INTRO TO MACHINE LEARNING
ASSIGNMENT 2
HANDWRITTEN DIGITS CLASSIFICATION

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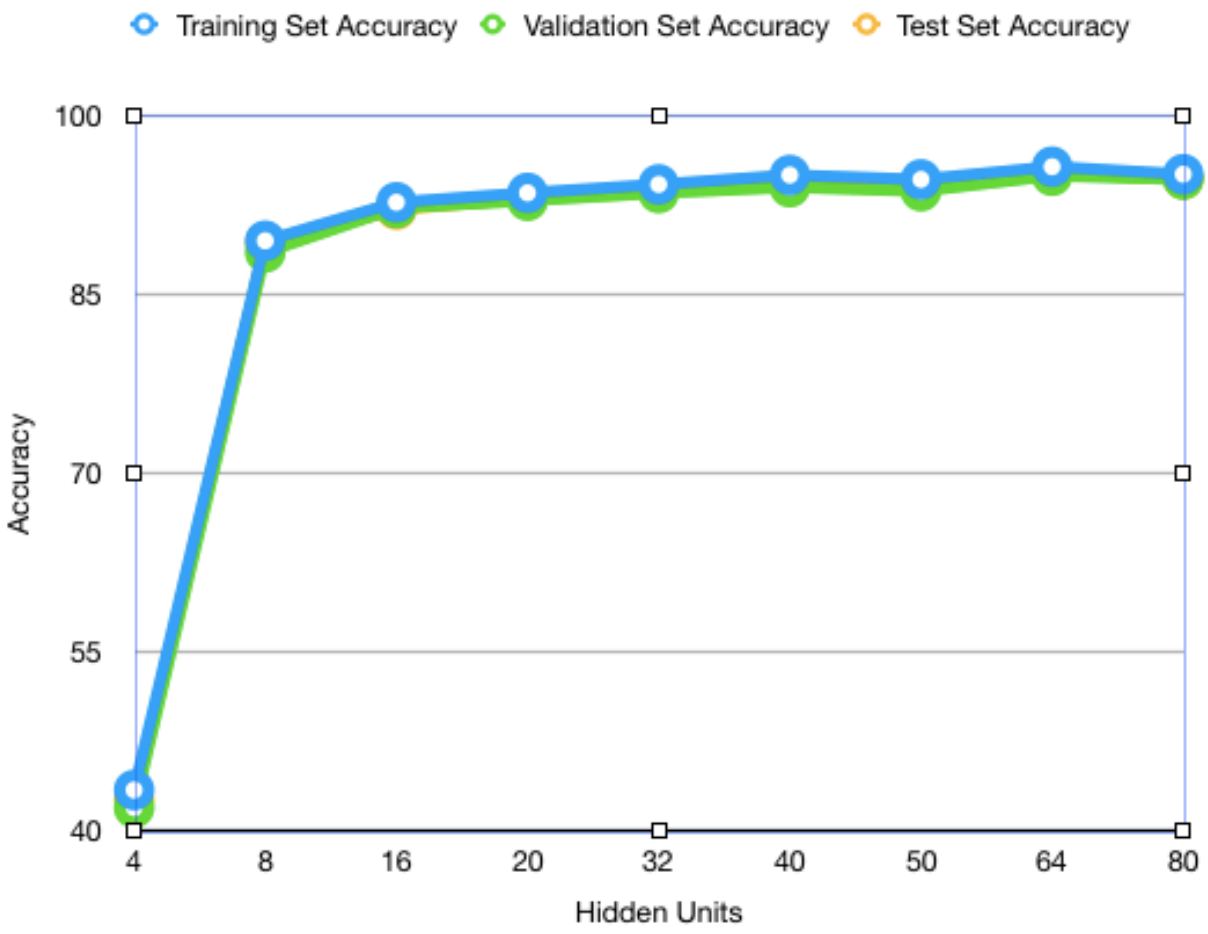
Part 1: To Select Hyper Parameters using nnScript:

Aim: To compare the accuracy and time taken for Neural networks based on different values of hidden units and constant lambda.

Comparing accuracy based on Hidden Units

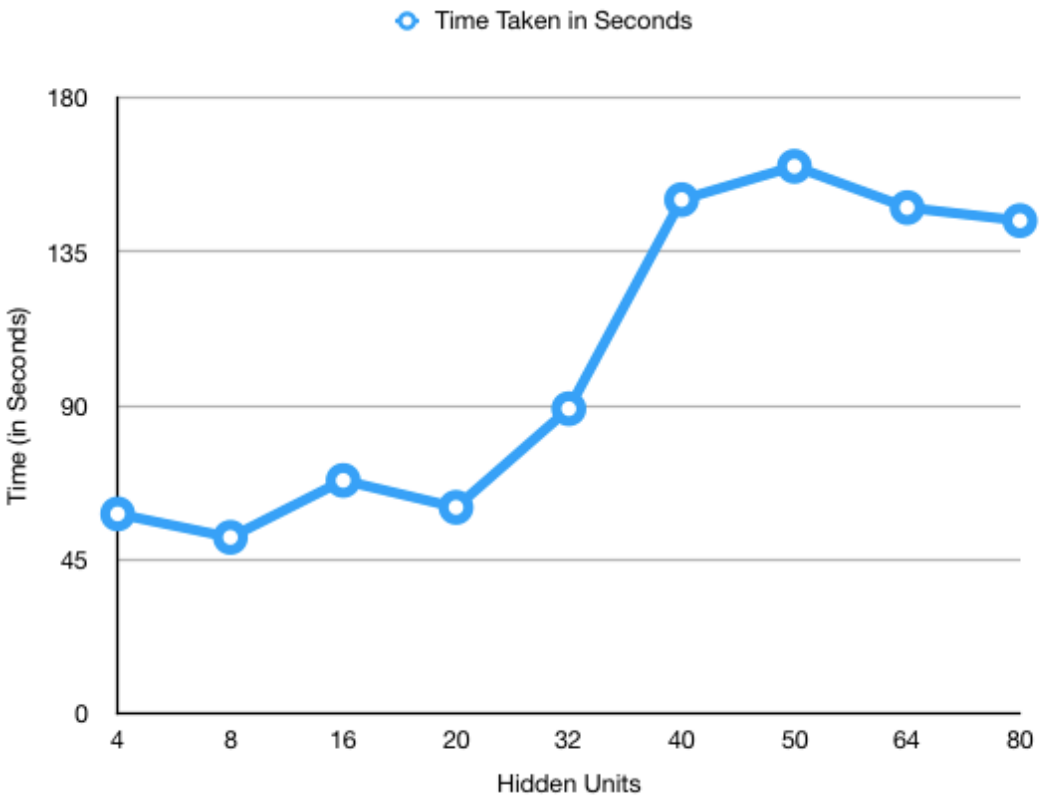
Hidden Units	Lambda	Training Set Accuracy	Validation Set Accuracy	Test Set Accuracy	Time Taken in Seconds
4	0	43.456	41.97	42.62	58.266
8	0	89.478	88.51	89.29	51.40
16	0	92.7	92.24	92.09	68.07
20	0	93.49	92.84	93.01	60.188
32	0	94.198	93.48	93.86	89.060
40	0	94.98	93.97	94.45	150.258
50	0	94.616	93.64	94.16	160.011
64	0	95.682	94.93	95.09	147.932
80	0	95.052	94.63	94.63	144.115

We ran nnScript for Lambda = 0 and Hidden values = {4,8,16,20,32,40,50,64,80} and observed the Training set, Validation Set and Test set accuracy along with the time taken to execute for different values of hidden units.



Observations:

- With increase in the number of Hidden units, the accuracy of Neural network increases.
- The best Test, train and validation set accuracy was observed for **64 Hidden units**.
- The objective function also converges quickly with increase in the number of hidden units.



Observations:

- The above graph shows Time taken for the execution of Neural Networks for different value of Hidden Units.
- It can be observed that time taken increases with increase in number of hidden units. It also starts decreasing after certain number of hidden units.

Conclusion:

- From the above experiments, we found that the Neural network performs best when the Number of Hidden units = 64 (optimal value from observation).
- We have considered the accuracy to be more important than the time taken.

Aim: To compare the accuracy and time taken for Neural networks based on different values of lambda and constant hidden unit for which optimal value of accuracy was obtained from previous observation.

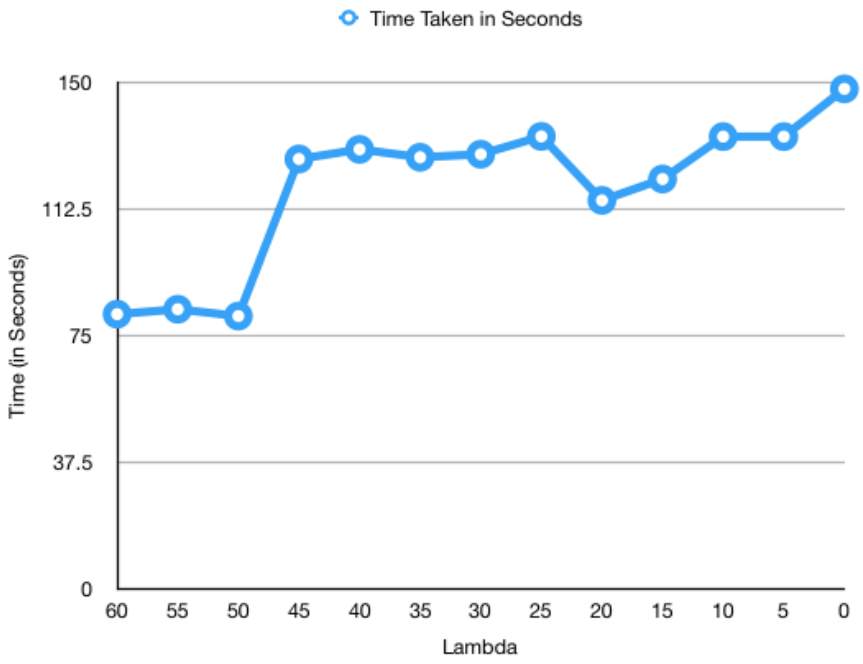
Comparing accuracy based on different Lambda values

Lambda	Hidden Units	Training Set Accuracy	Validation Set Accuracy	Test Set Accuracy	Time Taken in Seconds
60	64	93.102	92.63	92.9	81.3269
55	64	93.766	93.27	93.67	82.785
50	64	93.46	92.3	92.95	80.756
45	64	93.792	93.13	93.6	127.199
40	64	93.974	93.47	93.63	130.051
35	64	94.1	93.37	93.91	127.71
30	64	94.05	93.34	93.6	128.60
25	64	93.832	93.34	93.36	133.874
20	64	94.7	94.45	94.4	114.97
15	64	95.052	94.23	94.83	121.279
10	64	94.506	93.94	94.15	133.82
5	64	95.636	94.73	95.6	133.809
0	64	95.084	94.21	94.23	147.931

We ran nnScript for Hidden value = 64 and Lambda values = {60,55,50,45,40,35,30,25,20,15,10,5,0} and observed the Training set, Validation Set and Test set accuracy along with the time taken to execute for different values of lambda.

Observations:

- The above graph shows the accuracy obtained for Neural networks based on different values of lambda.
- We try to obtain the optimal value of lambda. Lambda is the regularization coefficient used to avoids over-fitting due to which there might be problems with prediction on test data.



Conclusion:

- The optimal value of lambda obtained is 5 according to our observation.
- When the lambda is too large, under-fitting happens.
- The optimal values of Lambda is 5, Hidden Units is 64.
- The Training set, Validation set, Test set and Time for Lambda = 5, and Hidden Units = 64 is shown below:

Lambda	Hidden Units	Training Set Accuracy	Validation Set Accuracy	Test Set Accuracy	Time Taken in Seconds
5	64	95.636	94.73	95.6	133.809

Part 2: Comparison of Deep Neural network and Neural network.

Aim: To evaluate the accuracy of single hidden layer Neural Network on CelebA data set using facennScript.

Observations:

- For default values, Lambda 10 and Hidden Units 256.

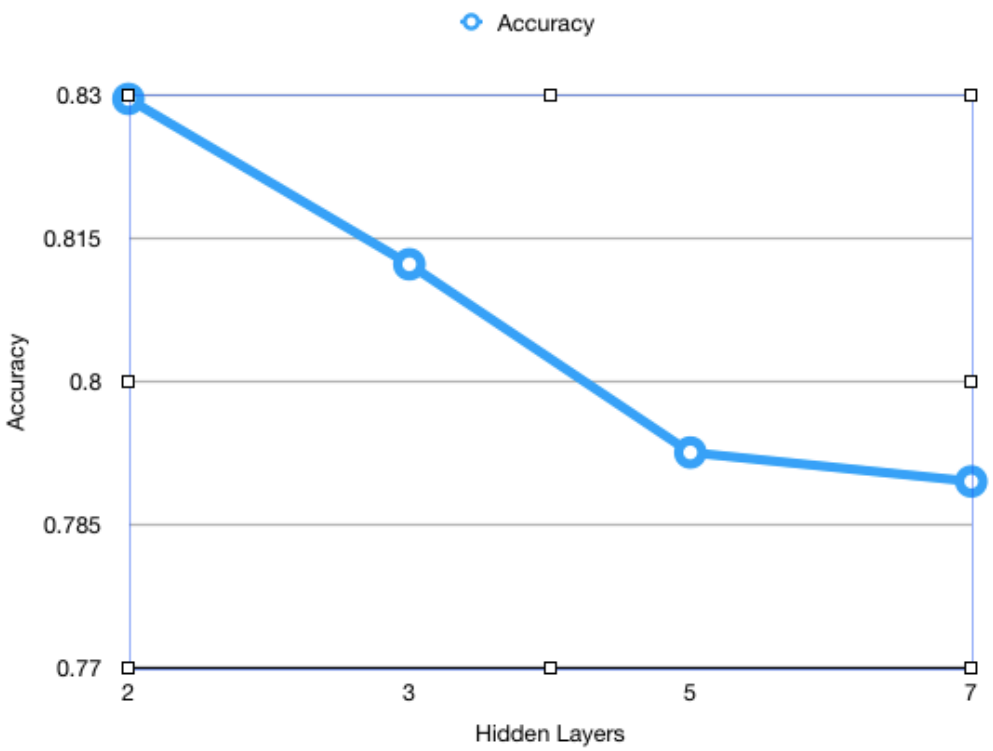
Lambda	Hidden Units	Training Set Accuracy	Validation Set Accuracy	Test Set Accuracy	Time Taken in Seconds
10	256	85.606	84.09	85.655	137.966

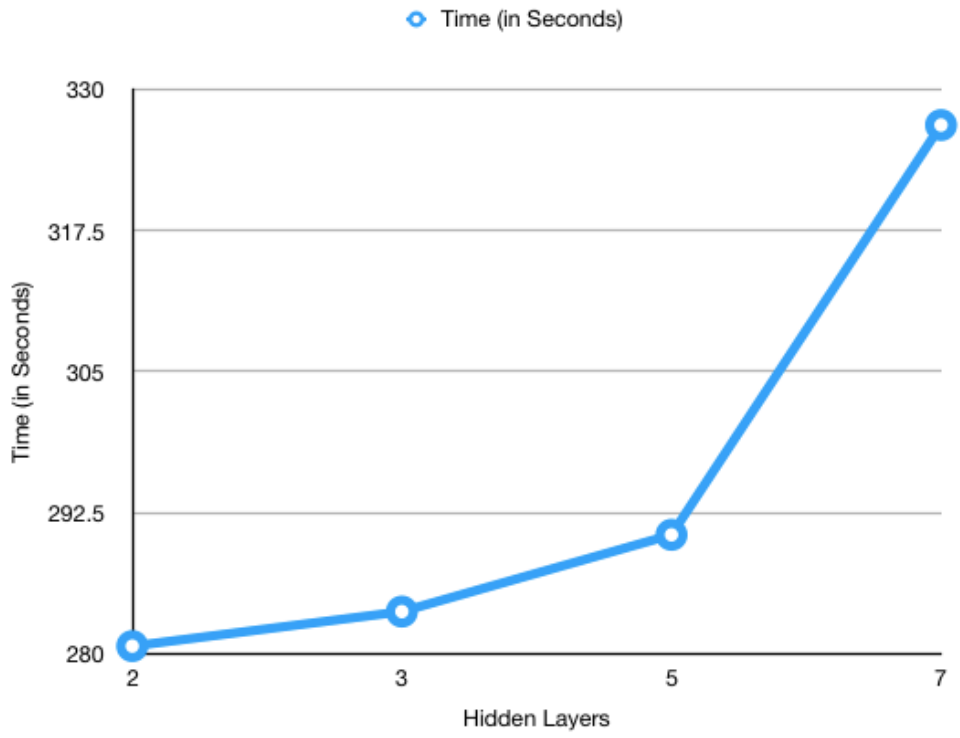
- For optimal values from previous observation: Lambda = 5, Hidden Units = 64

Lambda	Hidden Units	Training Set Accuracy	Validation Set Accuracy	Test Set Accuracy	Time Taken in Seconds
5	64	85.943	84.465	86.033	114.601

Aim: Evaluate the accuracy of deep Neural Network on CelebA data set using deepnnScript.

Hidden Layers	Accuracy	Time (in Seconds)
2	0.829553	280.661
3	0.812263	283.722
5	0.792581	290.532
7	0.789553	326.881





Observations:

- The above graphs show Time vs Hidden Layers and Accuracy vs Hidden Layers.

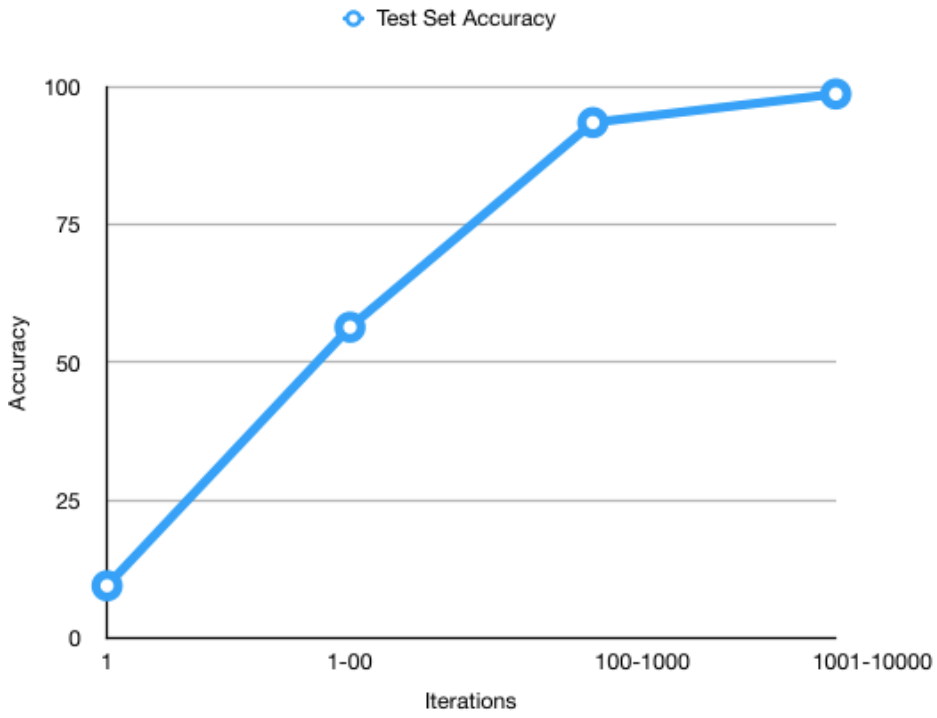
- We can see that the accuracy decreases with increase in the number of layers and Time taken for the Deep Neural network increases with increase in the number of layers.

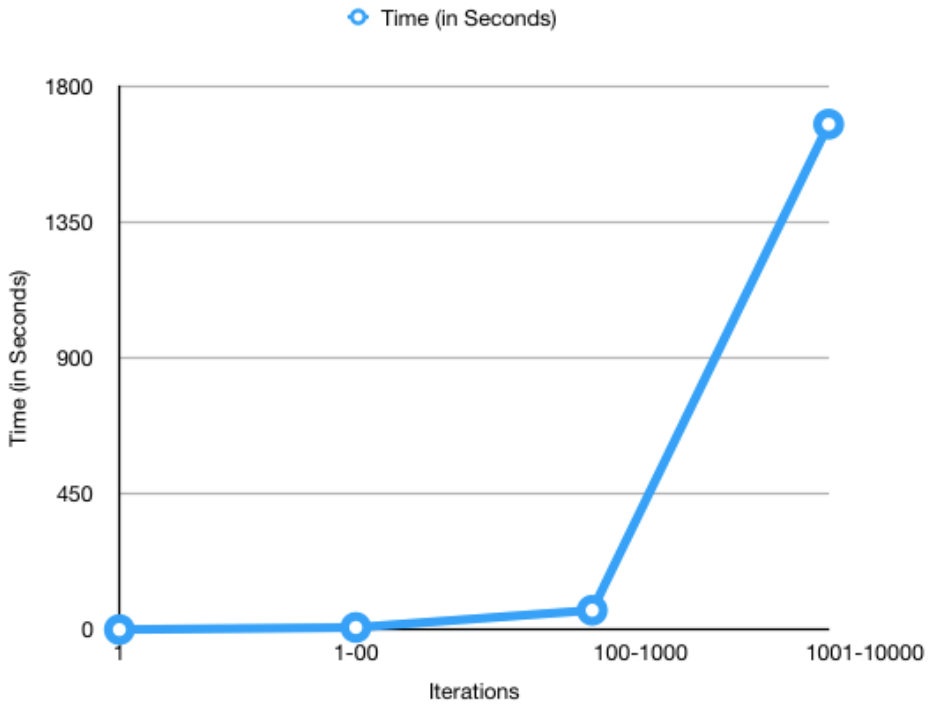
Aim: Compare the performance of single vs. deep Neural Networks in terms of accuracy on test data and learning time.

- **Accuracy:** From the above observations, we can conclude that neural network with one hidden layer for optimized values of hyper-parameters has an accuracy 86.033% on the Celeb dataset as compared to the Deep neural network which has a maximum accuracy of 82.9% for 2 hidden layers.
- **Time:** Time taken by Neural network with one hidden layer is less as compared to time taken by Deep neural network according to our observation.

Part 3: Convolution Neural Network.

Iterations	Test Set Accuracy	Time (in Seconds)
1	9.4	0
1-00	56.4	7
100-1000	93.6	64
1001-10000	98.8	1673





Observations:

The above graph shows Accuracy vs Iterations and Time vs Iterations.
It shows how accuracy increases with the number of iterations and time.

Final Output:

Confusion Matrix obtained after 10,000 iterations.

```
Confusion Matrix:
[[ 970    0    1    0    0    5    1    1    2    0]
 [   0 1130    2    0    0    0    1    1    1    0]
 [   0    1 1018    4    1    0    0    4    4    0]
 [   0    0    0 1006    0    1    0    1    2    0]
 [   0    0    0    0  980    0    0    1    0    1]
 [   2    0    0    8    0  878    1    1    2    0]
 [   6    2    1    0    6   10  933    0    0    0]
 [   0    1    7    1    0    0    0 1017    2    0]
 [   2    0    3    4    3    3    0    3  953    3]
 [   1    4    0    4    8    5    0    4    2  981]]
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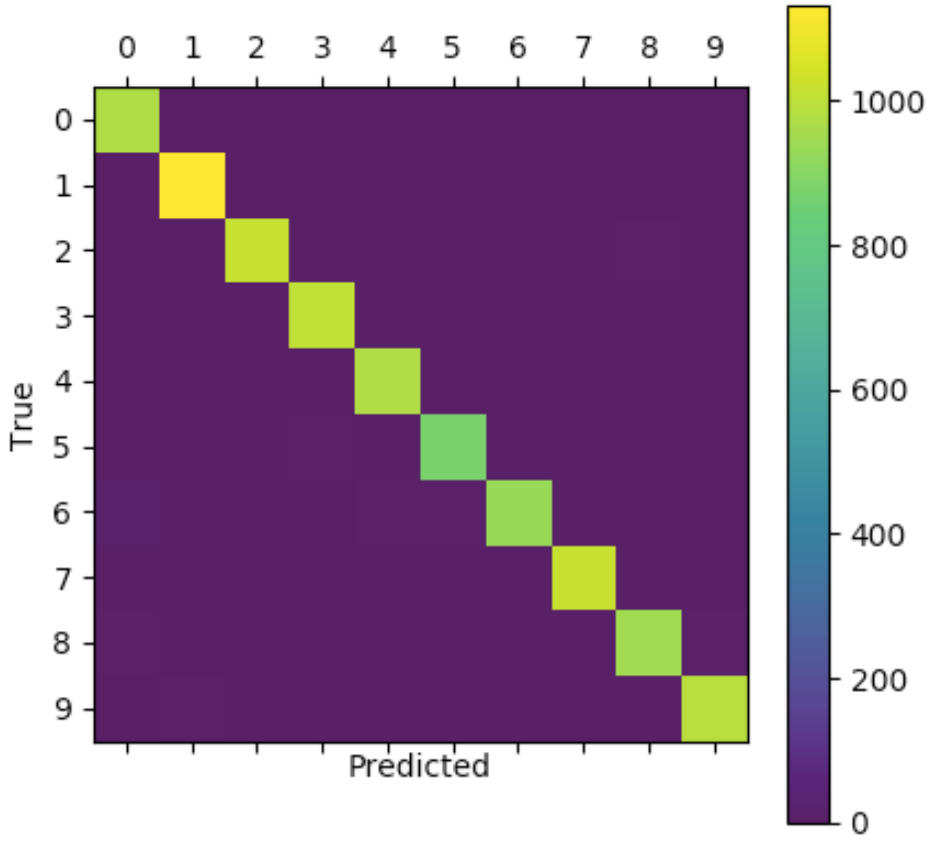
0
1
2
3
4
5
6
7
8
9
True
Predicted
1000
800
600
400
200
0