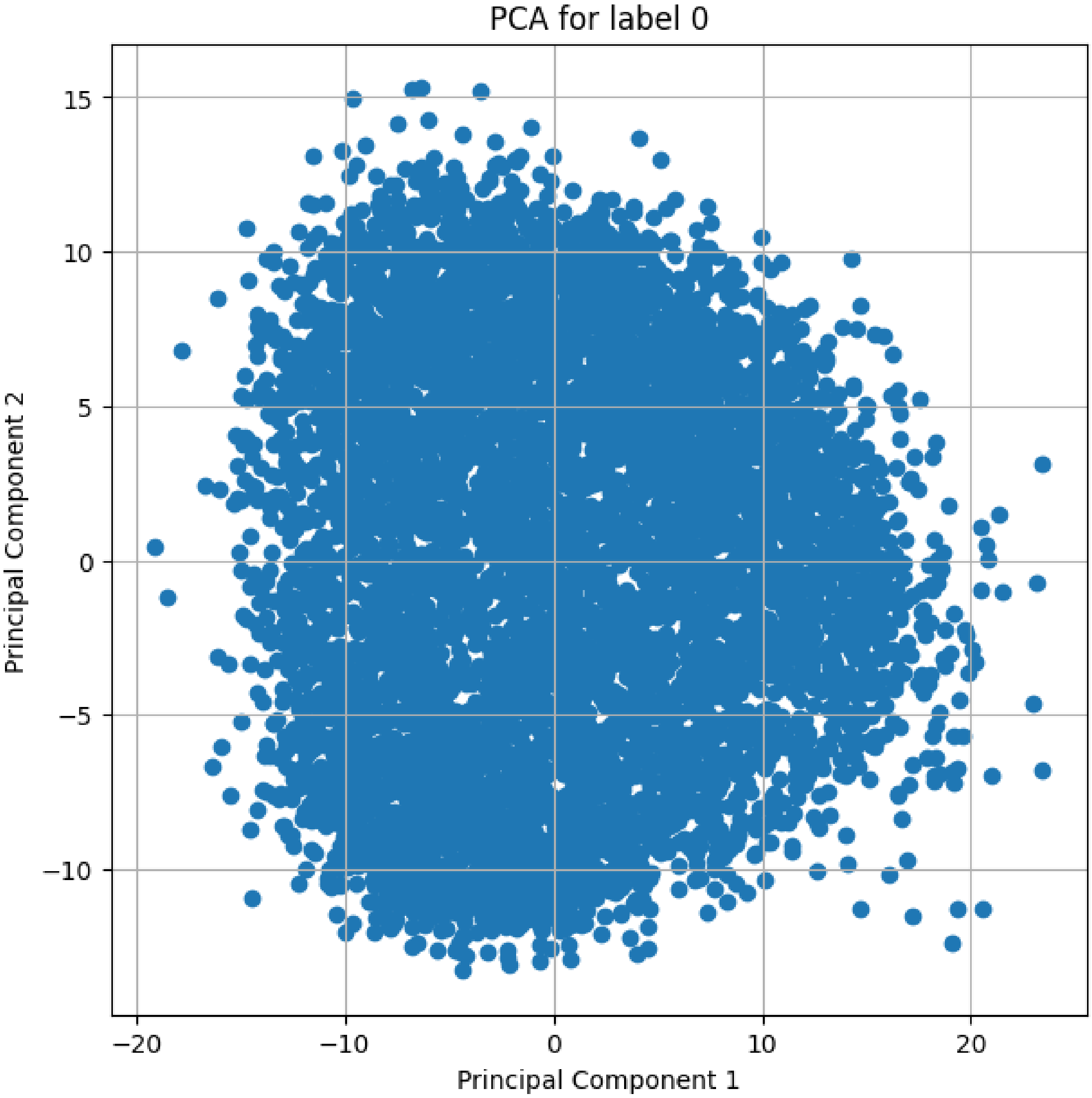
```
PCASets = [[] for _ in range(10)]
for i in range(10):
    NormalizedSets[i] = scaler.fit_transform(Sets[i])
    pca = PCA(n_components=50)
    pca.fit(NormalizedSets[i])
    PCASets[i] = pca.transform(NormalizedSets[i])
print(PCASets[0].shape)
```

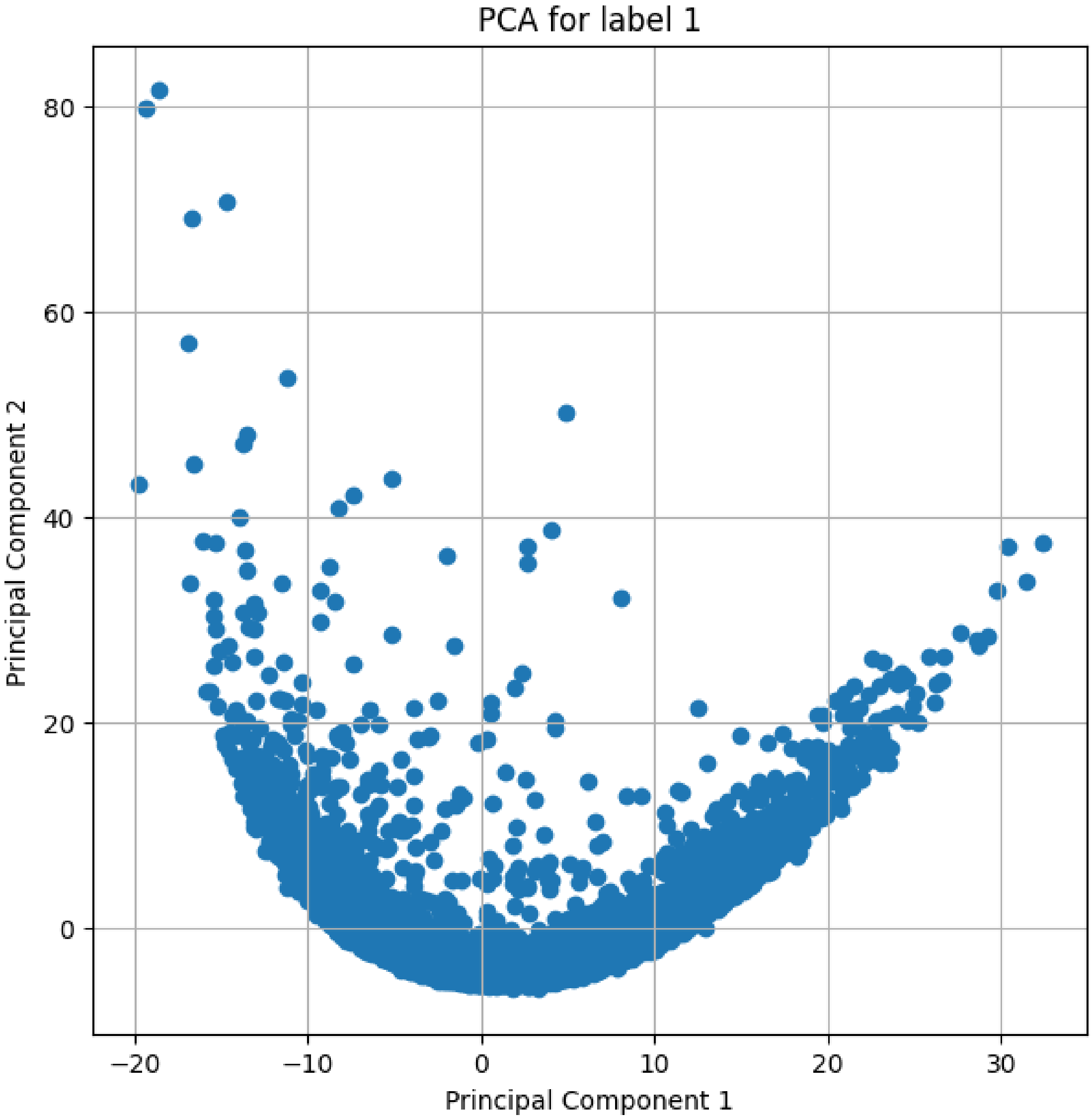
```
(6903, 50)
```

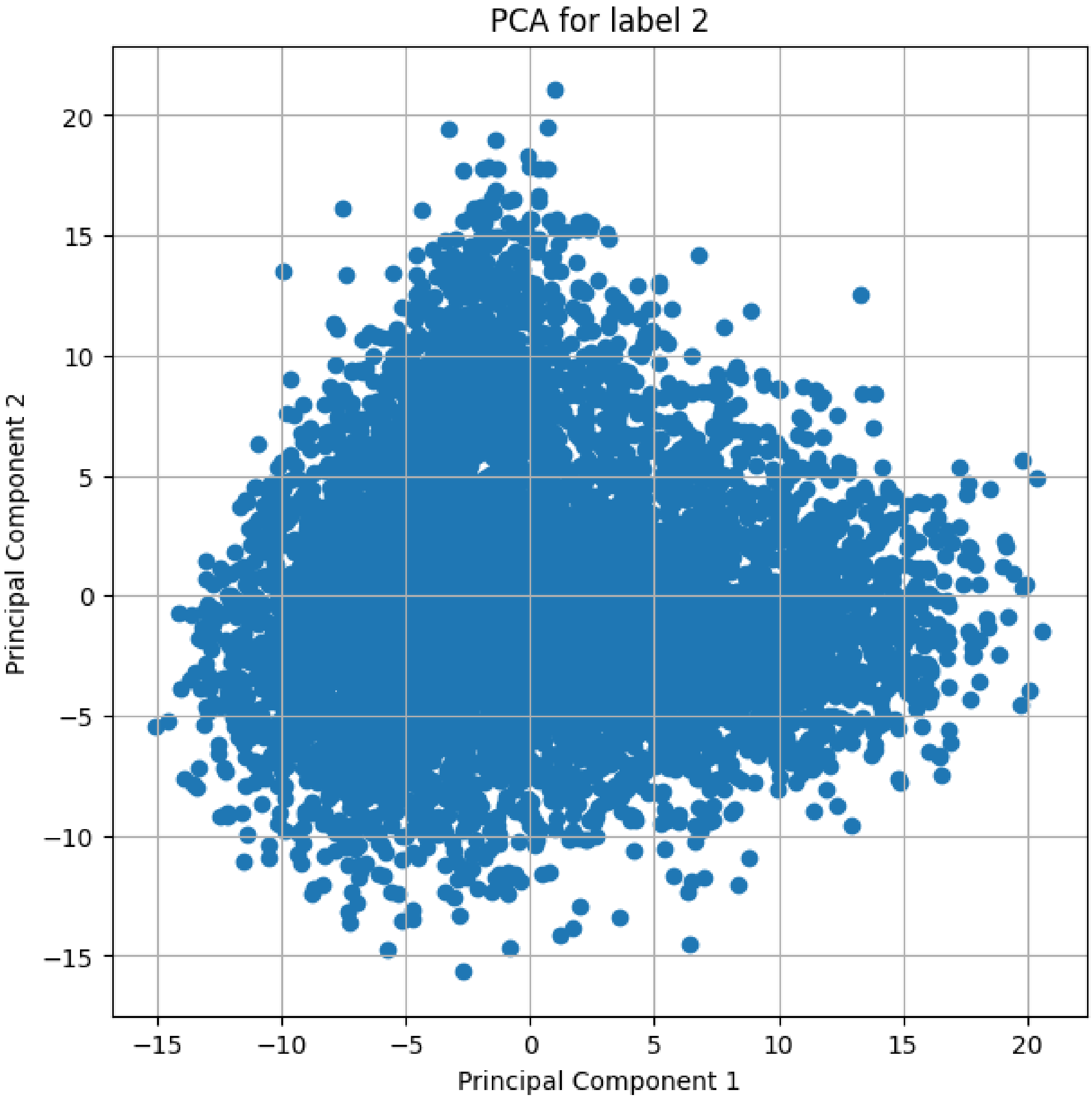
b. Plot first PC vs. Second PC

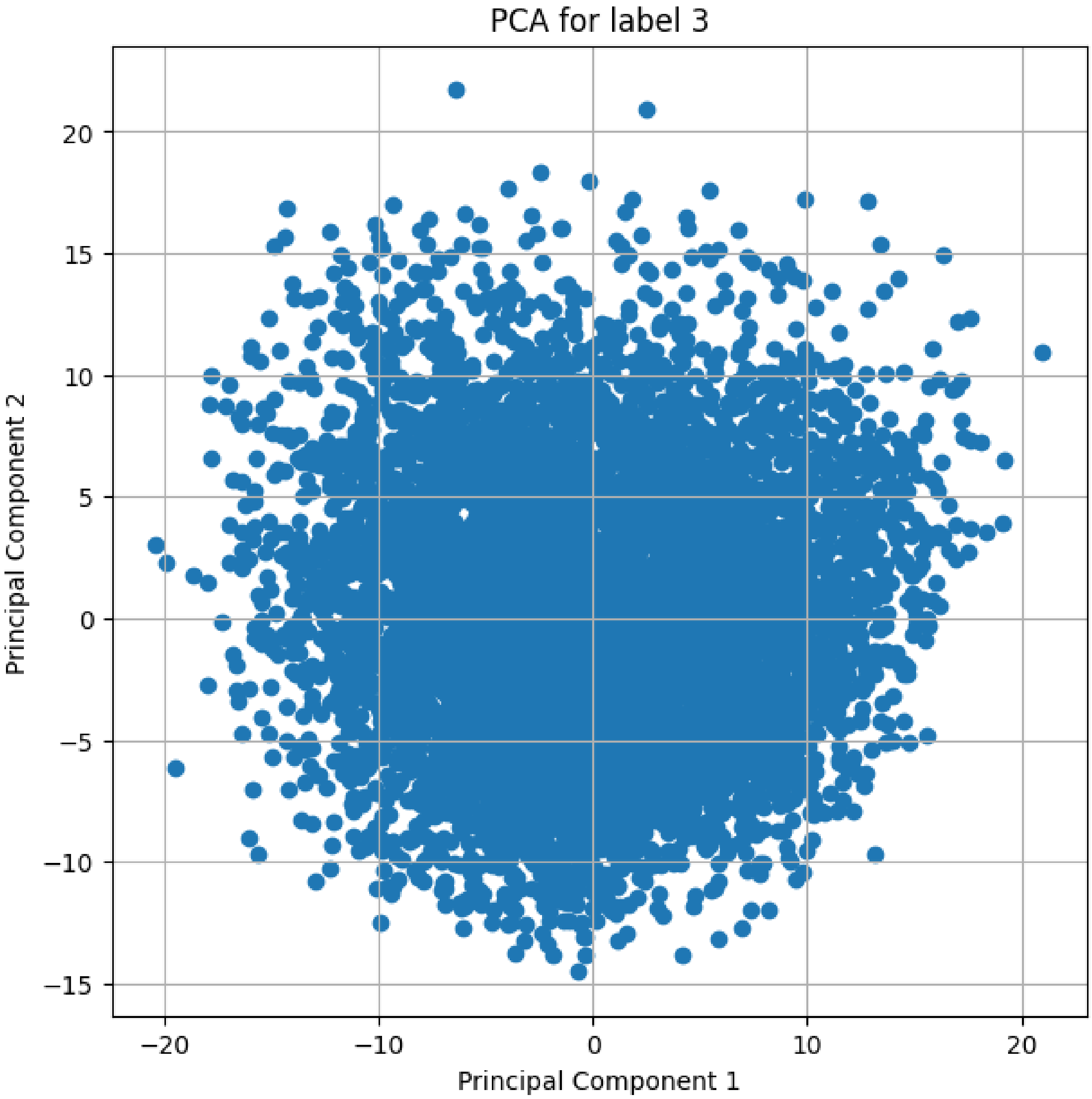
[105]:

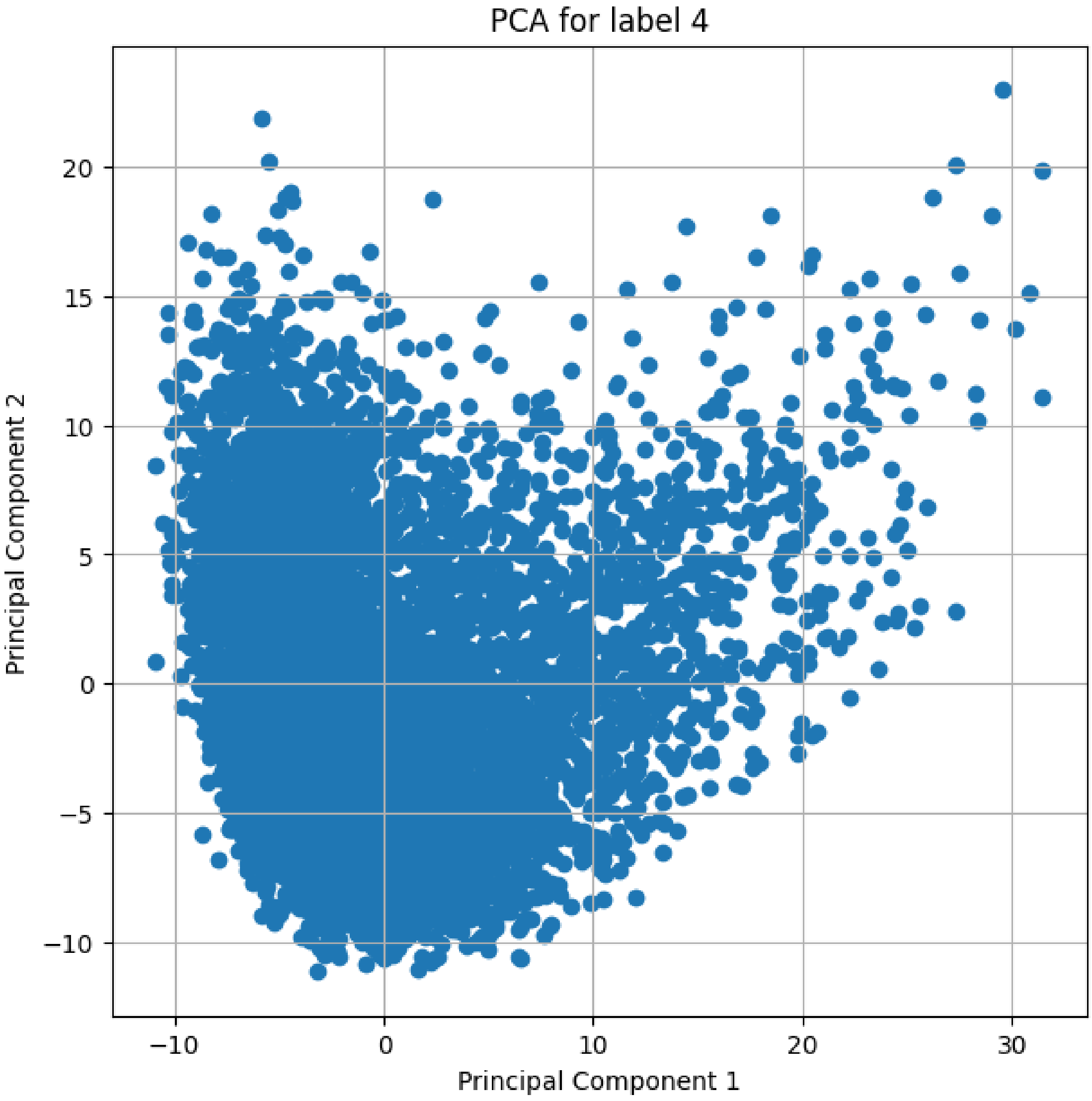
```
for i in range(10):
    plt.figure(figsize=(7, 7))
    plt.scatter(PCASets[i][:, 0], PCASets[i][:, 1])
    plt.xlabel('Principal Component 1')
    plt.ylabel('Principal Component 2')
    plt.title(f'PCA for label {i}')
    plt.grid(True)
    plt.show()
```

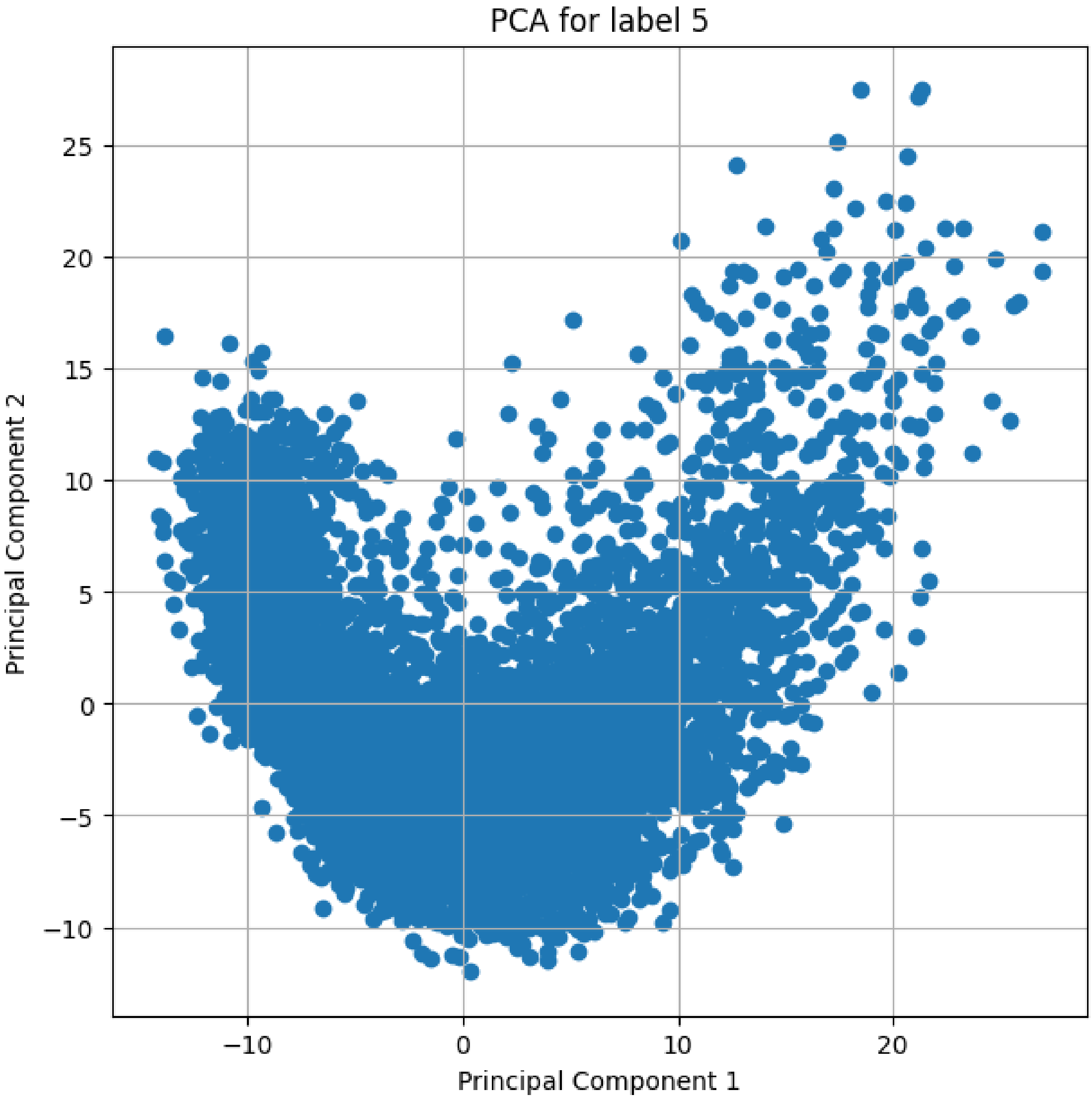

PCA for label 0
Principal Component 2
15
10
5
0
−5
−10
−20
−10
0
10
20
Principal Component 1

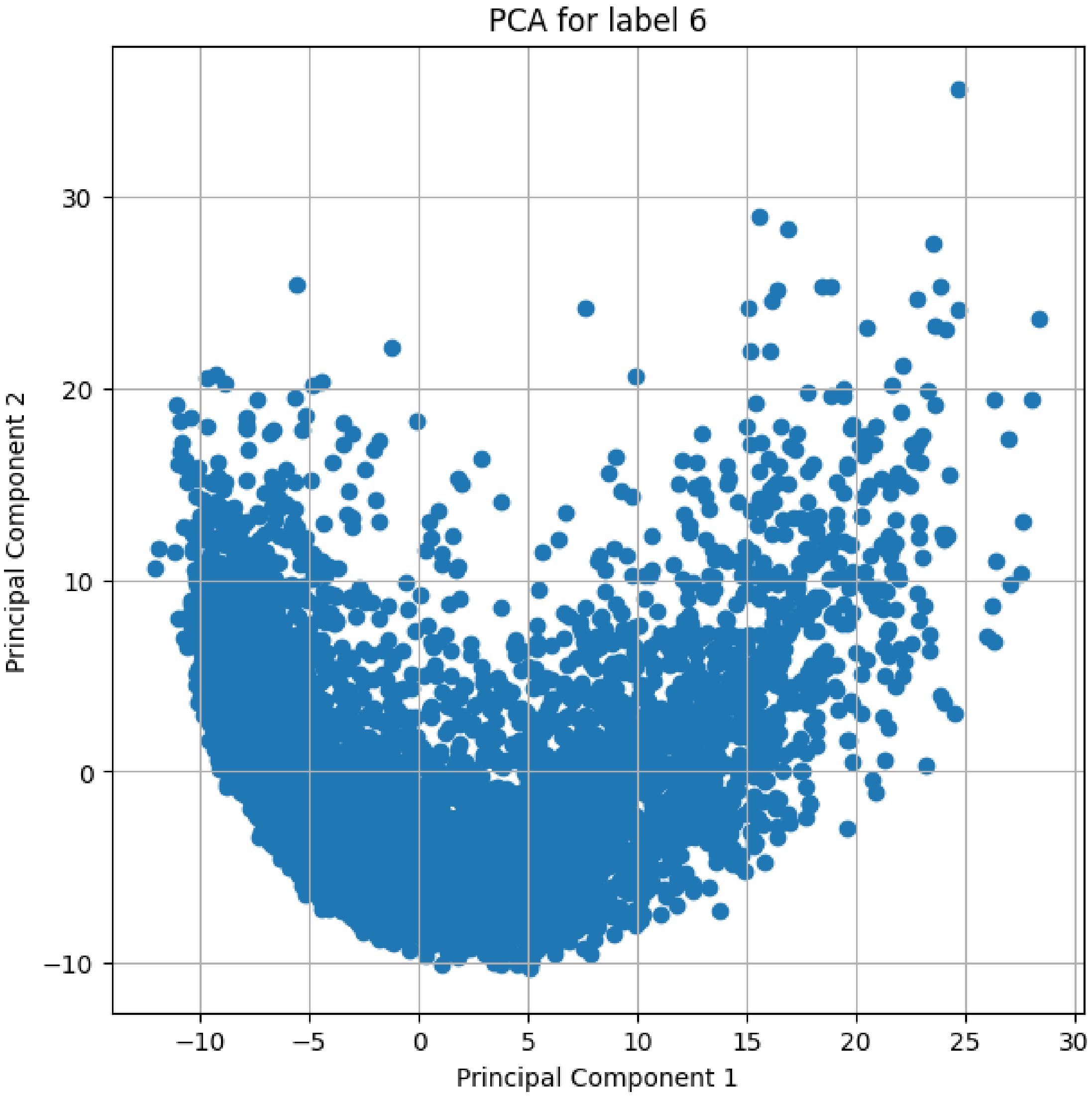

PCA for label 1
Principal Component 2
Principal Component 1
80
60
40
20
0
−20
−10
0
10
20
30

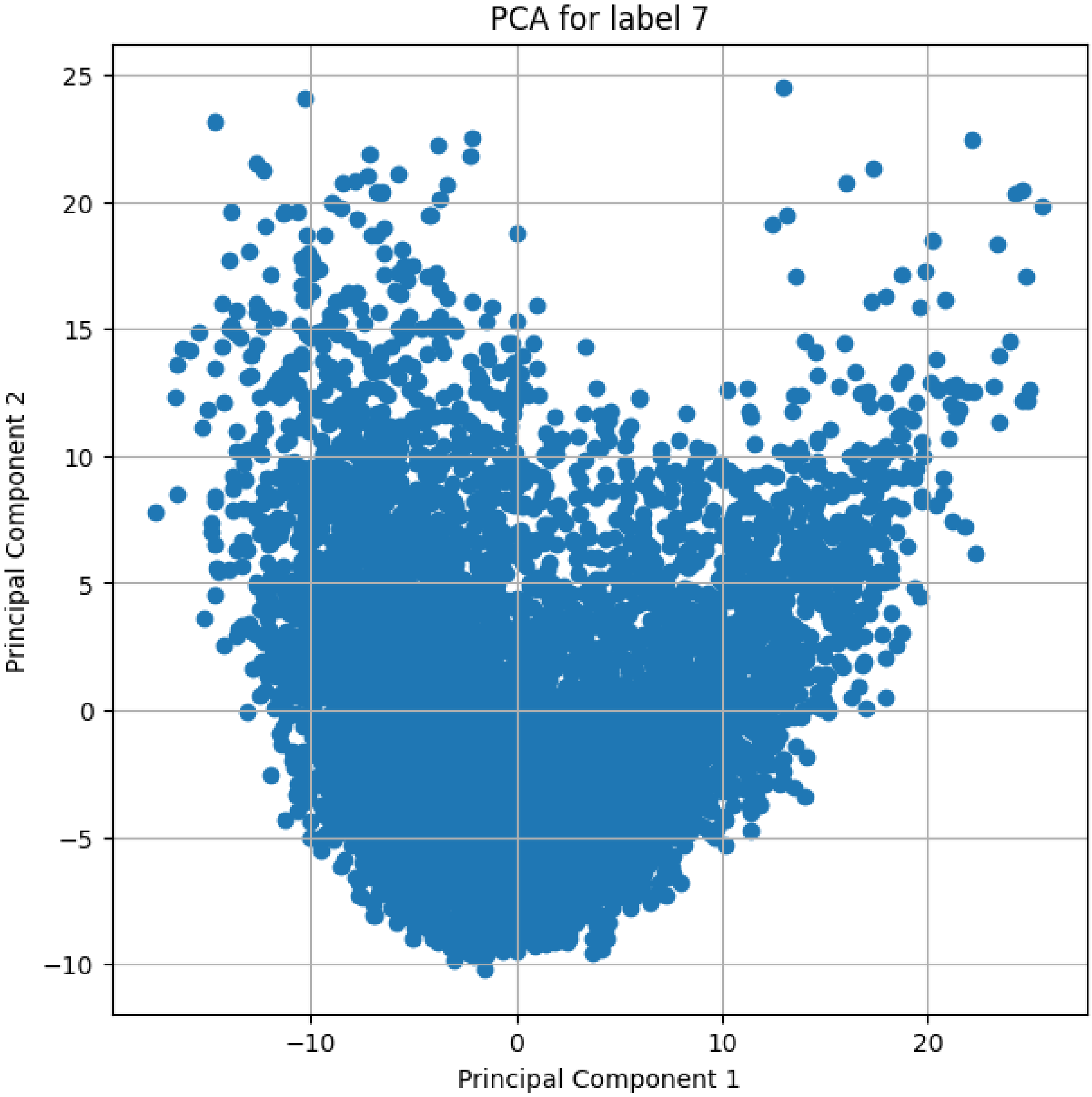

PCA for label 2
Principal Component 2
Principal Component 1
20
15
10
5
0
−5
−10
−15
−15
−10
−5
0
5
10
15
20

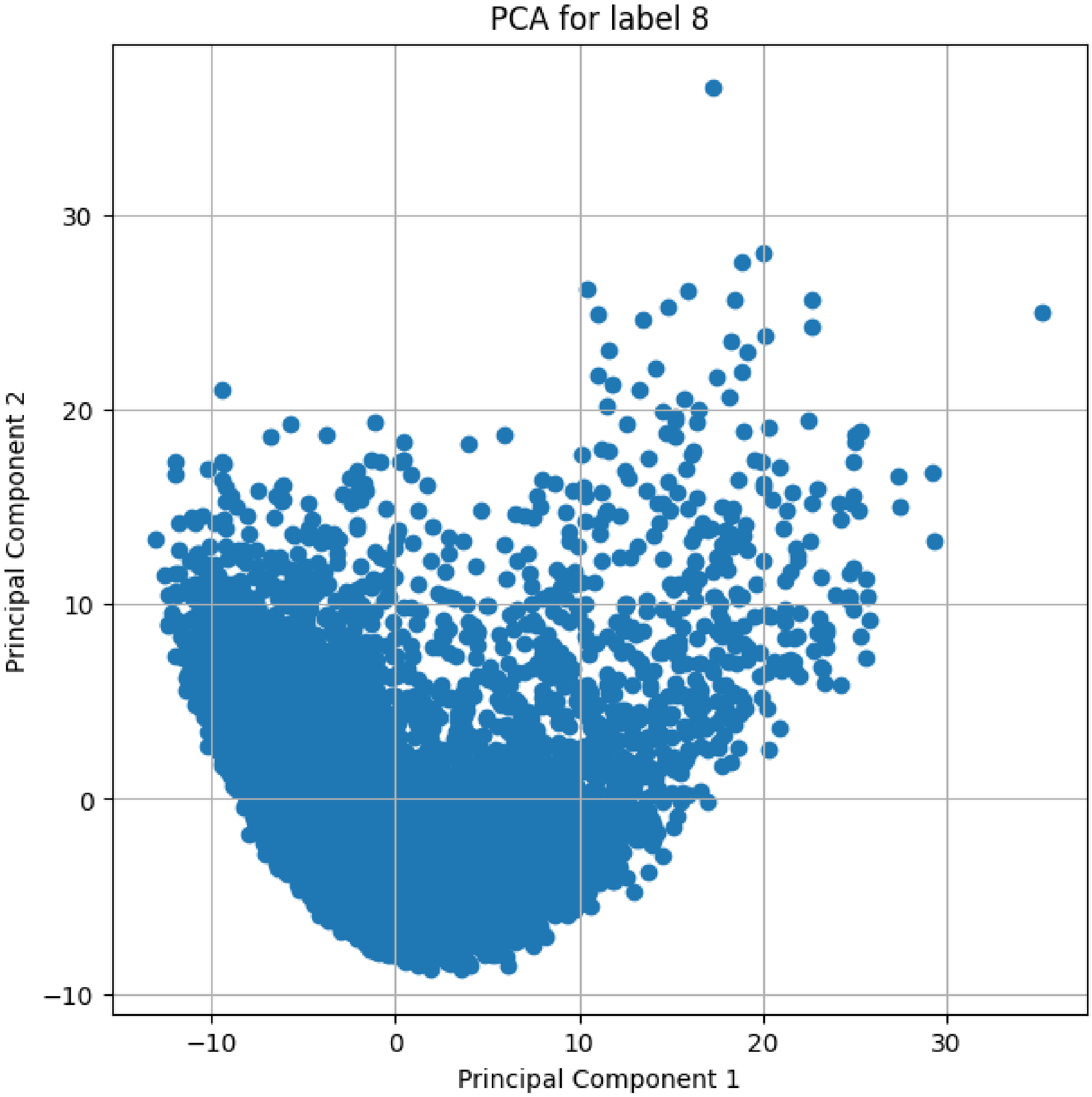

PCA for label 3
Principal Component 2
Principal Component 1
20
15
10
5
0
−5
−10
−15
−20
−10
0
10
20

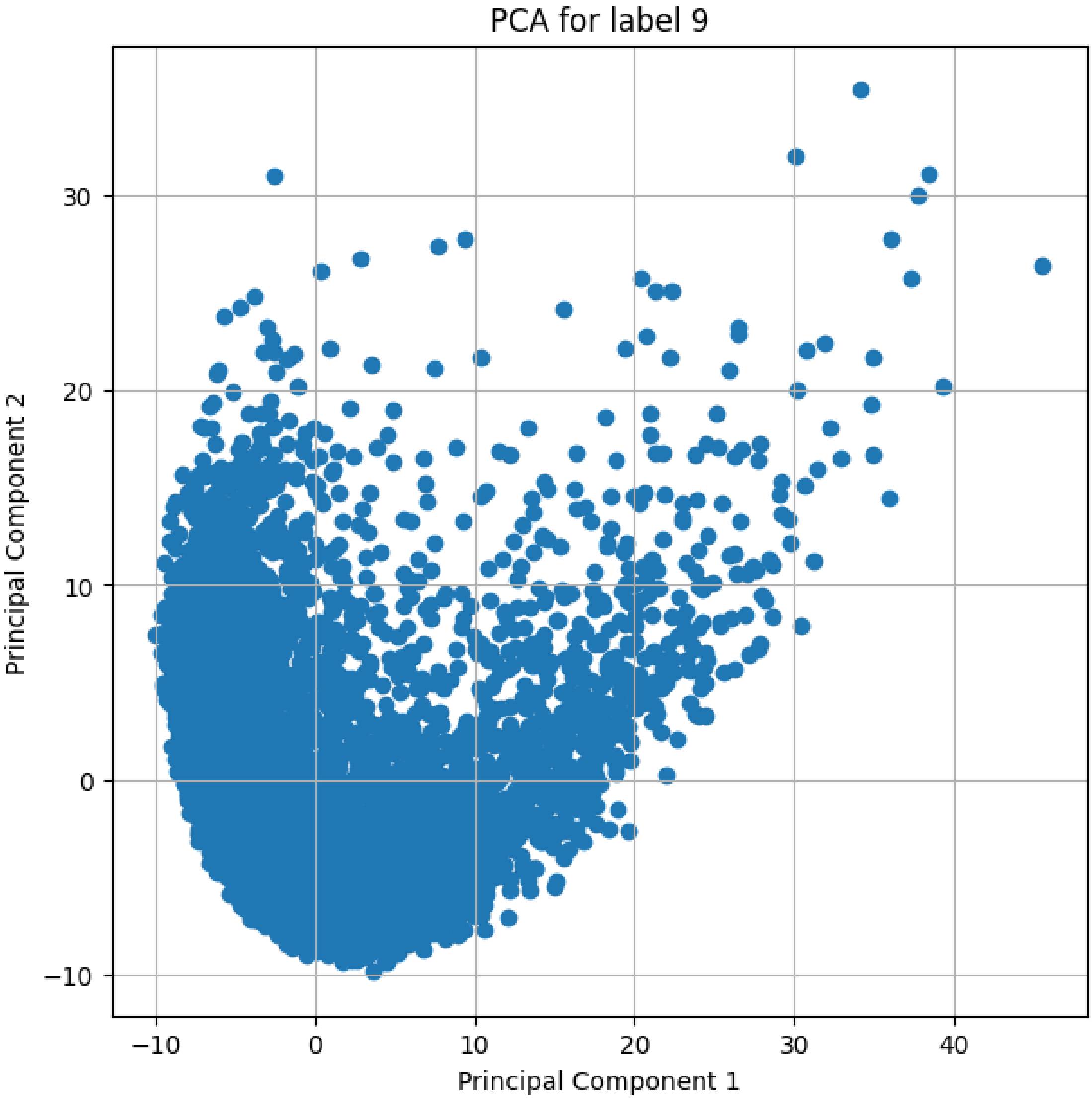

PCA for label 4
Principal Component 2
Principal Component 1
20
15
10
5
0
−5
−10
−10
0
10
20
30


PCA for label 5
Principal Component 2
Principal Component 1
25
20
15
10
5
0
−5
−10
−10
0
10
20


PCA for label 6
Principal Component 2
30
20
10
0
−10
−10
−5
0
5
10
15
20
25
30
Principal Component 1

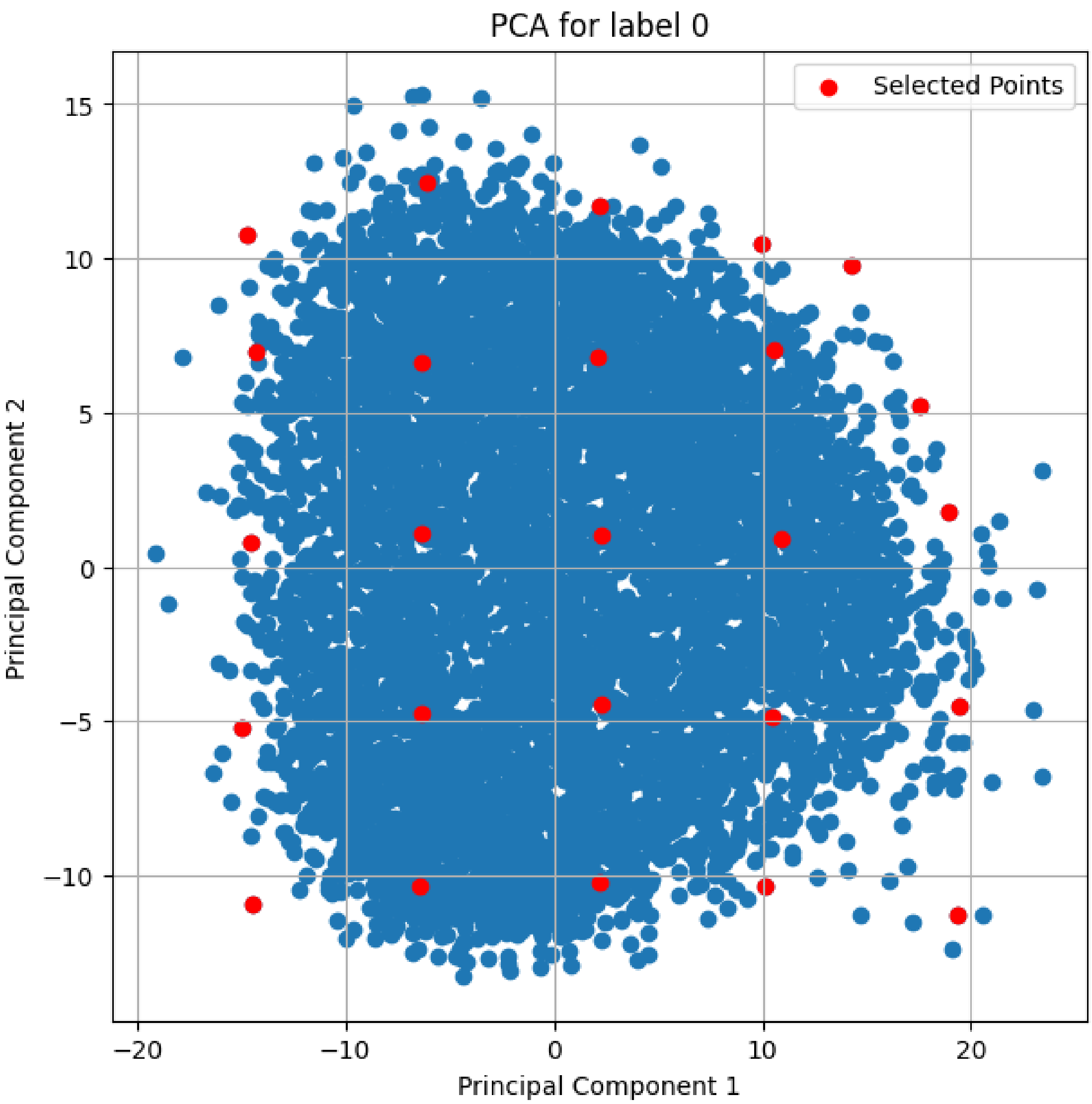

PCA for label 7
Principal Component 2
Principal Component 1
25
20
15
10
5
0
−5
−10
−10
0
10
20

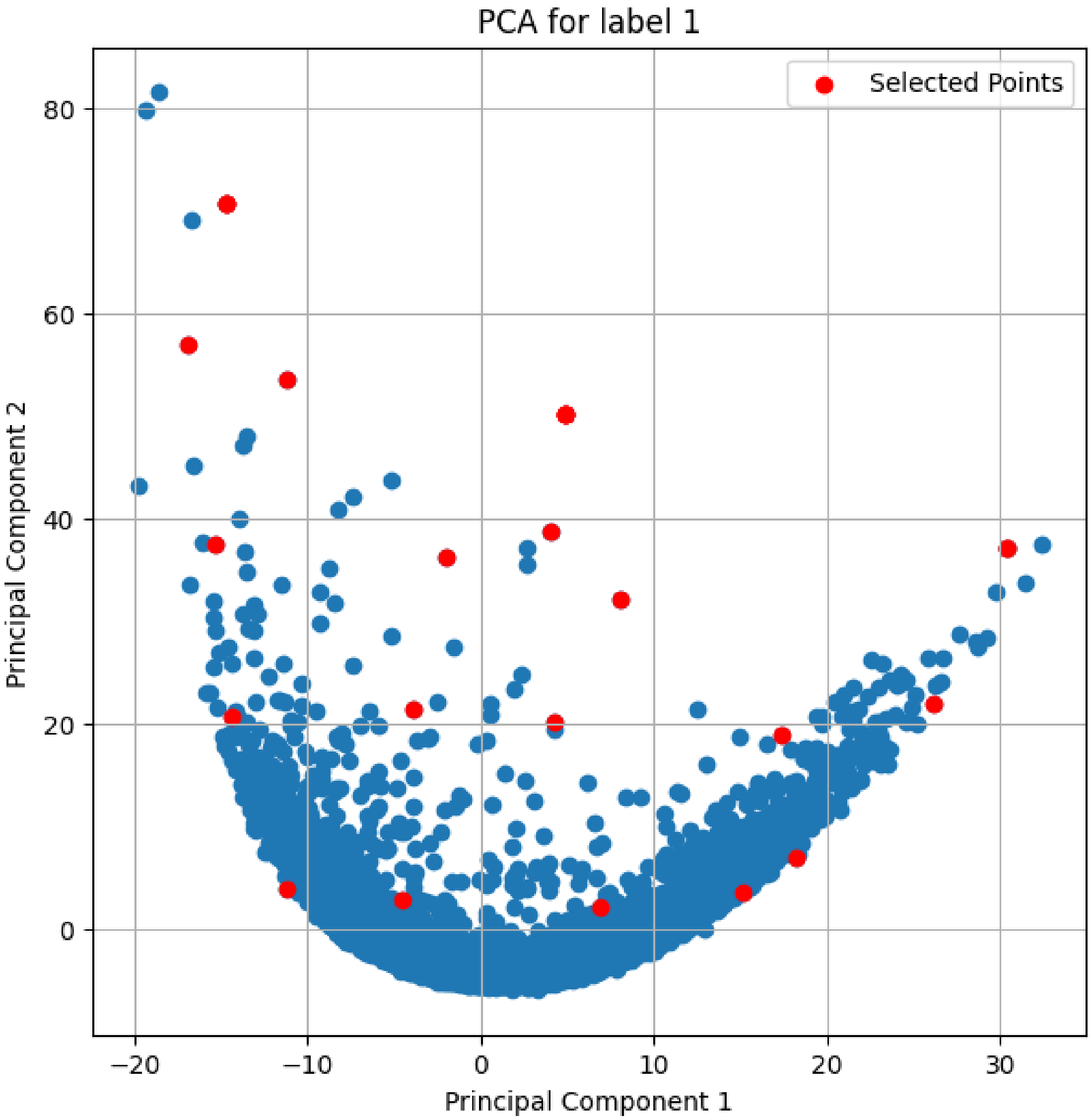

PCA for label 8
Principal Component 2
Principal Component 1
30
20
10
0
−10
−10
0
10
20
30

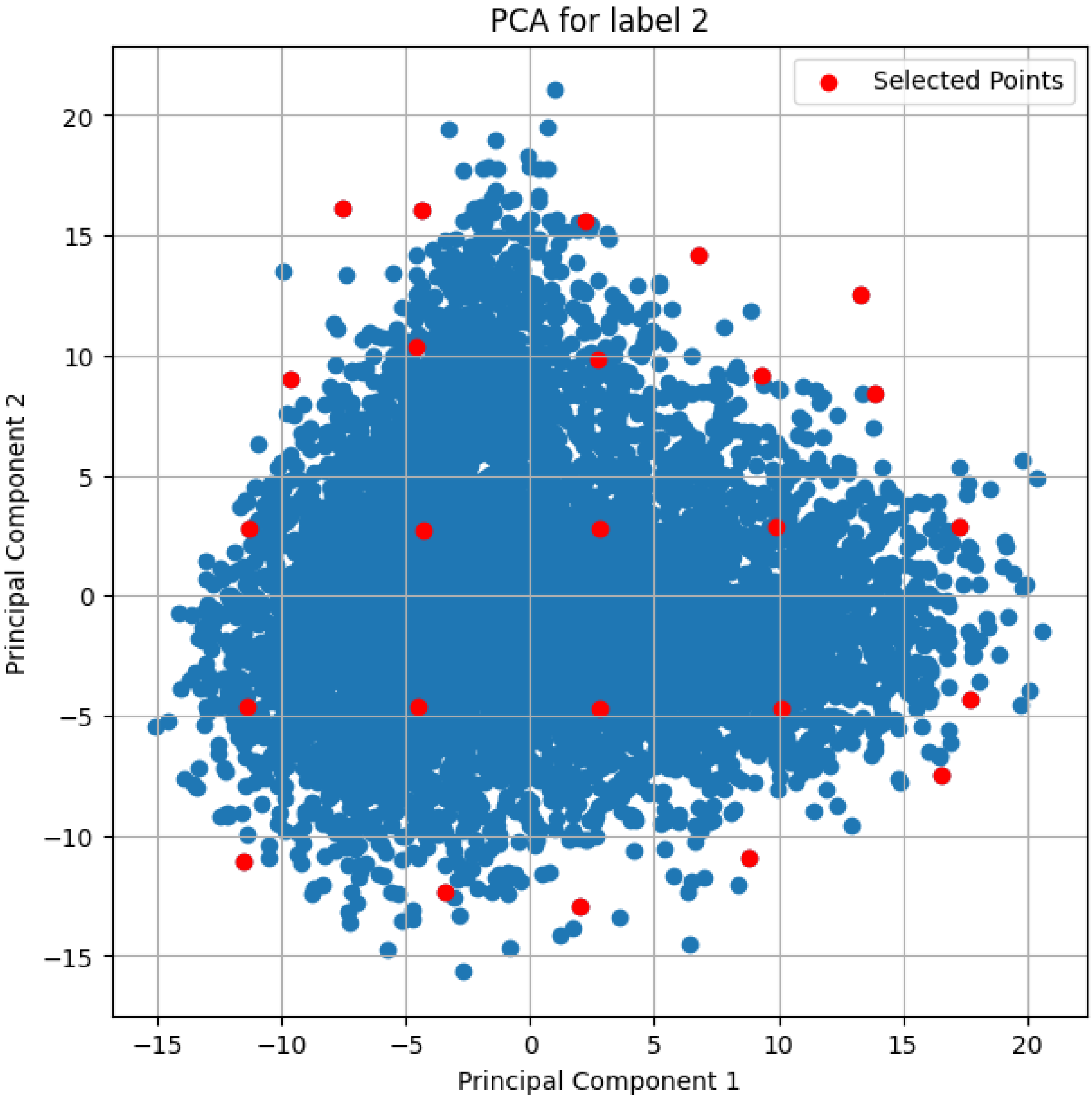


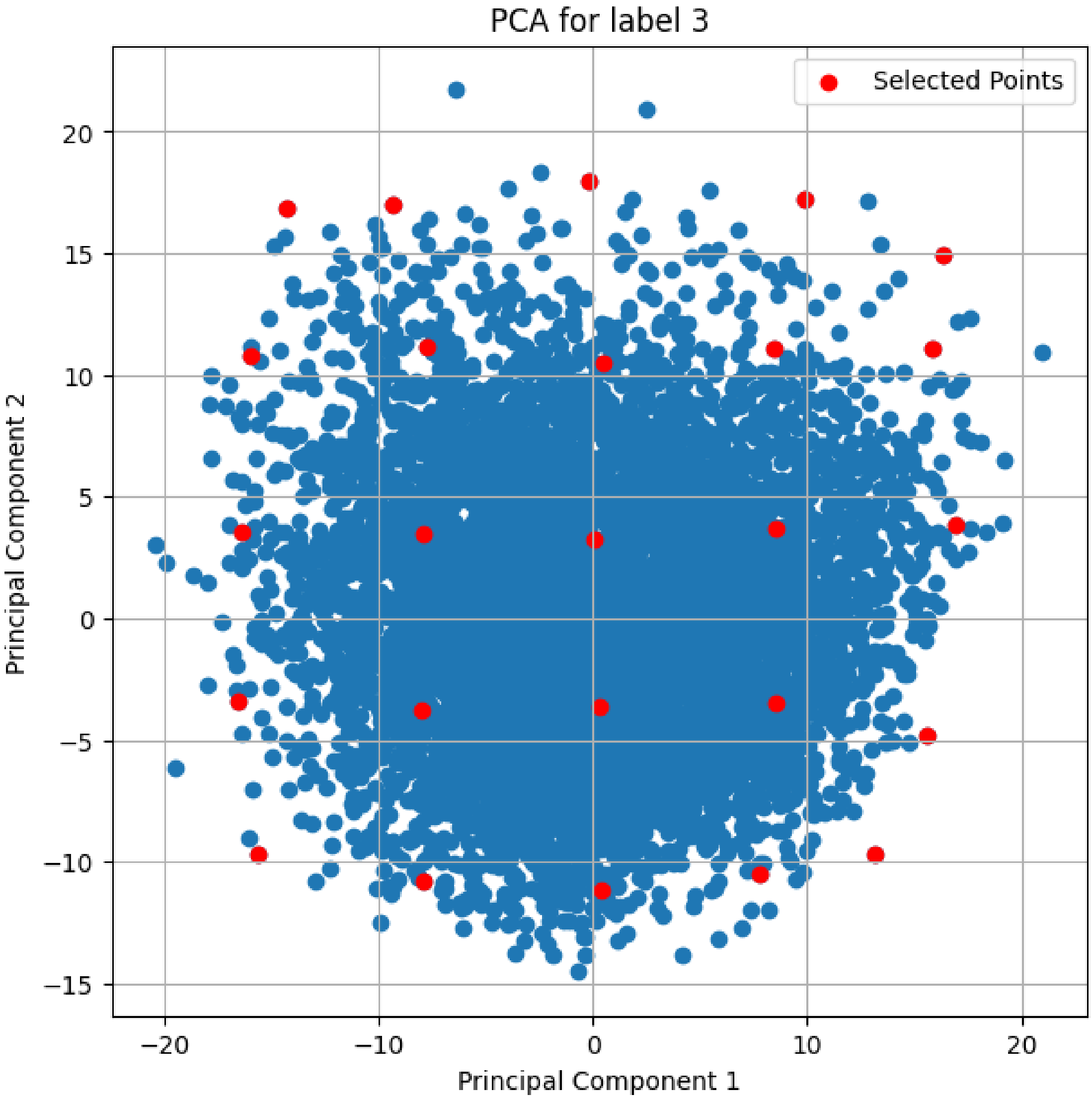
c. Assume the points in this scatter plot are spread between (1, 2) and (1, 2) (which are the min and max of PC1 and PC2). Split this space into a 5x5 grid, and for each cell select a point that is closest to the center of that cell. Highlight these points in the scatter plot from the previous step.

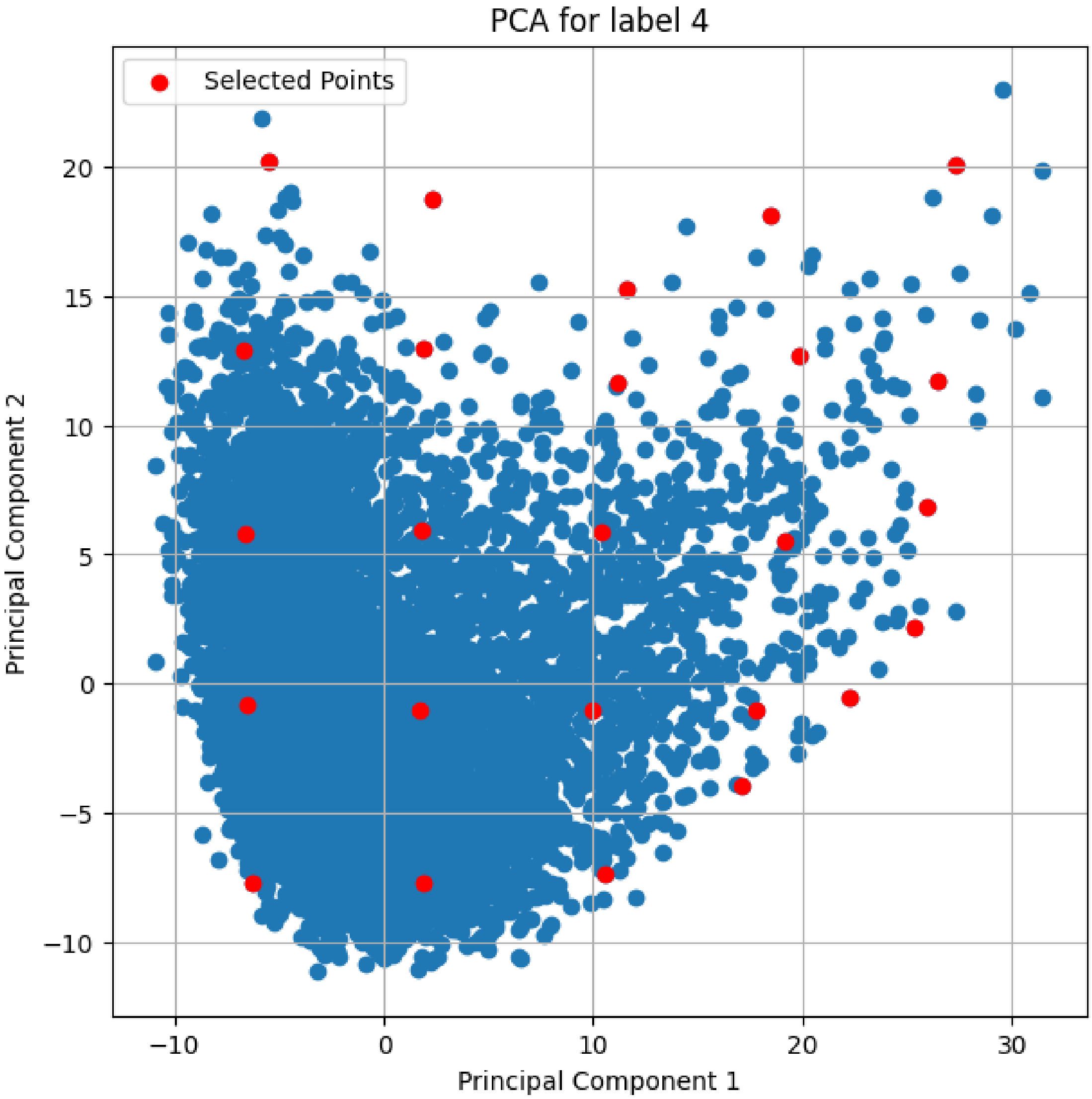
[106]:
```
PointsList = []
for s in range(10):
    x1, x2 = np.min(PCASets[s][:, 0]), np.max(PCASets[s][:, 0])
    y1, y2 = np.min(PCASets[s][:, 1]), np.max(PCASets[s][:, 1])
    #print(x1,x2)
    #print(y1,y2)

    gridX = np.linspace(x1, x2, 6)
    gridY = np.linspace(y1, y2, 6)
    #print(gridX)
    #print(gridY)

    Points = []
    for i in range(len(gridX)-1):
        for j in range(len(gridY)-1):
            centerX = (gridX[i] + gridX[i+1]) / 2
            centerY = (gridY[j] + gridY[j+1]) / 2
            distance = np.sqrt((PCASets[s][:, 0] - centerX)**2 + (PCASets[s][:,␣
↪1] - centerY)**2)
            closest = np.argmin(distance)
            Points.append(closest)
    PointsList.append(Points)

    plt.figure(figsize=(7, 7))
    plt.scatter(PCASets[s][:, 0], PCASets[s][:, 1])
    plt.xlabel('Principal Component 1')
    plt.ylabel('Principal Component 2')
    plt.title(f'PCA for label {s}')

    Points = np.array(Points)
    plt.scatter(PCASets[s][Points, 0], PCASets[s][Points, 1], color='red',␣
↪marker='o', label='Selected Points')
    plt.legend()

    plt.grid(True)
    plt.show()
```

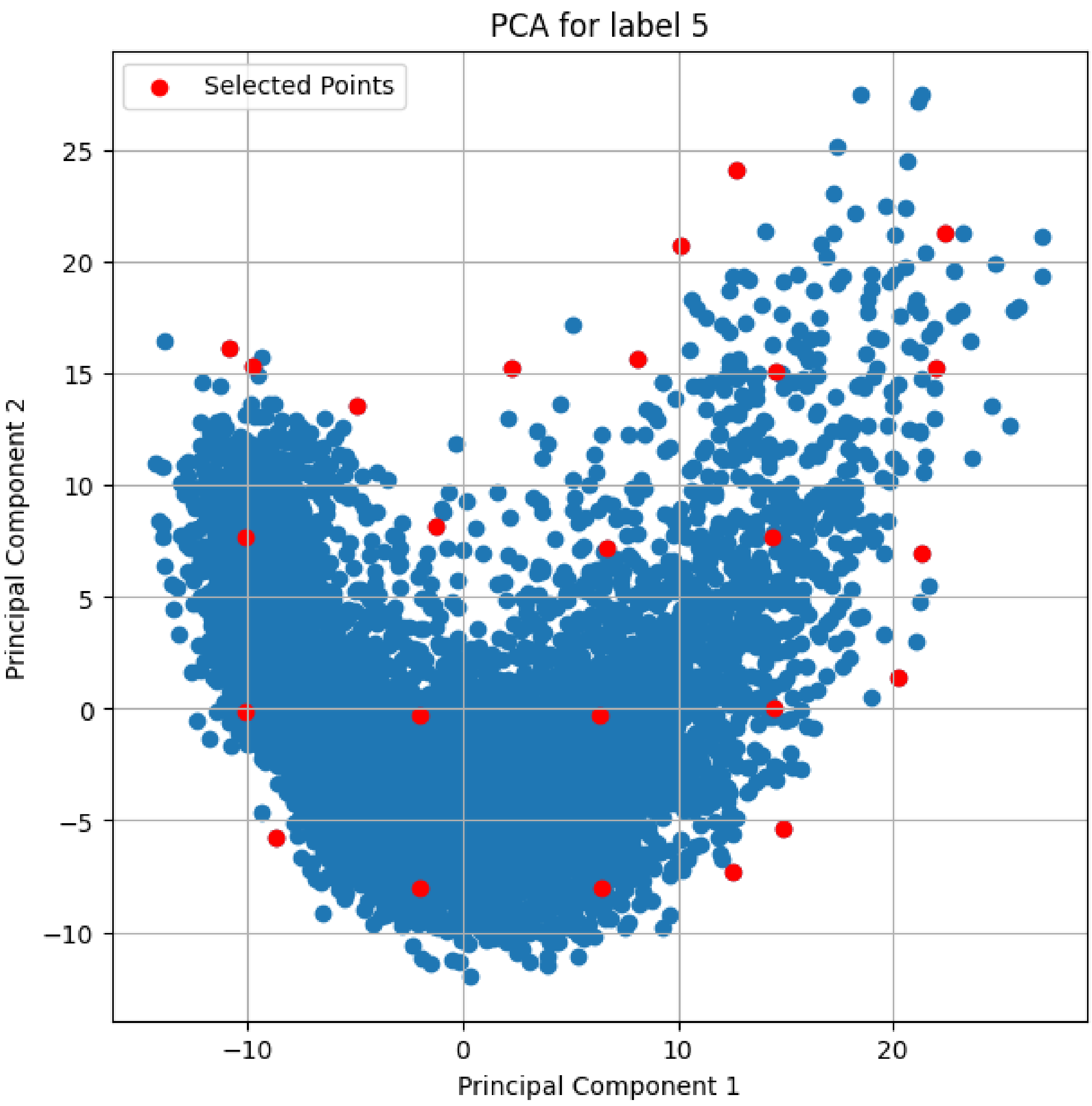

PCA for label 0
Selected Points
Principal Component 2
Principal Component 1
15
10
5
0
−5
−10
−20
−10
0
10
20

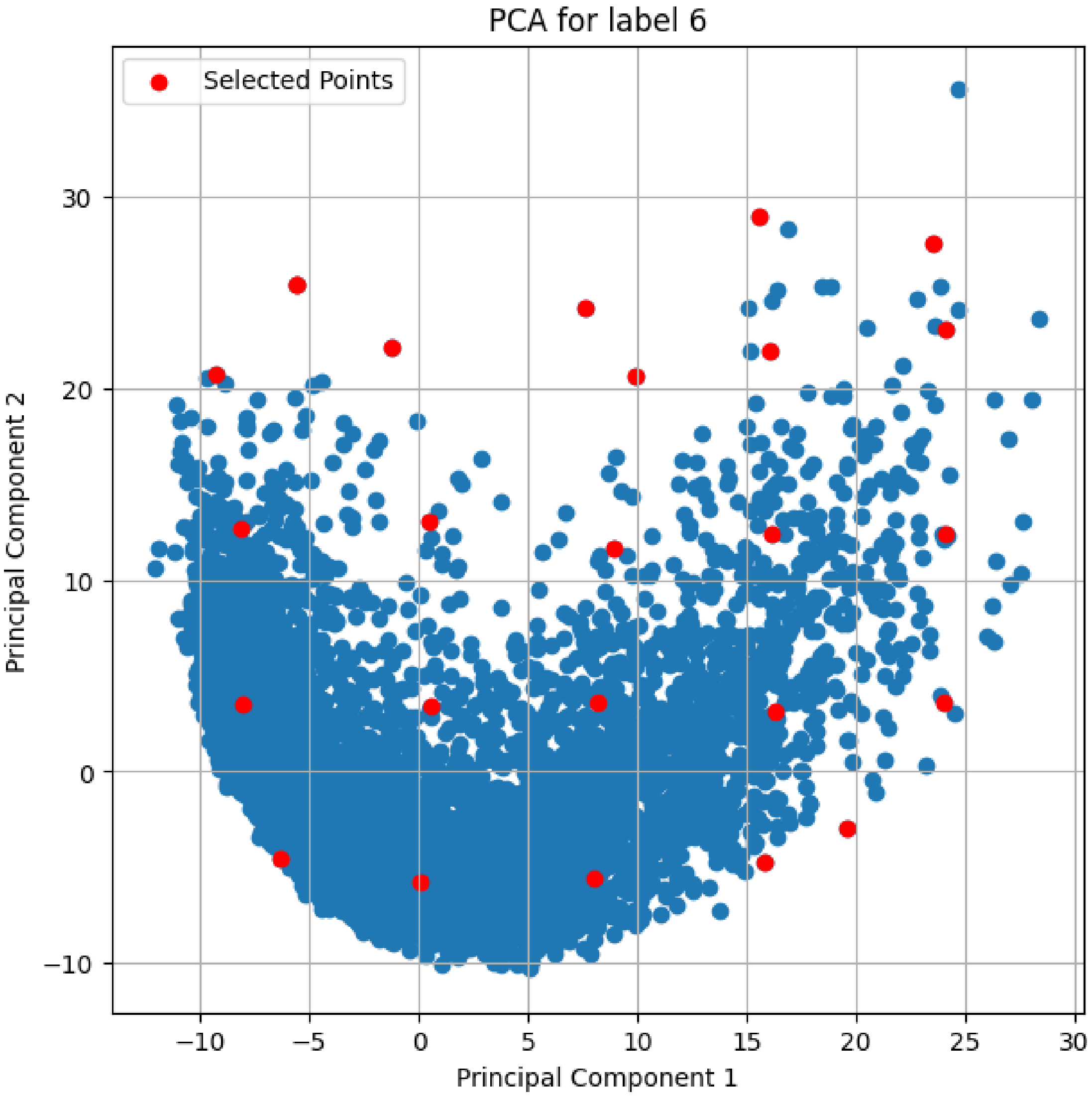

PCA for label 1
Selected Points
Principal Component 2
Principal Component 1
80
60
40
20
0
−20
−10
0
10
20
30

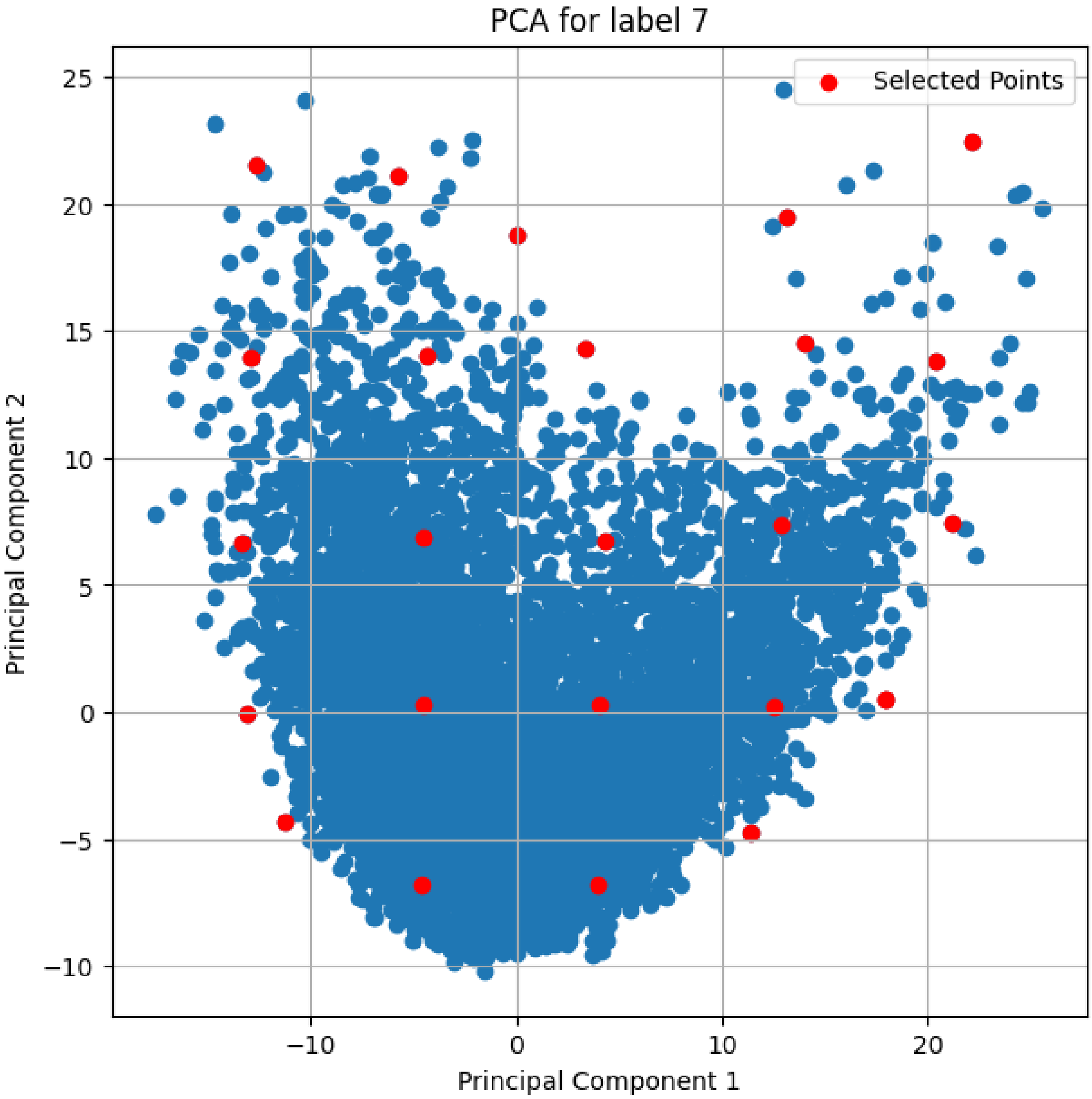

PCA for label 2
● Selected Points
Principal Component 1
Principal Component 2
20
15
10
5
0
−5
−10
−15
−15
−10
−5
0
5
10
15
20

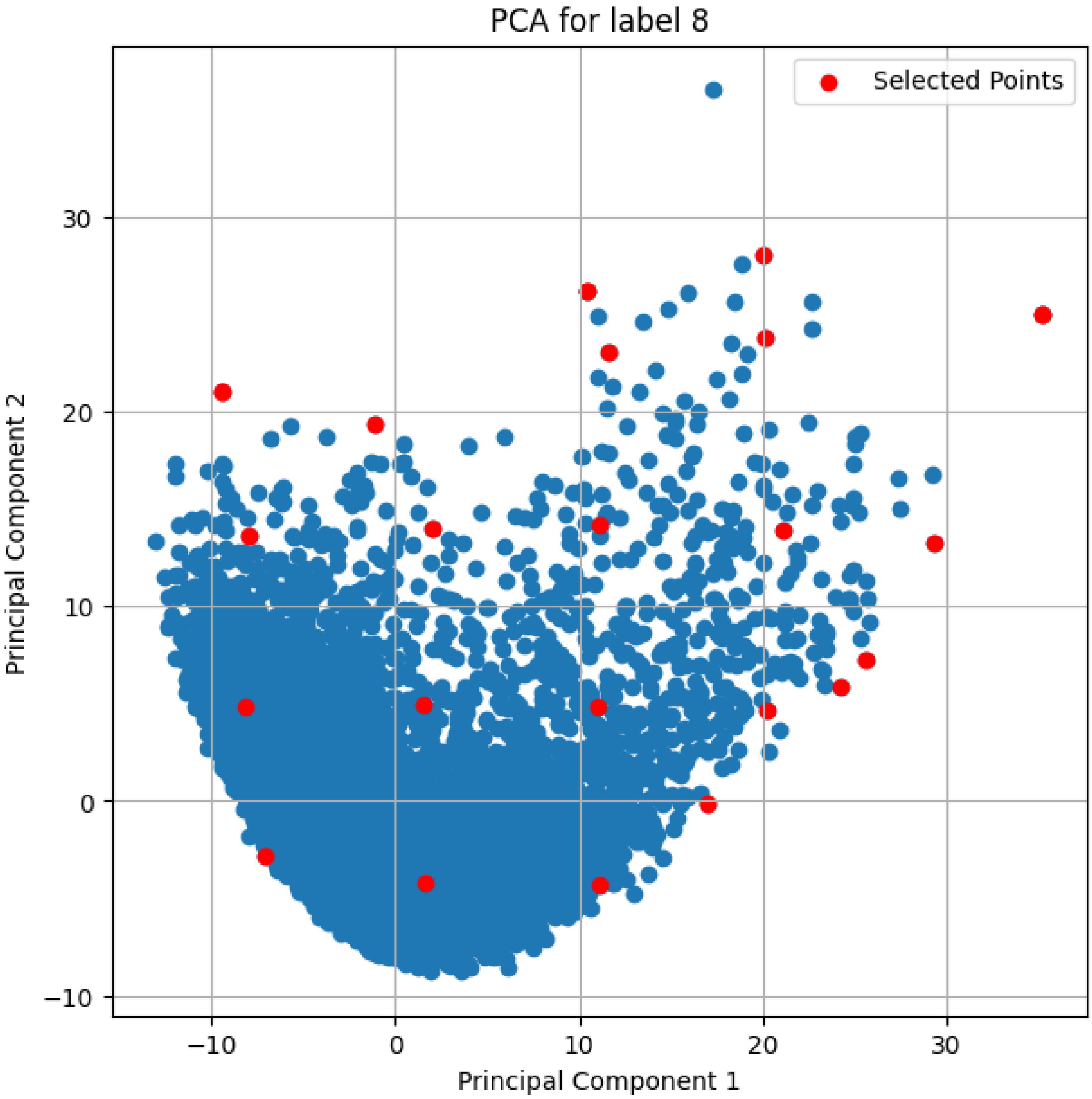

PCA for label 3
● Selected Points
Principal Component 2
20
15
10
5
0
−5
−10
−15
−20
−10
0
10
20
Principal Component 1

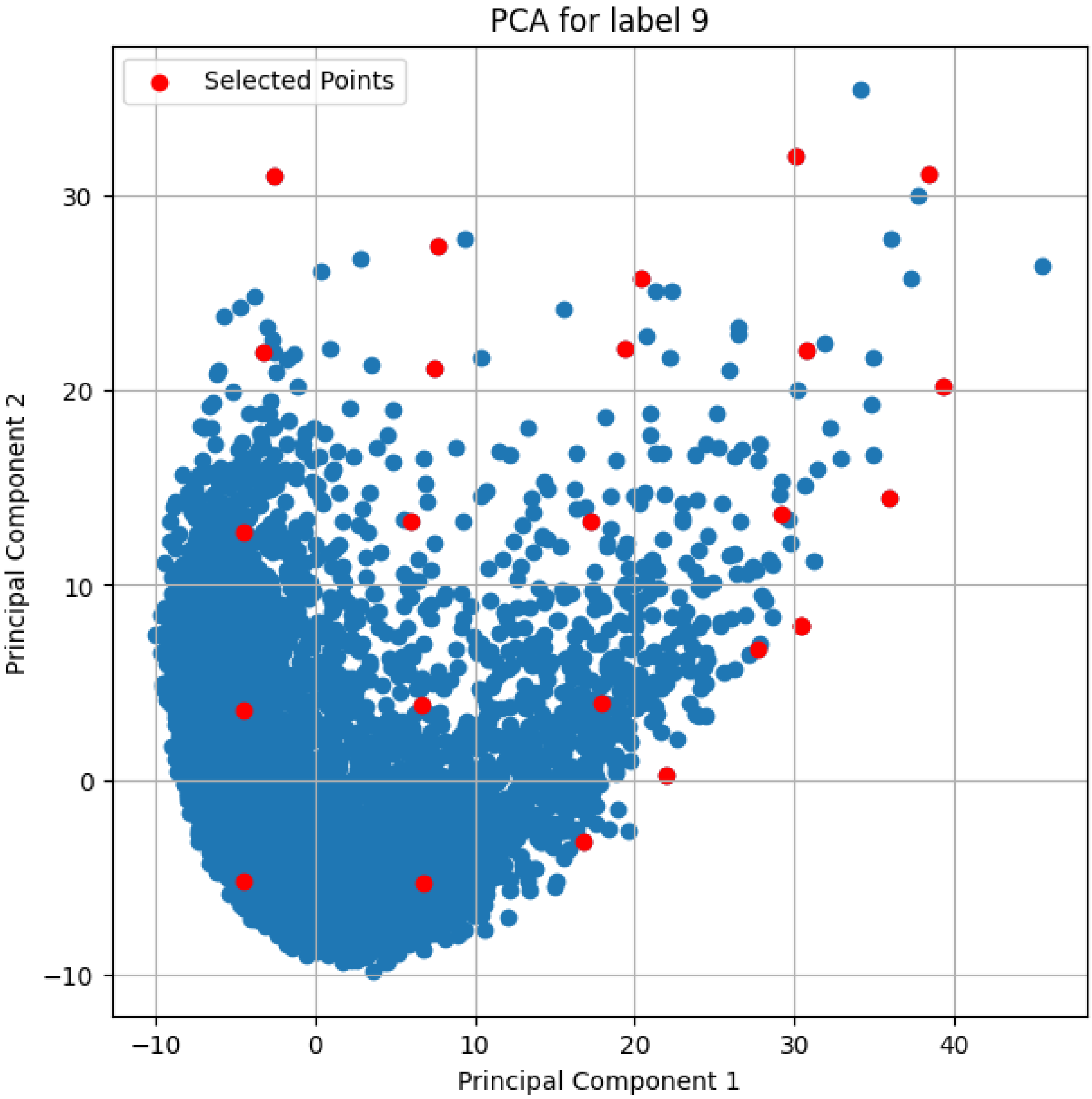

PCA for label 4
Selected Points
Principal Component 2
Principal Component 1
20
15
10
5
0
−5
−10
−10
0
10
20
30


PCA for label 5
● Selected Points
Principal Component 1
Principal Component 2
−10
0
10
20
25
20
15
10
5
0
−5
−10


PCA for label 6
● Selected Points
Principal Component 2
30
20
10
0
−10
−10
−5
0
5
10
15
20
25
30
Principal Component 1

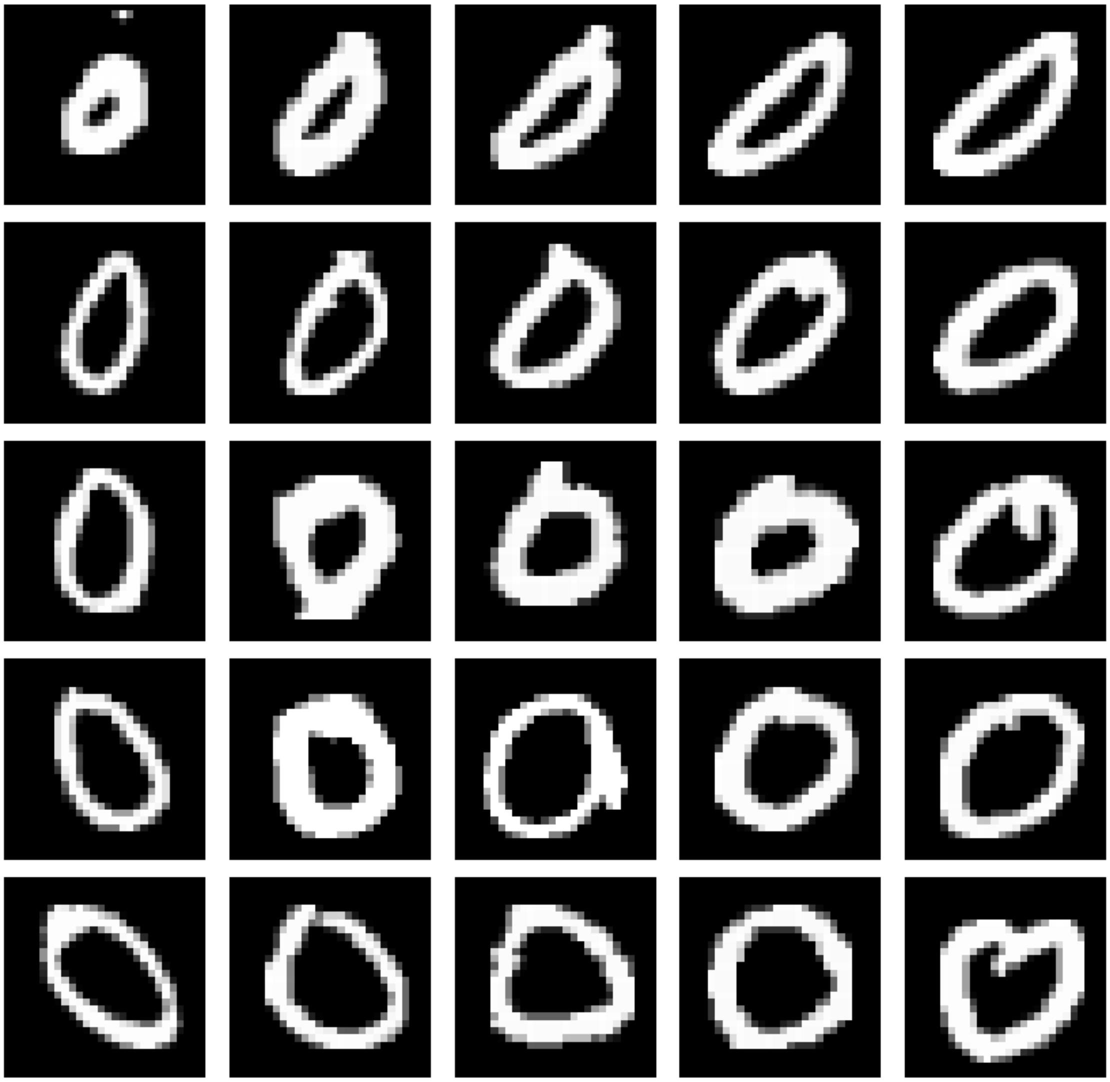

PCA for label 7
Selected Points
Principal Component 1
Principal Component 2
25
20
15
10
5
0
−5
−10
−10
0
10
20


PCA for label 8
Selected Points
Principal Component 1
Principal Component 2
−10
0
10
20
30
−10
0
10
20
30

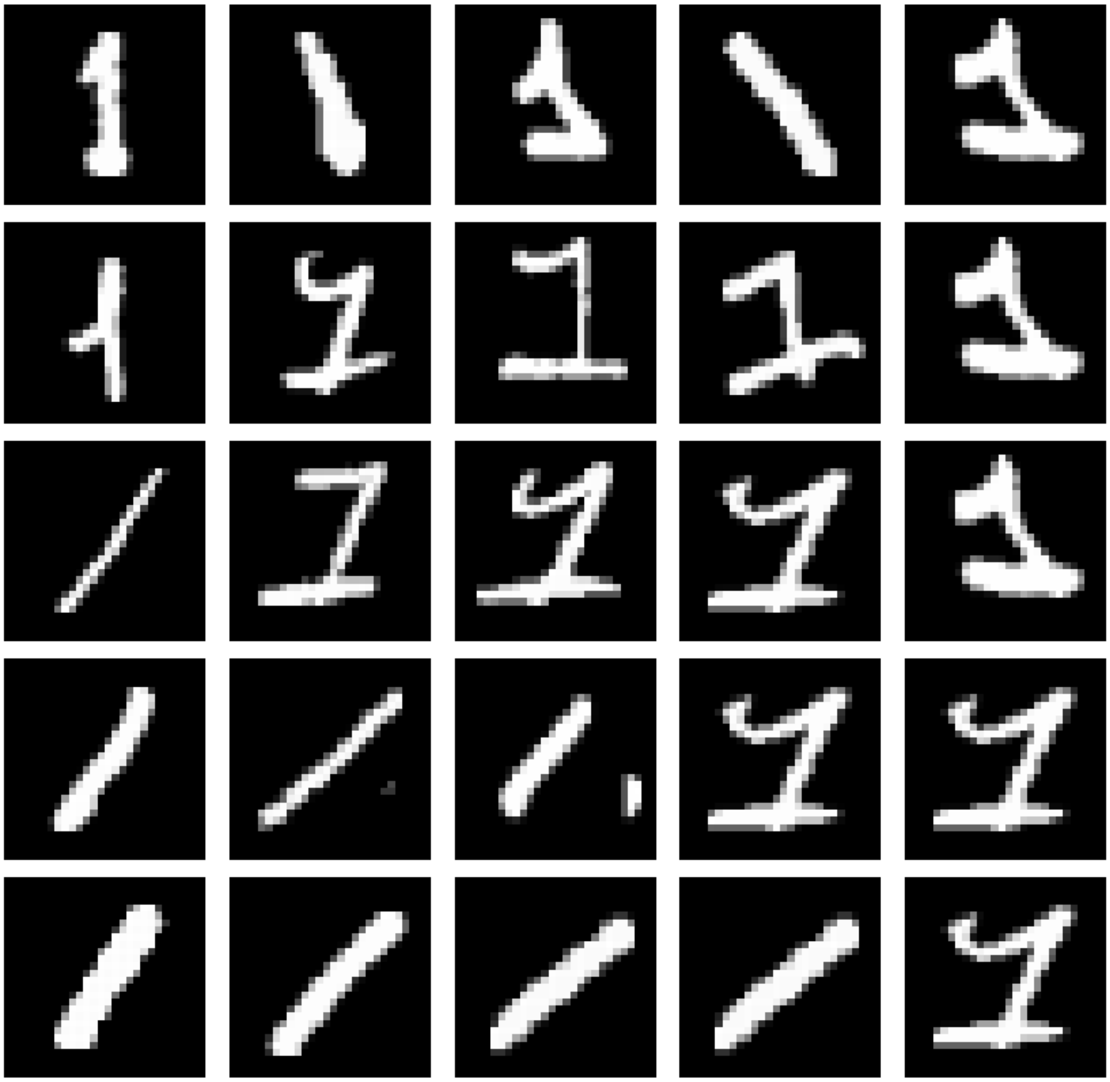


d. Draw the original pictures corresponding to the 25 selecting points. (See figure 14.23 of Element of Statistical Learning for an example)

```
[121]: for u in range(10):
           plt.figure(figsize=(10, 10))
           for i, idx in enumerate(PointsList[u]):
               plt.subplot(5, 5, i + 1)
               plt.imshow(Sets2[u][idx], cmap='gray')
               plt.axis('off')

           plt.suptitle(f'Original pictures for label {u}')
           plt.tight_layout()
           plt.show()
```

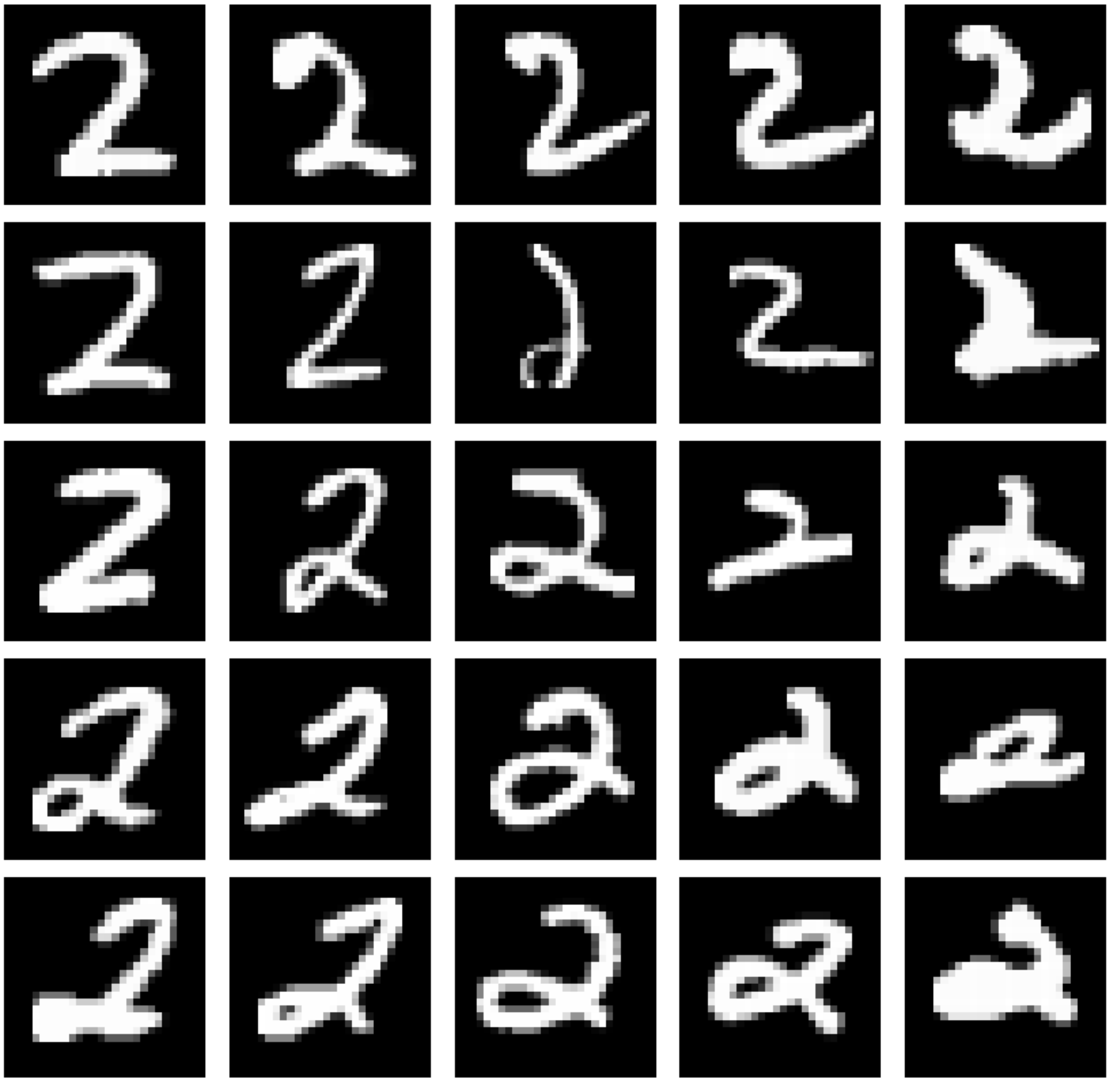


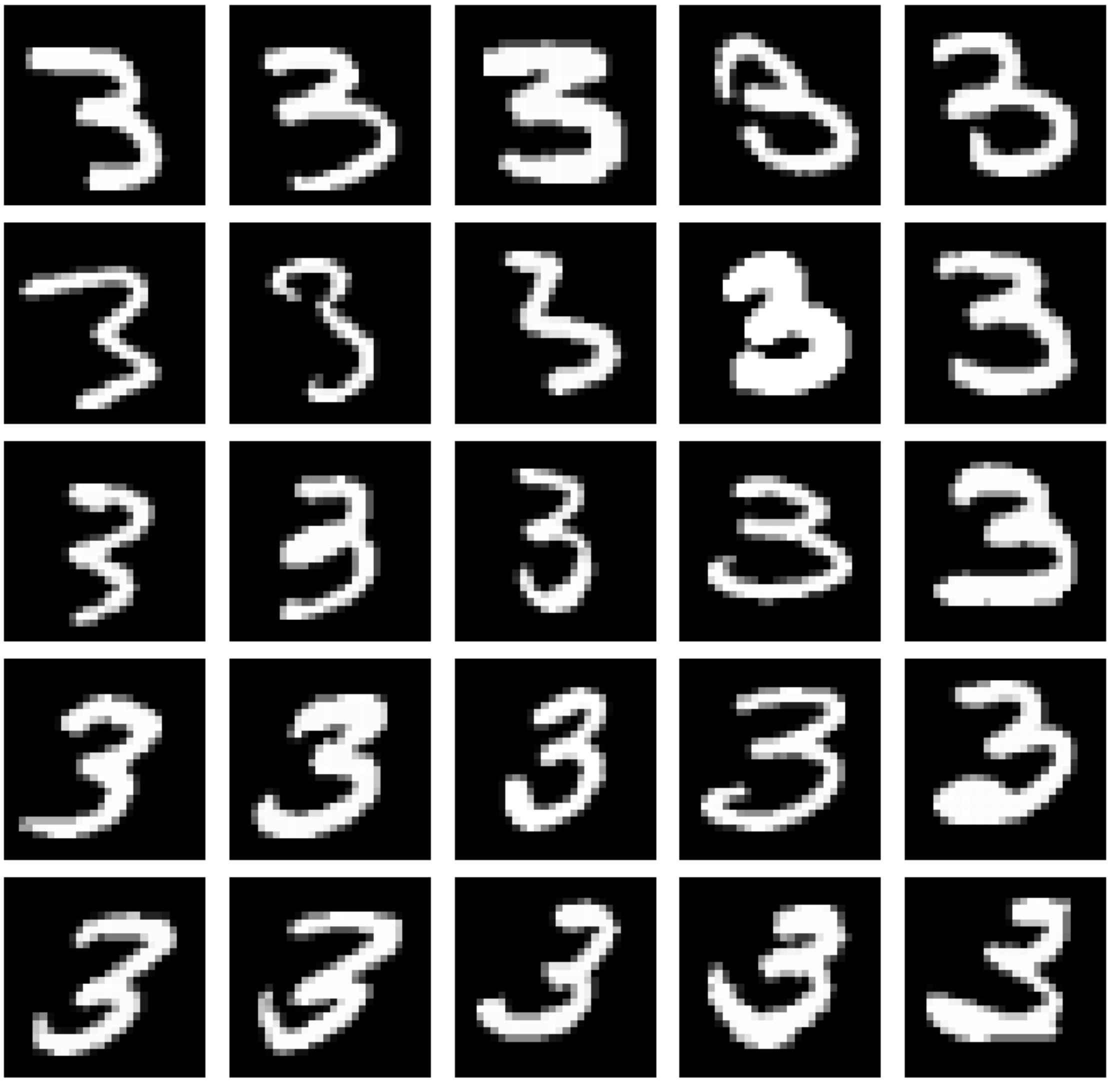
Original pictures for label 0



Original pictures for label 1

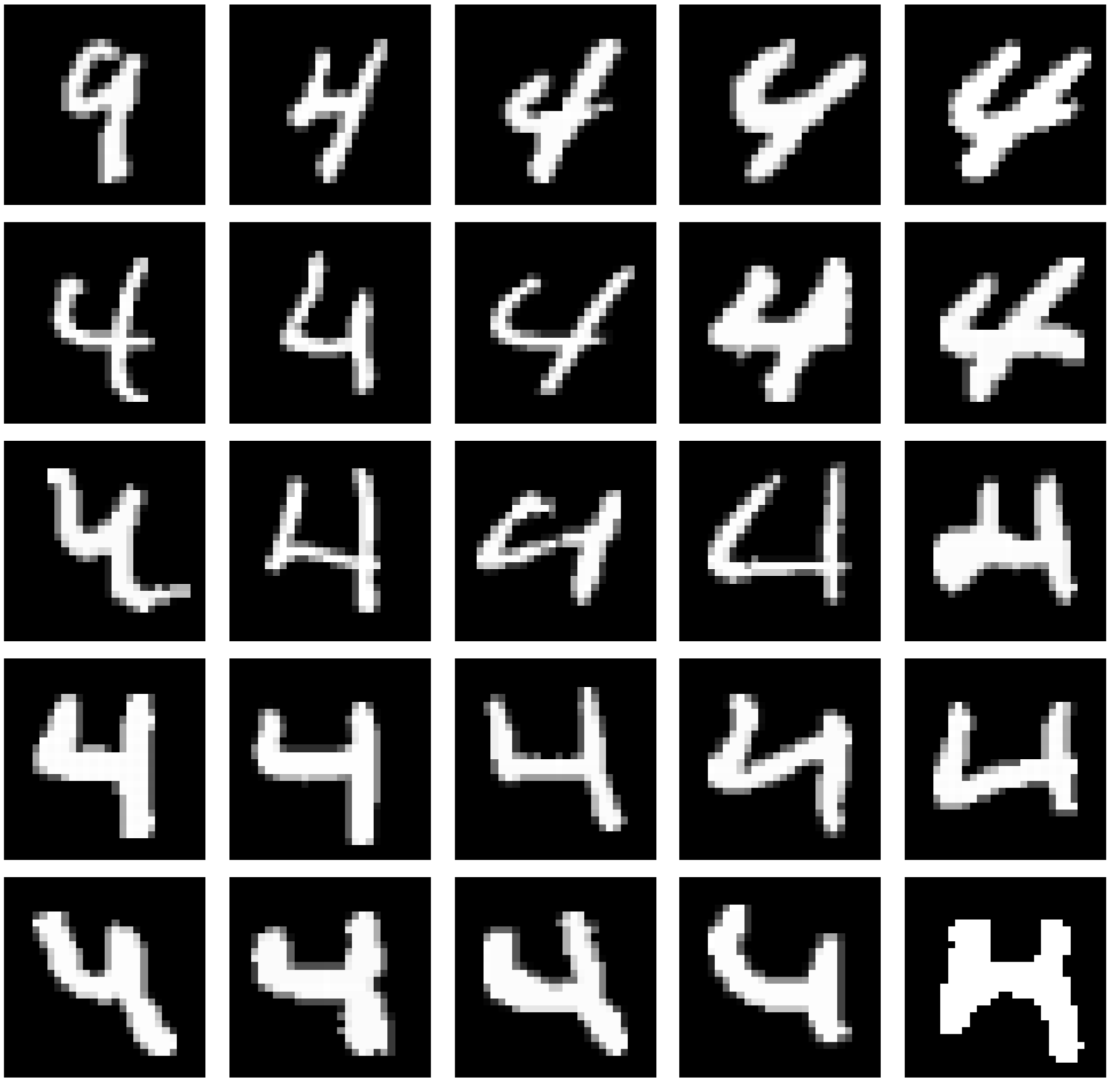
Original pictures for label 2

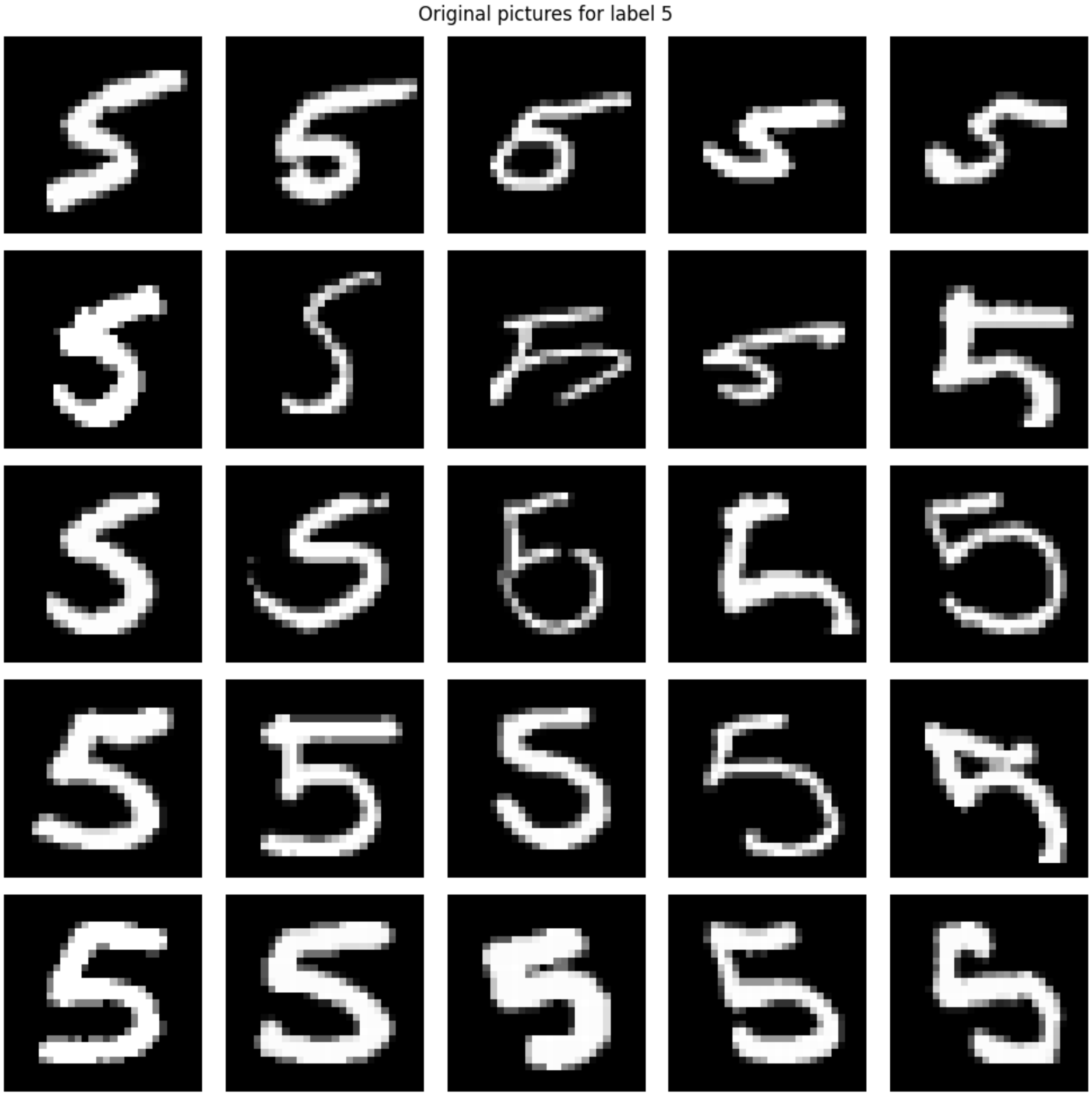




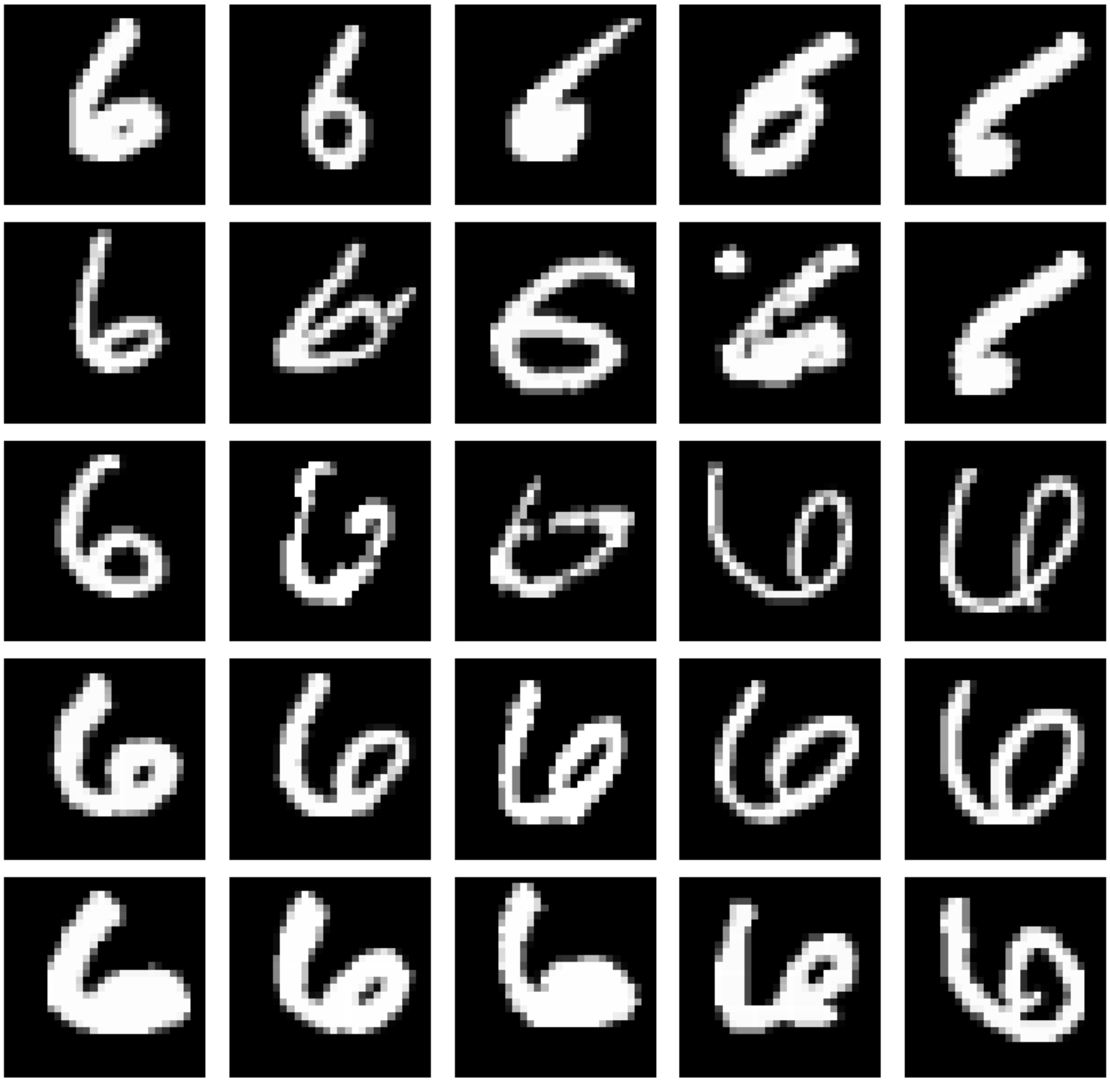
Original pictures for label 3

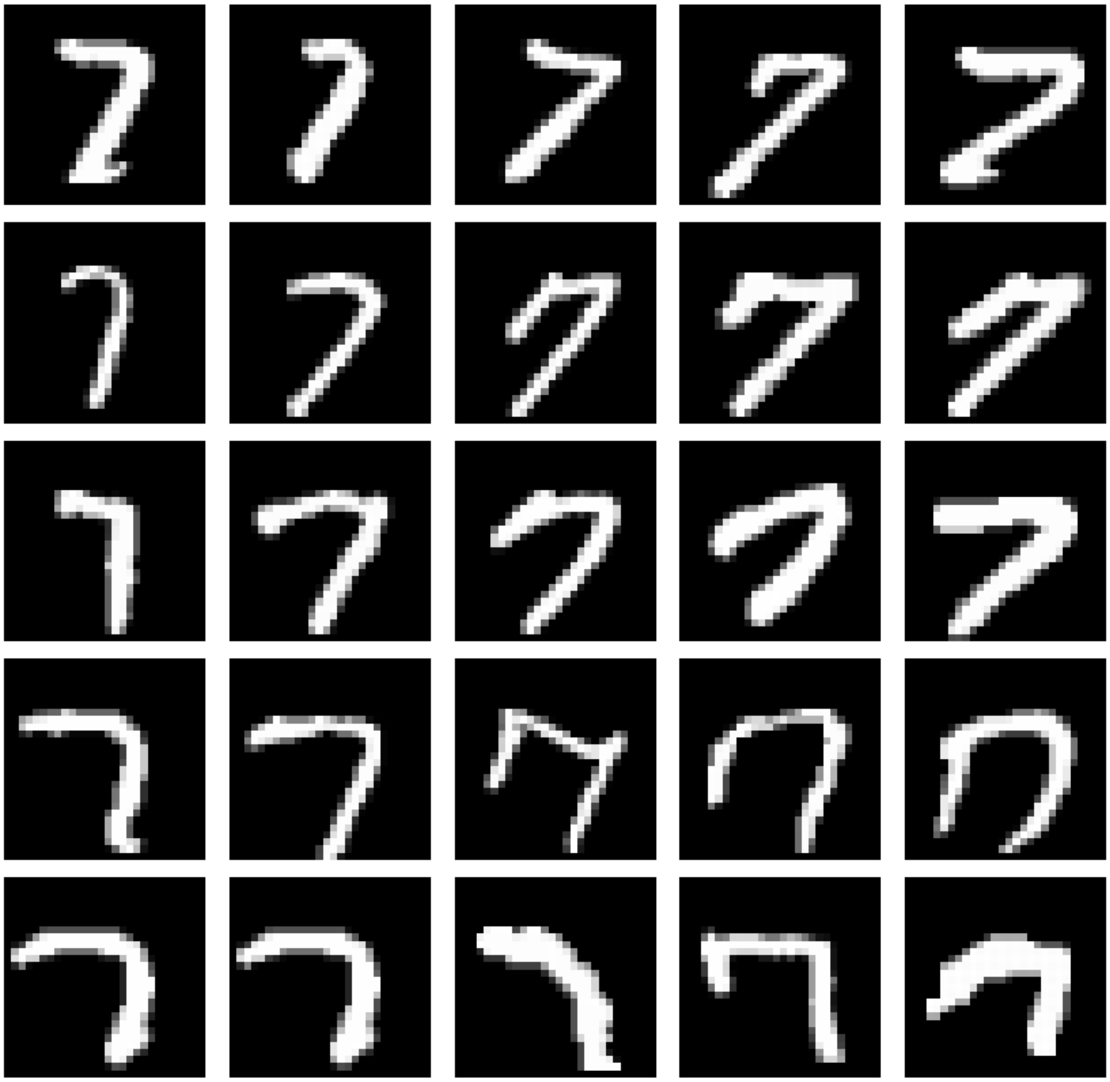
Original pictures for label 4




Original pictures for label 5

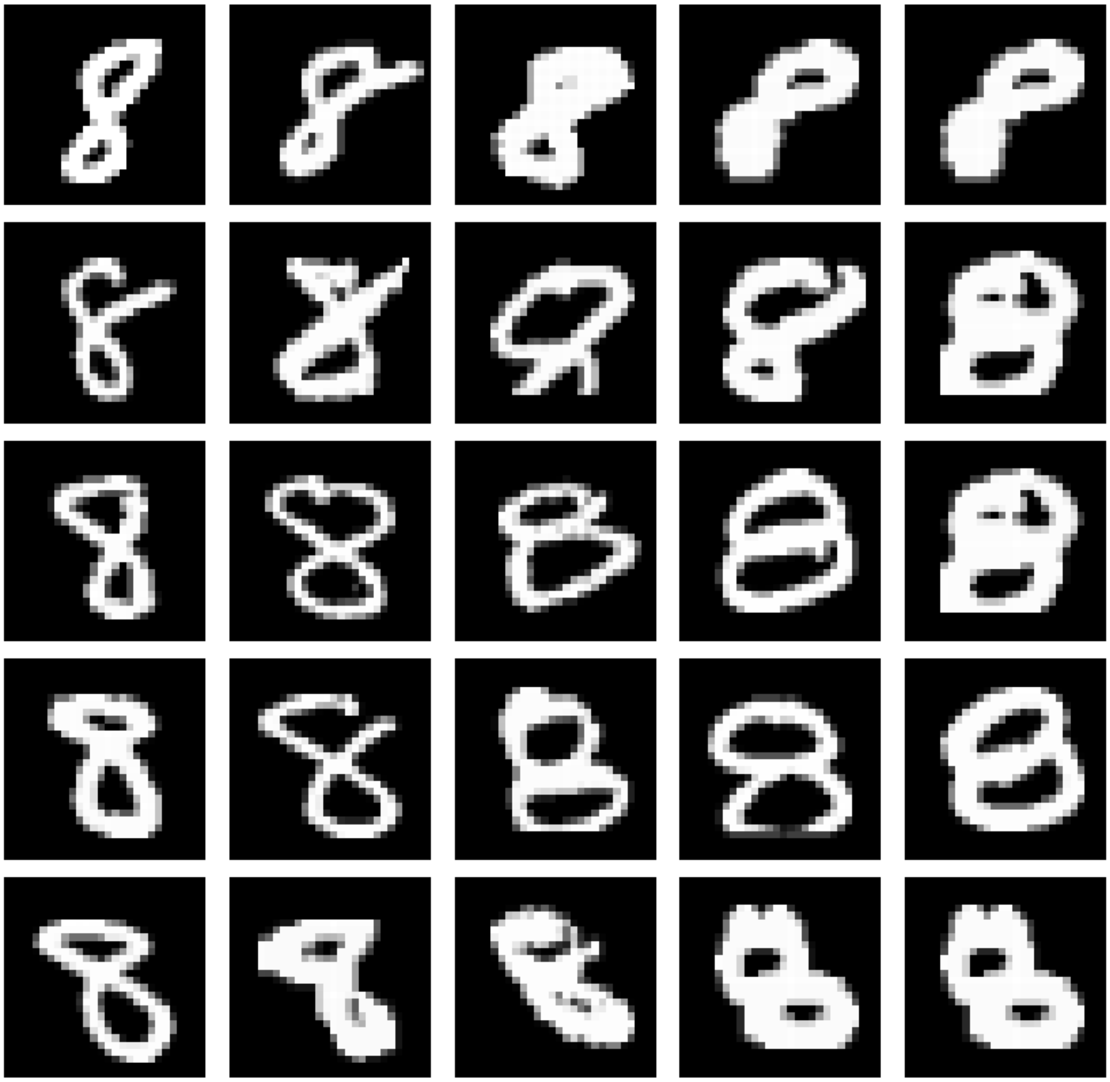
Original pictures for label 6



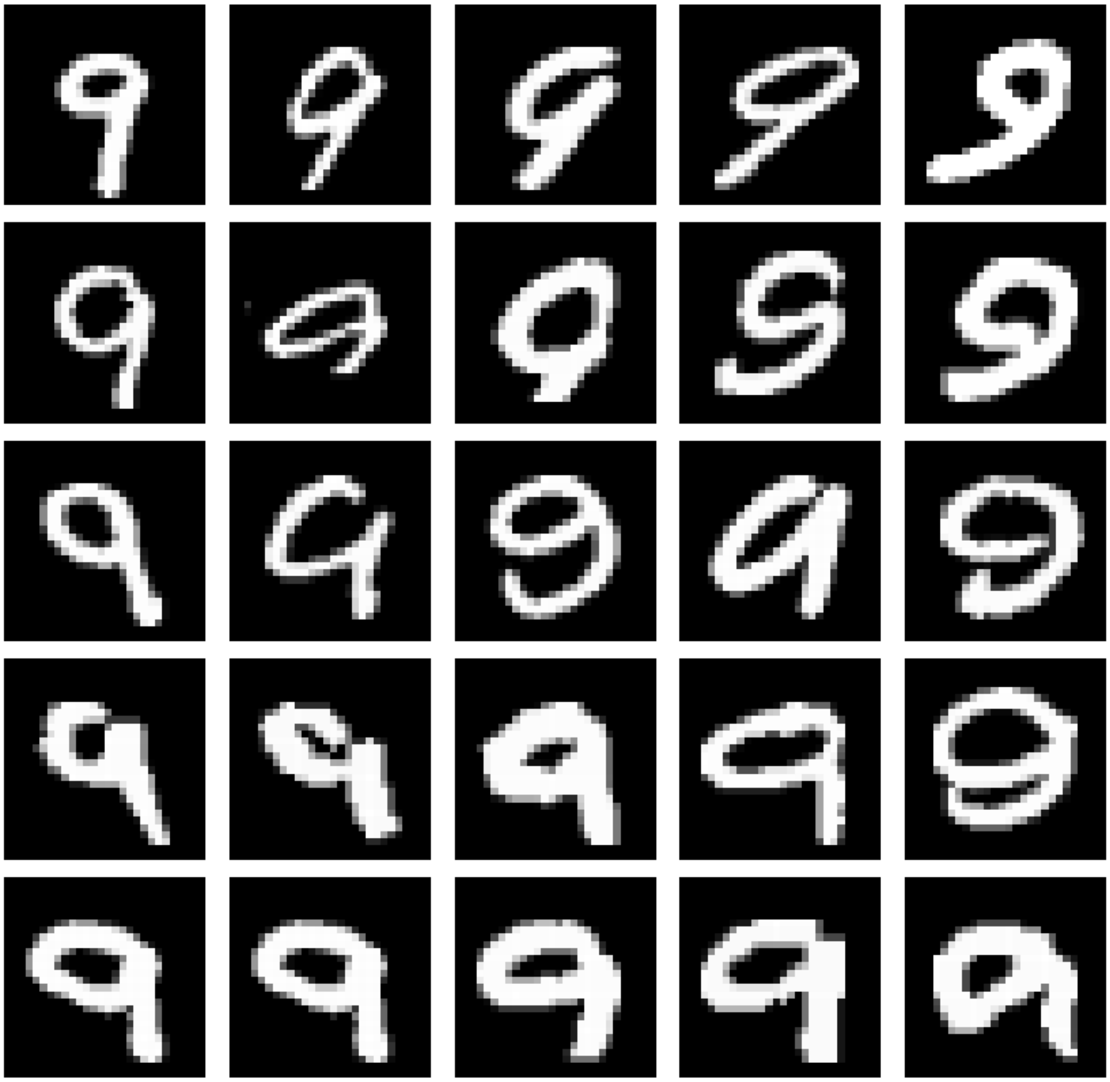


Original pictures for label 7

Original pictures for label 8



Original pictures for label 9



[ ]: