CSE574 Programming Assignment 2

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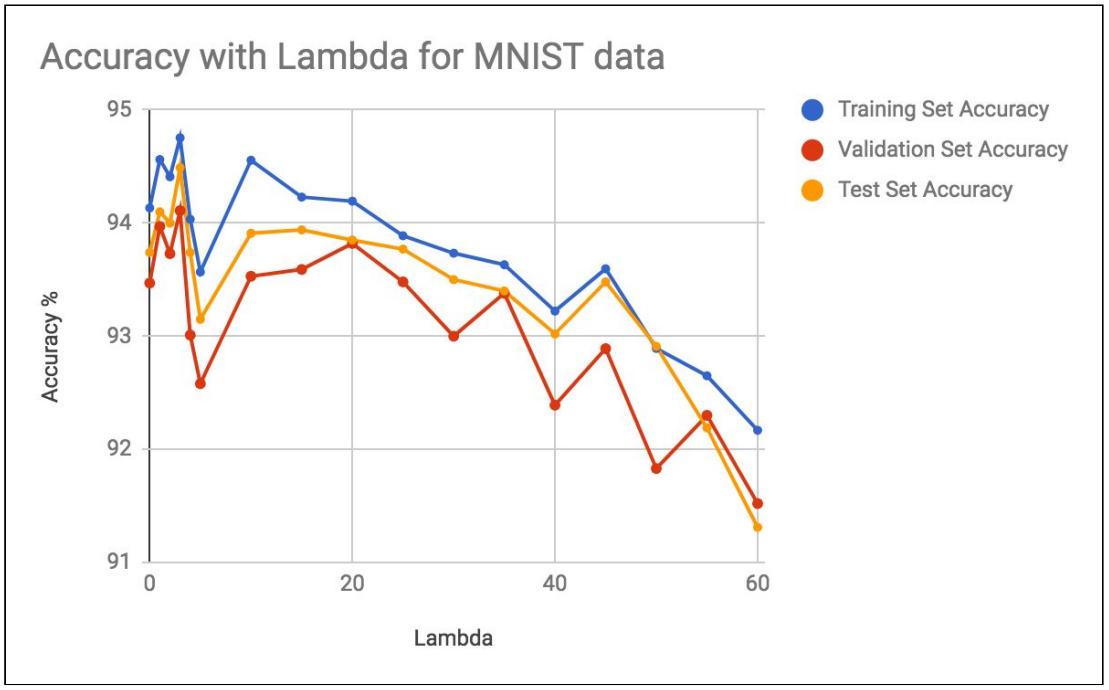
1. Hyper-Parameter for Neural Network

Influence of Regularization Parameter(Lambda) on Accuracy



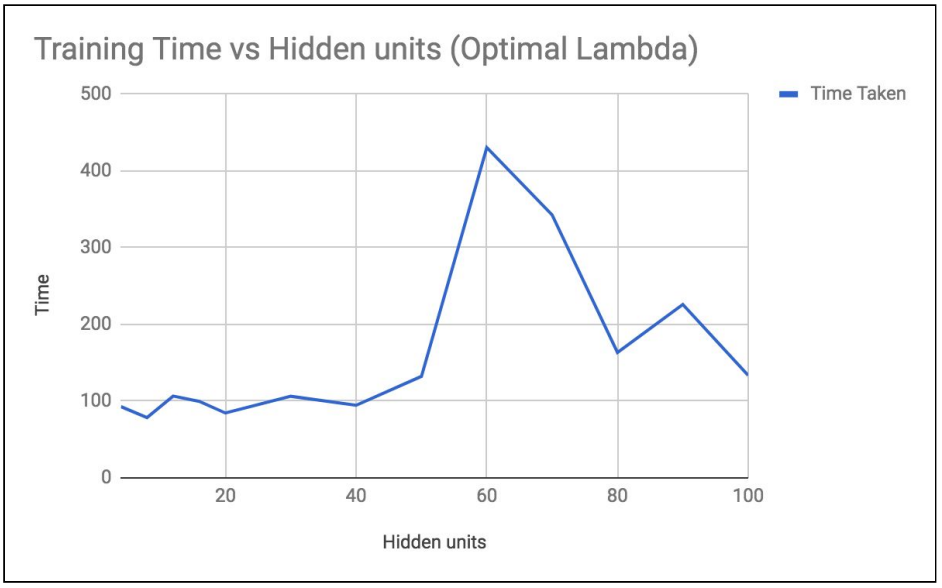
The above graph depicts the change in accuracy as we increase the regularization parameter, in this case Lambda. As we increase lambda, we see that the validation accuracy increases initially between 0-5 and eventually decreases as the lambda increases.

After experimenting with different values of lambda, we concluded that at lambda = 35, the difference between training accuracy and testing accuracy is least. This implies that overfitting is at its minimum and hence we choose 35 as our optimal lambda value.

The collected data can be found here.

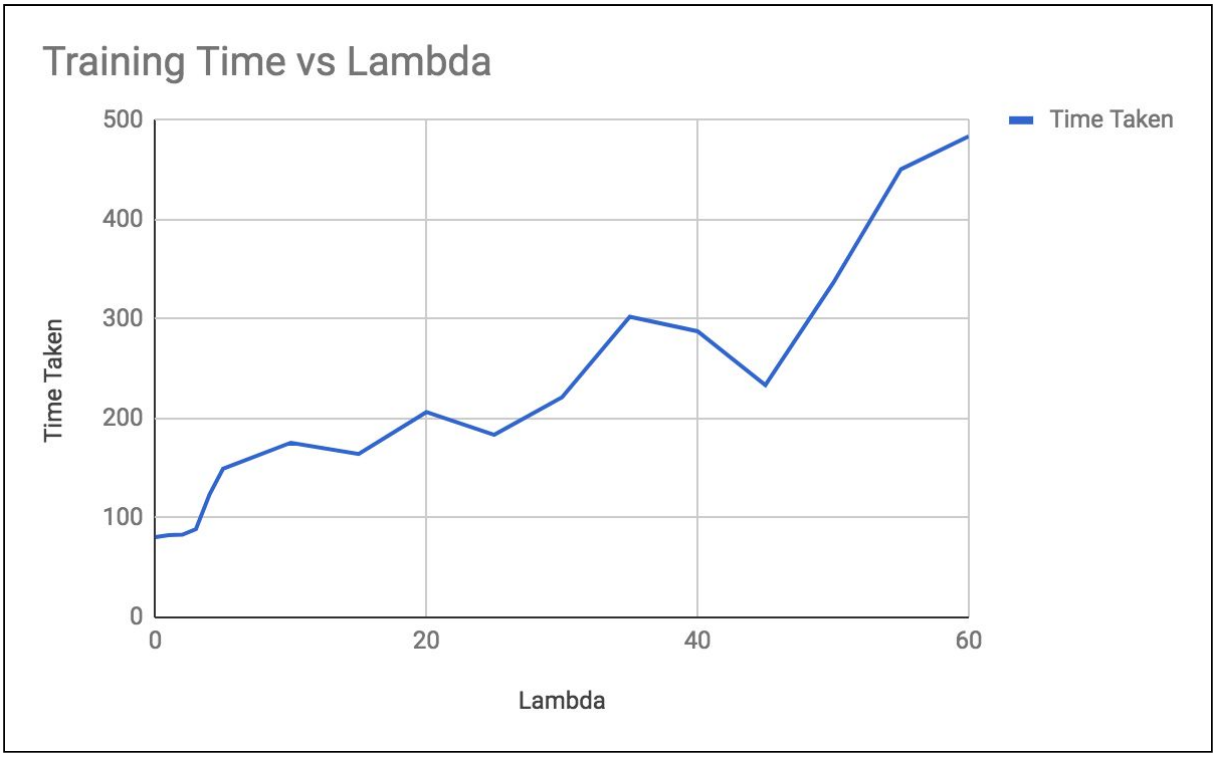
Performance Analysis of Neural Network

- Performance wrt Hidden Units



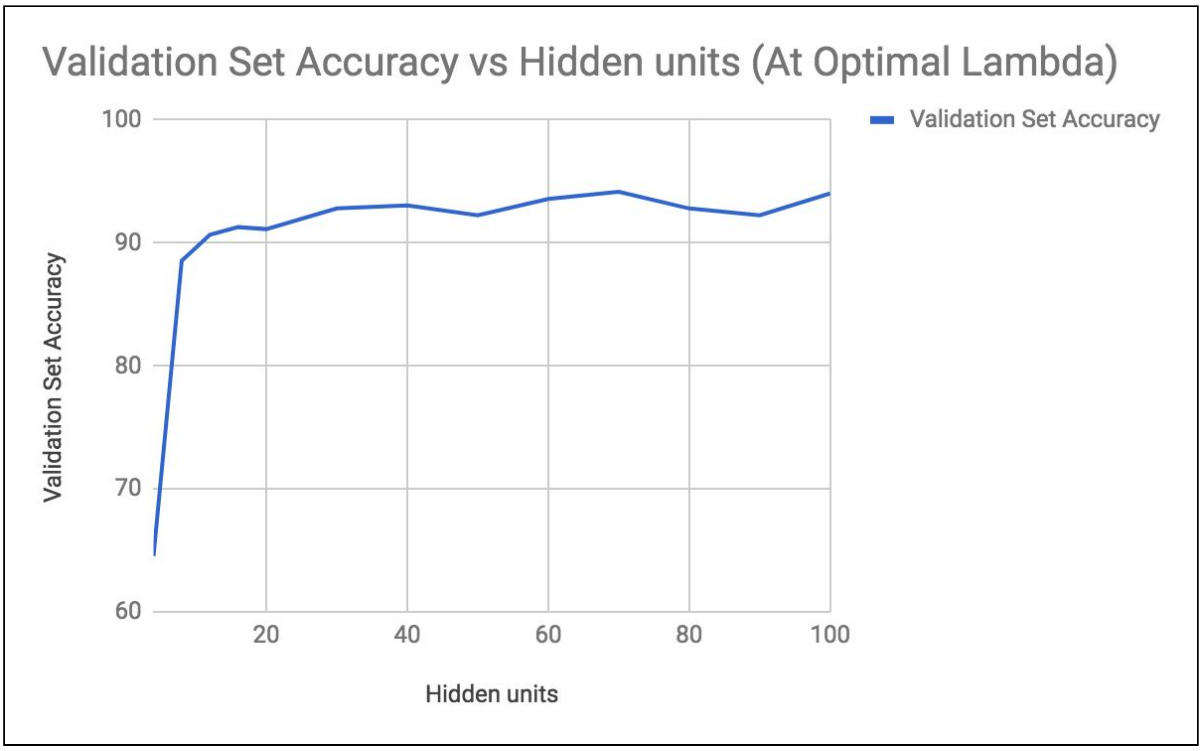
We can infer from the above graph that as the number of hidden units increases the training time increases, which implies that the performance increases as the hidden units increases. Note: after further analysis we have noticed that the load on the operating system affects the training time. But overall we can conclude that the training time increases with hidden units.

- Performance wrt Regularization Parameter



The above graph shows that as the regularization parameter increases the training time also increases which means that the performance decreases.

- Accuracy with Hidden Units



As seen from the above graph, increasing the number of hidden units increases the validation set accuracy only upto a point. The accuracy remains more or less constant after 20 hidden units and we can conclude that the accuracy is 93.05% when hidden units = 40.

Note: We have run the neural network script for lambda values from 10 to 60, increasing in steps of 10, each with varying number of hidden units (4,8,12,16,20). This collected data can be found here.

2. **Handwritten Digits Accuracy**

As previously discussed, lambda = 35 is optimal since it minimizes overfitting. At this lambda:
Training set accuracy = 93.632%
Validation set accuracy = 93.38%
Test set accuracy = 93.4%

The collected data can be found here.

3. **CelebA Accuracy**

Lambda = 10
Training set accuracy = 83.98104265%

Validation set accuracy = 82.21388368%
Test set accuracy = 84.14080242%

4. Comparison of Neural Network with Deep Neural Network

With Hidden Layer = 1	**Accuracy(%)**	**Training Time**
Neural Network	84.14080242	132.299715
Deep Neural Network	83.80015	228.173877

After experimental analysis, we see that accuracy of deep neural network is slightly less and training time is more compared to the accuracy of neural network due to difference in method of computation.

Hidden Layer (Deep Neural Network)	**Accuracy(%)**	**Training Time**
1	83.80015	228.173877
2	79.22029	253.1161659
3	79.40954	313.8552687
5	75.92733	375.2372663
7	74.45117	499.61989

As we increase the number of hidden layers in the deep neural network, we expect the accuracy to increase as well. However, we observe that accuracy actually decreases, along with increase in training time. This might be due to overfitting.

5. Convolutional Neural Network

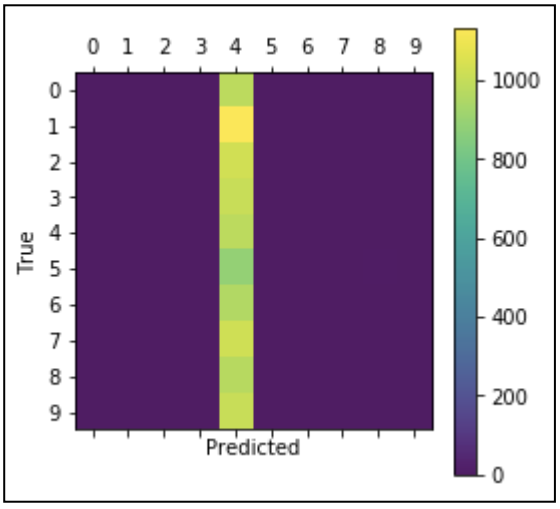
Iterations	**Accuracy(%)**	**Training Time**
1	9.8	00:00
100	63.9	00:06
1000	93	01:02
10000	98.6	10:48

Confusion Matrix:

a. Iterations=1

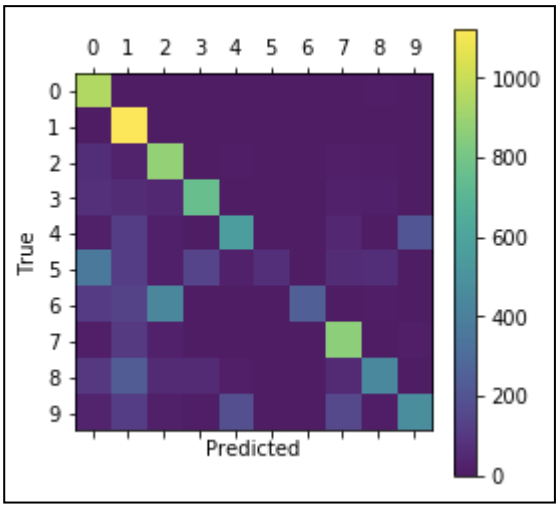
```
[[   0    0    0    0  980    0    0    0    0    0]
 [   0    0    0    0 1135    0    0    0    0    0]
 [   0    0    0    0 1032    0    0    0    0    0]
 [   0    0    0    0 1010    0    0    0    0    0]
 [   0    0    0    0  982    0    0    0    0    0]
 [   0    0    0    0  887    0    0    0    5    0]
```

```
[   0    0    0    0  958    0    0    0    0    0]
[   0    0    0    0 1028    0    0    0    0    0]
[   0    0    0    0  974    0    0    0    0    0]
[   0    0    0    0 1009    0    0    0    0    0]]
```



b. Iterations=100

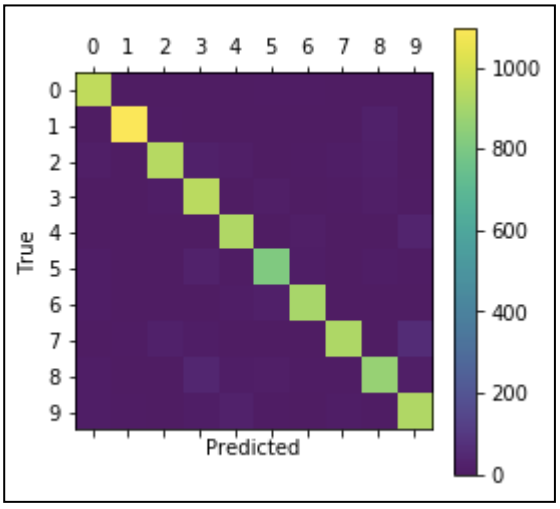
```
[[ 951    6    7    5    0    0    0    1   10    0]
 [   0 1125    4    5    0    0    1    0    0    0]
 [  70   34  881    7   12    0    0   17   11    0]
 [  76   63   52  761    4    0    0   27   23    4]
 [  20  118   24    0  563    0    0   46    1  210]
 [ 372  115   25  141   30   72    0   64   70    3]
 [ 111  140  440    0    3    0  254    1    9    0]
 [  15  102   30    0    3    0    0  862    1   15]
 [ 100  233   59   60   14    0    0   56  448    4]
 [  36  115   20    9  186    0    0  156    9  478]]
```



c. Iterations=1000

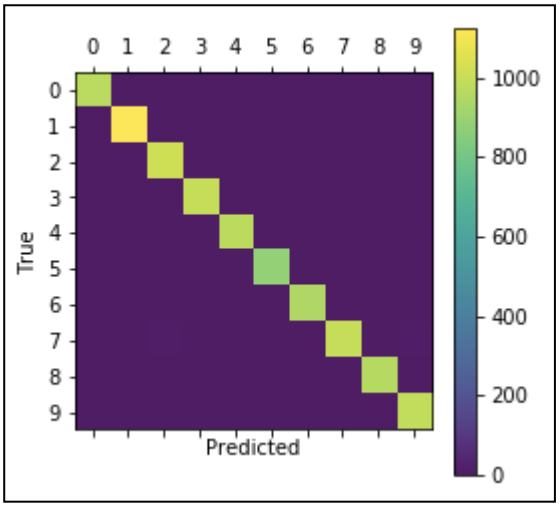
```
[[ 960    0    1    3    0    5    5    2    4    0]
 [   0 1098    5    4    1    1    4    0   22    0]
```

```
[ 13   1 939  25  17   1   6  10  18   2]
[  3   2  12 946   0  17   0   7  16   7]
[  1   0   3   0 923   0  14   1   4  36]
[  9   1   2  30   8 813  11   1  10   7]
[ 10   3   3   2  11  19 907   1   2   0]
[  3   6  24   9   4   1   0 918   1  62]
[  9   2   4  41   9  14   6   8 868  13]
[ 10   5   3  12  29   8   0  11   5 926]]
```



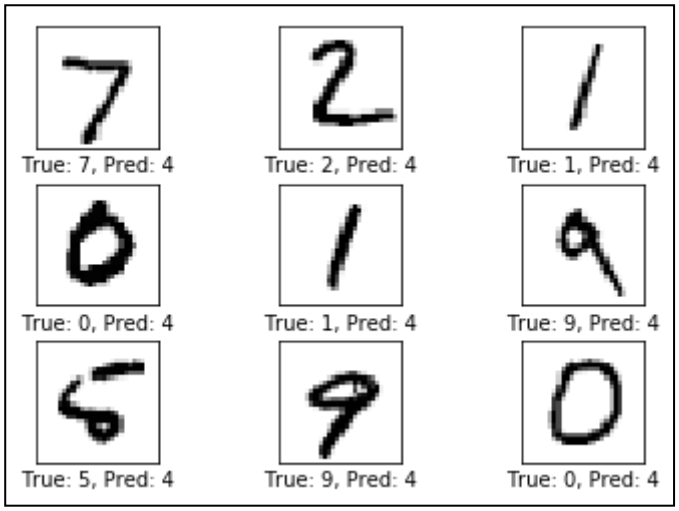
d. Iterations=10000

```
[[ 970    0    0    0    0    0    4    1    5    0]
 [   0 1126    2    0    0    0    2    0    5    0]
 [   2    4 1017    0    0    0    0    1    8    0]
 [   1    0    1  995    0    7    0    1    3    2]
 [   0    0    2    0  973    0    1    0    0    6]
 [   1    0    0    3    0  883    3    0    1    1]
 [   2    2    0    0    1    2  950    0    1    0]
 [   1    4   13    3    0    0    0  995    3    9]
 [   2    0    1    2    1    1    1    2  962    2]
 [   2    6    0    2    3    3    1    1    4  987]]
```

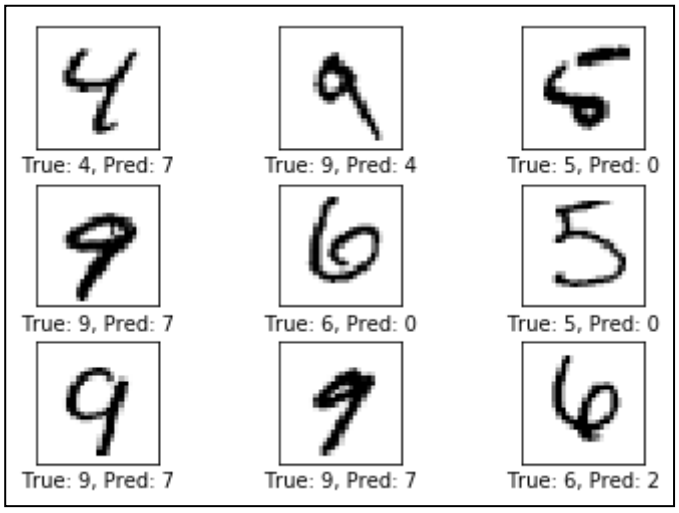


Error Examples:

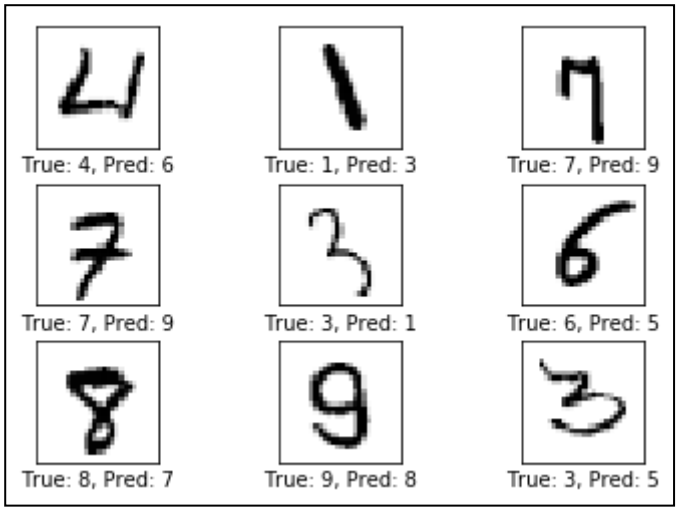
a. Iterations=1



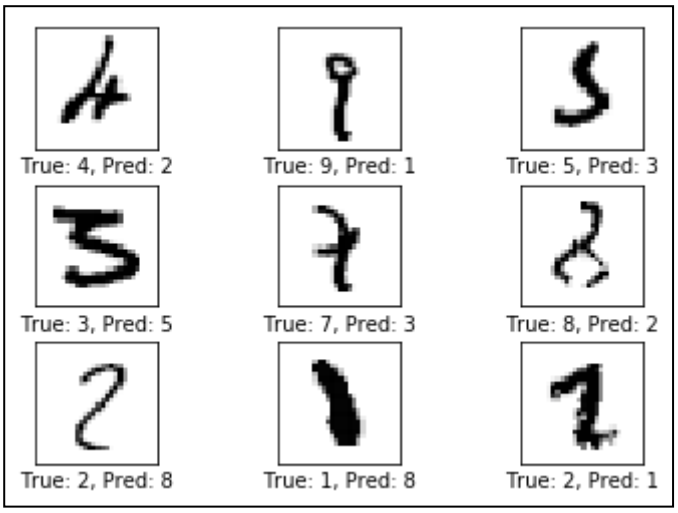
b. Iterations=100



c. Iterations=1000



d. Iterations=10000



6. Conclusion

These are the optimal values found from the neural network:
Lambda = 35
Hidden Units = 40
Accuracy = 93.05%

7. Experimental Data Collected

Lambda vs Accuracy

Lambda	Training Set Accuracy	Validation Set Accuracy	Test Set Accuracy	Training Time
0	94.134	93.47	93.74	80.60365272
1	94.562	93.97	94.1	82.65270662
2	94.41	93.73	94	83.16693497
3	94.754	94.11	94.49	88.75089073
4	94.034	93.01	93.74	123.640312
5	93.568	92.58	93.15	149.4653044
10	94.556	93.53	93.91	175.6390932
15	94.23	93.59	93.94	164.3489239
20	94.194	93.82	93.85	206.4897697
25	93.888	93.48	93.77	183.686357
30	93.734	93	93.5	221.2923102
35	93.632	93.38	93.4	302.3858707
40	93.222	92.39	93.02	287.8013628

45	93.596	92.89	93.48	233.6071515
50	92.892	91.83	92.91	336.279072
55	92.65	92.3	92.19	450.7621658
60	92.168	91.52	91.31	483.8349526

Neural Network with varying Lambda and hidden units

Neural Network with Lambda =10 and varying hidden units

Hidden units	Training Time	Training Set Accuracy	Validation Set Accuracy	Test Set Accuracy
4	61.1409831	72.29	70.8	72.19
8	62.05872822	87.156	86.34	87.4
12	84.15759873	92.234	90.73	91.62
16	90.08823299	90.924	90.15	90.84
20	113.1393597	94.168	93.24	93.42

Neural Network with Lambda =20 and varying hidden units

Hidden units	Training Time	Training Set Accuracy	Validation Set Accuracy	Test Set Accuracy
4	64.52818394	77.644	76.23	77.75
8	71.41847444	89.458	88.73	89.33
12	79.83605528	90.128	90.07	89.95
16	87.4409349	91.094	90.55	90.95
20	105.9068024	93.464	92.81	93.09

Neural Network with Lambda =30 and varying hidden units

Hidden units	Training Time	Training Set Accuracy	Validation Set Accuracy	Test Set Accuracy
4	64.1635201	53.402	52.12	52.75
8	70.22066975	86.848	85.91	87.11
12	86.34434438	91.102	90.64	91.13
16	118.9557559	92.316	92.36	92

20	59.41443658	92.818	92.37	92.67

Neural Network with Lambda =40 and varying hidden units

Hidden units	Training Time	Training Set Accuracy	Validation Set Accuracy	Test Set Accuracy
4	90.50815964	65.506	64.37	64.45
8	112.2613876	88.106	87.04	87.74
12	76.4680655	90.422	89.76	90.35
16	83.48499346	90.904	89.97	90.87
20	86.52355123	91.674	90.83	91.47

Neural Network with Lambda =50 and varying hidden units

Hidden units	Training Time	Training Set Accuracy	Validation Set Accuracy	Test Set Accuracy
4	61.54487014	63.162	60.9	62.55
8	55.71366835	86.586	85.64	86.19
12	101.5844946	90.382	89.68	89.86
16	93.32682538	91.67	90.66	91.55
20	128.203063	91.548	91.28	91.5

Neural Network with Lambda =60 and varying hidden units

Hidden units	Training Time	Training Set Accuracy	Validation Set Accuracy	Test Set Accuracy
4	44.59376502	79.006	77.63	79.03
8	84.81847692	86.584	86.08	86.26
12	87.04651856	90.962	89.92	90.71
16	97.30121469	91.732	90.85	91.62
20	146.0134103	91.77	90.44	91.67