

ENAS 991: Assignment 3

(Writeup)

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Problem 1

- (1) The network obtains a *testing accuracy*, i.e., the fraction of test images classified correctly, of **71.48%** with the out-of-the-box network.
- (2) The following confusion matrix represents the classification trends of the trained network, as evaluated on the test set. (Matrix obtained from the network tool box). The class labels on the figure indicate class numbers, where class 1 maps to digit zero, 2 maps to one, 3 to two, and so on.

Confusion Matrix obtained from the Neural Net GUI box.

Test Confusion Matrix											
Output Class	1	2	3	4	5	6	7	8	9	10	
	58 7.7%	3 0.4%	1 0.1%	2 0.3%	1 0.1%	1 0.1%	1 0.1%	3 0.4%	0 0.0%	3 0.4%	79.5% 20.5%
	0 0.0%	53 7.1%	8 1.1%	4 0.5%	1 0.1%	2 0.3%	3 0.4%	1 0.1%	6 0.8%	2 0.3%	66.2% 33.8%
	2 0.3%	4 0.5%	54 7.2%	3 0.4%	1 0.1%	2 0.3%	0 0.0%	4 0.5%	2 0.3%	2 0.3%	73.0% 27.0%
	0 0.0%	1 0.1%	3 0.4%	53 7.1%	2 0.3%	8 1.1%	0 0.0%	0 0.0%	1 0.1%	1 0.1%	76.8% 23.2%
	2 0.3%	0 0.0%	3 0.4%	4 0.5%	64 8.5%	1 0.1%	1 0.1%	0 0.0%	3 0.4%	4 0.5%	78.0% 22.0%
	0 0.0%	0 0.0%	5 0.7%	16 2.1%	1 0.1%	41 5.5%	2 0.3%	0 0.0%	6 0.8%	1 0.1%	56.9% 43.1%
	1 0.1%	0 0.0%	2 0.3%	1 0.1%	1 0.1%	7 0.9%	59 7.9%	0 0.0%	7 0.9%	2 0.3%	73.8% 26.2%
	1 0.1%	1 0.1%	2 0.3%	3 0.4%	0 0.0%	0 0.0%	0 0.0%	64 8.5%	1 0.1%	4 0.5%	84.2% 15.8%
	0 0.0%	0 0.0%	2 0.3%	5 0.7%	6 0.8%	1 0.1%	5 0.7%	2 0.3%	52 6.9%	4 0.5%	67.5% 32.5%
	2 0.3%	0 0.0%	2 0.3%	1 0.1%	2 0.3%	3 0.4%	1 0.1%	2 0.3%	3 0.4%	51 6.8%	76.1% 23.9%
Target Class											
	1	2	3	4	5	6	7	8	9	10	
	87.9% 12.1%	85.5% 14.5%	65.9% 34.1%	57.6% 42.4%	81.0% 19.0%	62.1% 37.9%	81.9% 18.1%	84.2% 15.8%	64.2% 35.8%	68.9% 31.1%	73.2% 26.8%

Confusion Matrix obtained from Test Set

True Class	1	2	3	4	5	6	7	8	9	10
	437		17		4	3	11	7	7	14
	12	399	34	10	1	23	5	10	3	3
	17	25	350	53	15	11	11	7	4	7
	5	8	17	367	15	49	3	2	25	9
	5	8	7	14	387	3	24		27	25
	5	12	12	62	6	340	32	4	18	9
	8	25	9	7	28	22	337	1	36	27
	7	16	8	8	1		2	424	8	26
	11	9	6	54	25	25	26	4	327	13
	7	4	7	9	15	23	4	12	16	403
Predicted Class										

Yes, there are some trends in the mistakes that the network makes. Significant misclassifications occur between the following classes,

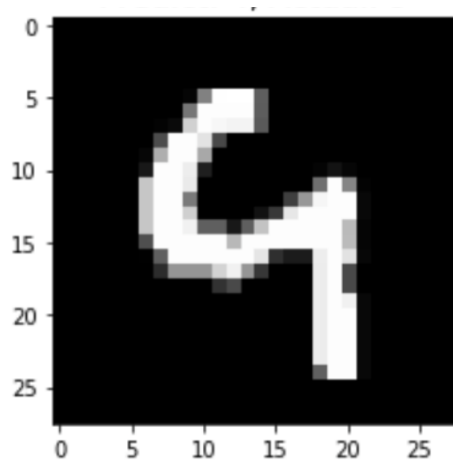
- 3 and 5.
 - 3 is identified as 5 in 49 instances.
 - 5 is identified as 3 in 62 instances.
- 2 and 1.
 - 2 is identified as 1 in 25 instances.
 - 1 is identified as 2 in 34 instances.
- 8 and 3.
 - 8 is identified as 3 in 54 instances.
 - 3 is identified as 8 in 25 instances.

These misclassifications can be attributed to the visual similarity of the digits, and even a slight artifact in the handwritten digit seems to lead to a misclassification.

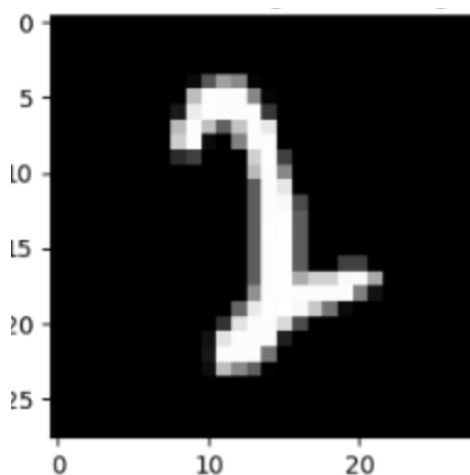
The easiest digit to identify was 0, which has a prediction accuracy of 87.4%. This is followed by the digit 7 with an accuracy of 84.8%.

The hardest numbers to identify were 8 and 6 with prediction accuracies 65.4% and 67.4%, respectively.

For instance, the following image represents 9, but was misclassified as 4.



And the following image represents 2, but was misclassified as 1.



(3)

The following network configurations were tried.

Number of Hidden Layers	1, 2, and 3
Sizes of Hidden Layers	[25], [50], [25 15], [50 25], [50 25 15]
Activation Functions	'compet', 'softmax', 'logsig', 'tansig', 'netinv'

The corresponding results obtained are presented below, where the performance measure is the classification accuracy measured on the test set.

	[25]	[50]	[25 15]	[50 25]	[50 25 15]
compet	10.0200	10.74	8.50	10.32	8.48
softmax	9.90	11.82	10.00	10.04	10.00
logsig	34.68	23.66	17.10	19.22	10.00
tansig (default)	87.02	91.06	85.66	93.84	92.54
netinv	23.64	24.56	12.34	12.30	10.04

The highest performance obtained is 93.84%.

Few observations in the performance trend:

- The activation function seems to play a significant role in the quality of classification obtained. The symmetric sigmoid function is the most effective among the once tried; it is also the default that the *net()* function uses and is a very commonly used activation function in neural networks.
- As the layer complexity increases from left to right within each number of layers, there is a general trend of increasing performance. In particular, the one layer models with 50 neurons perform better. And likewise, in the two layer setting, the larger model with 50 and 25 neurons in its two hidden layers tends to perform better.
- However, notably, for the three layer case, there is a consistent dip in performance. This is probably due to overfitting, since the network architecture is more complex than required to represent and classify the MNIST digits.