

Computer Vision  
Assignment# 1

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Contents

<b>1</b>	<b>Simple 2D classifier</b>	<b>1</b>
1.1	2.3 Training loop . . . . .	1
1.2	2.4 Multi-layer perceptron . . . . .	1
1.3	2.5 Feature transform . . . . .	1
<b>2</b>	<b>Digit classifier</b>	<b>1</b>
2.1	3.3 Multi-layer perceptron . . . . .	1
2.2	3.4 Convolutional network . . . . .	2
2.3	3.5 Comparison of number of parameters . . . . .	2
2.4	3.6 Confusion matrix . . . . .	3

**List of Figures**

1	Confusion Matrix (for CNN Model)	4
2	Confusion Matrix (for MLP Model)	5

## 1 Simple 2D classifier

### 1.1 2.3 Training loop

Accuracy achieved with Linear classifier was 47.6% (average of 10 runs) , which is expected because in 2-d plane we cannot find a straight line which can separate the regions (characterized by the two classes). The best that can be done is to either make the line pass through the center or let the line be outside of the both circular regions (in either case the best accuracy would be poor and close to random guess , assuming the number of data-points for both the classes are almost same).

### 1.2 2.4 Multi-layer perceptron

With Multi-layer perceptron, the accuracy achieved was 99.8% (avg. of 4 runs). It was possible because of the addition of hidden layers and the non-linear activation function. With addition of these two to the model, the model was now able to internally transform the input features to higher dimensional feature space where it is easy to find a set of parameters which can model the distribution of the data and thus find a separating boundary. Hence, the result was much better than the linear classifier.

### 1.3 2.5 Feature transform

I chose polar coordinate system  $(r, \theta)$  based on the given data. Since, the two classes are on concentric circles with different radii and center as origin, therefore, in polar coordinates the data points for these two classes will have significantly different values of  $r$  for any given  $\theta$ . Thus in  $(r, \theta)$  space a simple linear classifier can also model the line separating the two classes. With this transformed feature and linear classifier, the accuracy achieved was: 83.4% (avg. of 10 runs)

## 2 Digit classifier

### 2.1 3.3 Multi-layer perceptron

The following are the accuracies obtained for:  
 when using single layer: 91.12% (avg. of 5 runs), and  
 when using "MLP with one hidden layer of dimension 32 followed by ReLU and then the final linear prediction layer" : 94.29% (avg. of 5 runs)

## 2.2 3.4 Convolutional network

With this architecture (CNN based) , the accuracy obtained was: 98.14% (average of 5 runs)

## 2.3 3.5 Comparison of number of parameters

**For MLP model parameters:**

Since the image is converted to a vector (of length  $28 \times 28 = 784$  ) and hidden layer dimension is 32, therefore, the dimension of the first weight matrix will be  $784 \times 32$ , and the number of bias parameters will be 32

For the second (which is also the last) layer:

Number of weight parameters :  $32 \times 10$  (32 is the output dimension of the previous layer and 10 is the output dimension of current layer) ,and Bias parameters : 10

So total parameters =  $(784 \times 32 + 32) + (32 \times 10 + 10) = 25450$

Output of : [(n, p.numel()) for n, p in net.named\_parameters() if p.requires\_grad]

```
[('layers.0.weight', 25088), ('layers.0.bias', 32),
 ('layers.2.weight', 320), ('layers.2.bias', 10)]
```

**For CNN Model parameters, we have:**

First CNN layer:  $1 \times 3 \times 3 \times 8$  (*i.e.* number of input channels  $\times$  kernel dimension 1  $\times$  kernel dimension 2  $\times$  number of output channels weight parameters and 8 (number of output channels) bias parameters . Total of 80 parameters

Similarly,

Second CNN Layer:  $8 \times 3 \times 3 \times 6 + 16$

Third CNN Layer :  $16 \times 3 \times 3 \times 32 + 32$

For final Linear Layer:  $32 \times 10 + 10$

So CNN based model has a total of 6218 parameters. (Note: ReLu and MaxPooling has no trainable parameters)

Output of : [(n, p.numel()) for n, p in net.named\_parameters() if p.requires\_grad]

```
[('layers.0.weight', 72), ('layers.0.bias', 8),
 ('layers.3.weight', 1152), ('layers.3.bias', 16),
 ('layers.6.weight', 4608), ('layers.6.bias', 32),
 ('classifier.0.weight', 320), ('classifier.0.bias', 10)]
```

As compared to MLP the CNN model has less number of parameters (about one-fourth of the number of MLP parameters), still CNN achieves better accuracy. CNN based model is able to learn spatial features (of the image) easily and with less number of parameters.

## 2.4 3.6 Confusion matrix

Figure 1 shows the Confusion Matrix for CNN Model. Most of the predictions are correct (as reflected by bright diagonal).

We observe that model confuses the number 5 the most. It is expected too because written instances of 3 and 8 may match significantly with 5 due to the similarity in shapes. Similar situation can be observed with 2 and 7, wherein due to resemblance in shape some occurrences of 2 may have been predicted as 7.

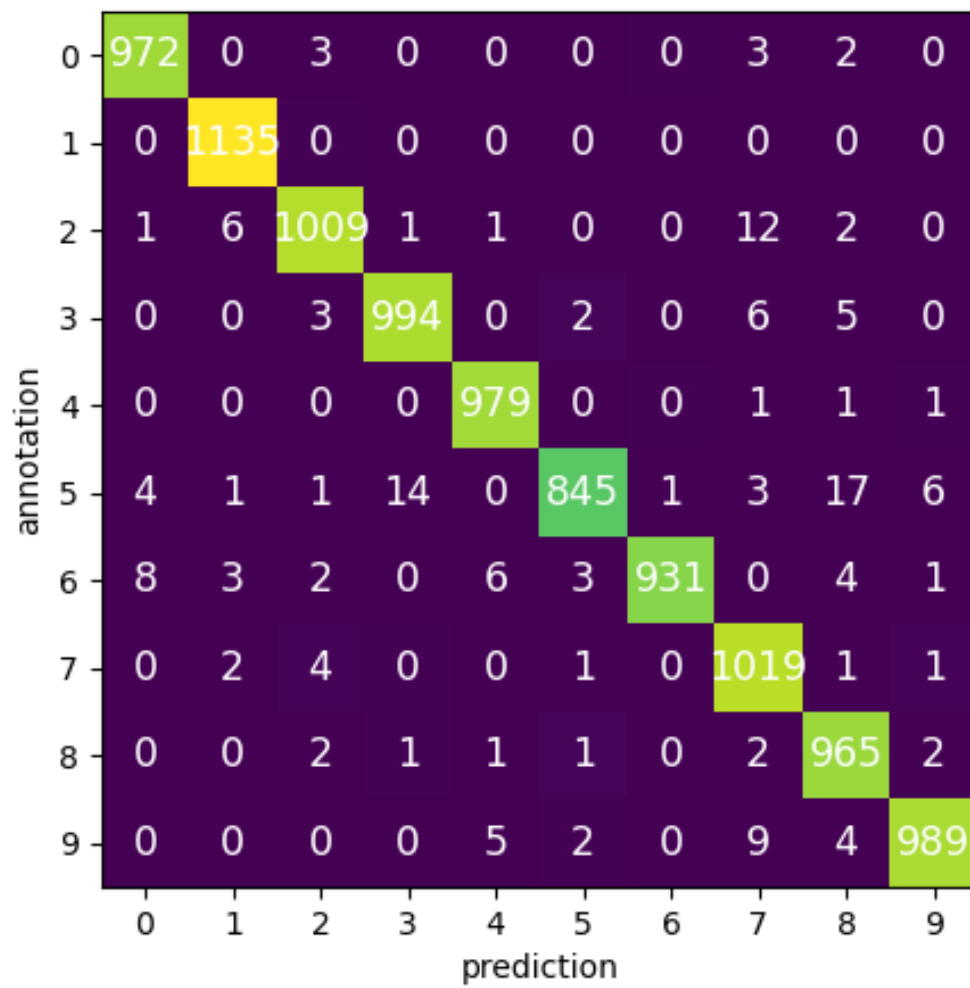


Figure 1: Confusion Matrix (for CNN Model)

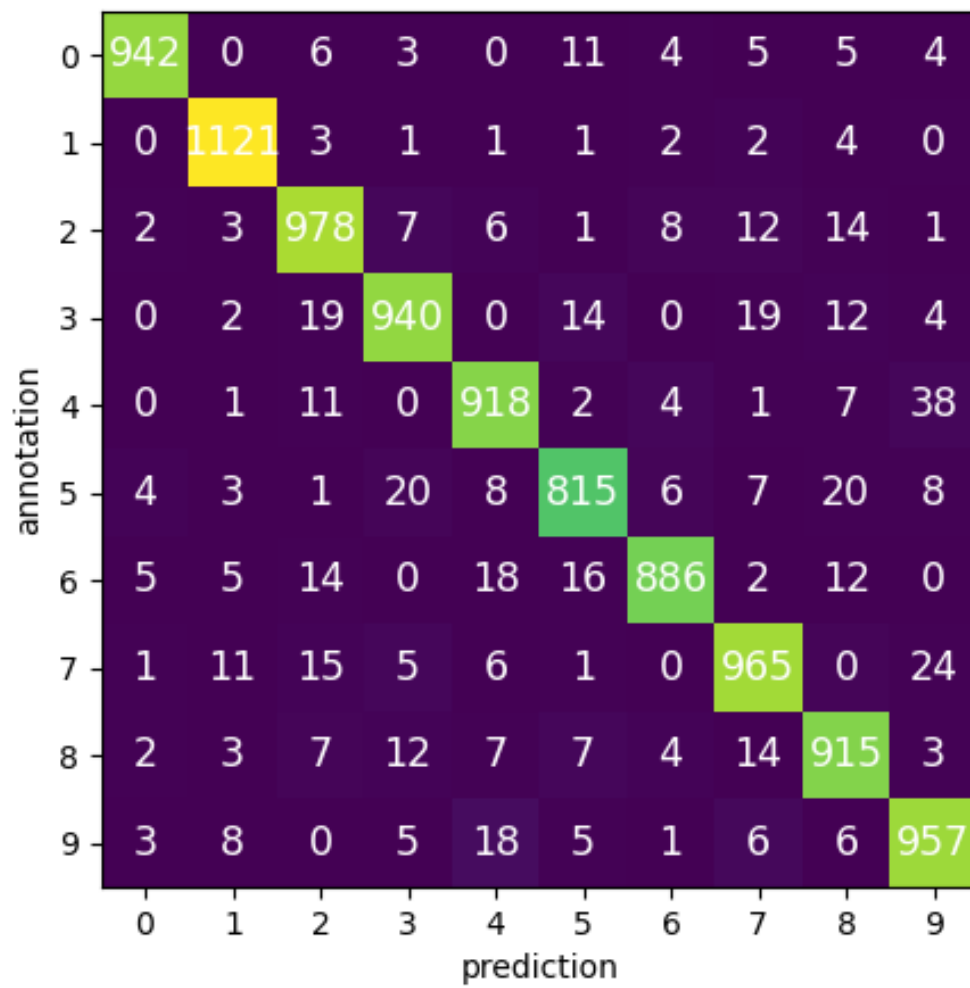


Figure 2: Confusion Matrix (for MLP Model)