

## Question 5 (4 points): Learning With Restarts

### Pen Data Accuracy:

Max	Average	Standard Deviation
0.9033733562035449	0.899199542595769	0.005556920212609628

### Car Data Accuracy:

Max	Average	Standard Deviation
0.985	0.977	0.006782329983125274

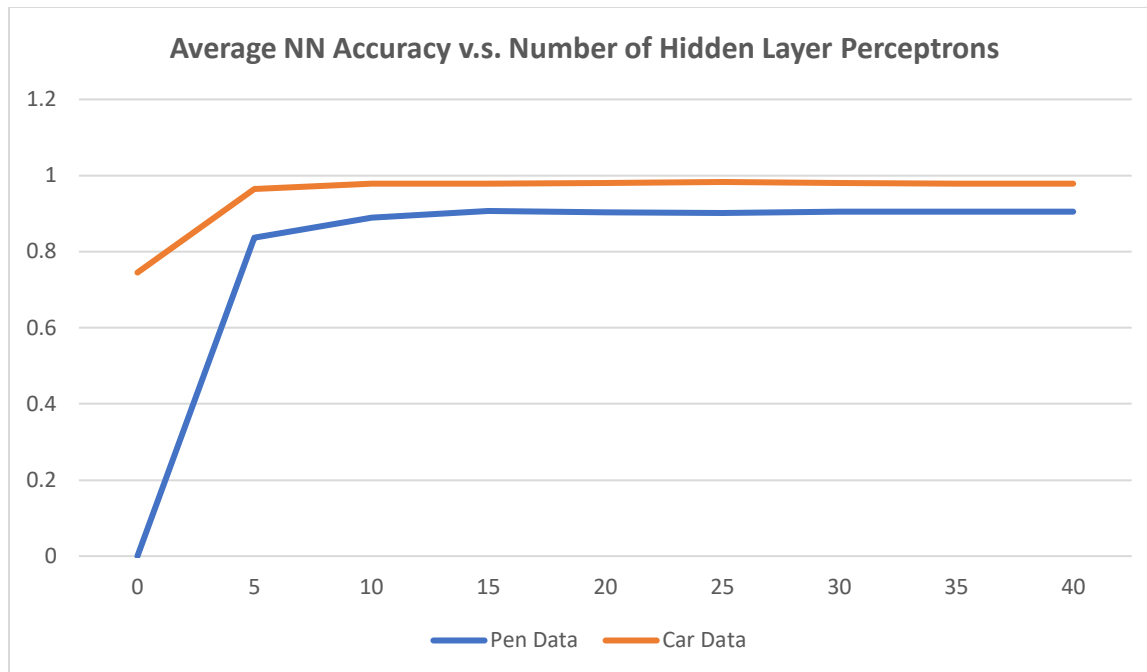
## Question 6 (4 points): Varying The Hidden Layer

### Pen Data Accuracy:

# of perceptron	Average	Max	Standard Deviation
0	0.0	0.0	0.0
5	0.8360205831903945	0.8487707261292167	0.009461815873226587
10	0.8886792452830189	0.89937106918239	0.009243357519936529
15	0.9068610634648371	0.9442538593481989	0.020111974833727224
20	0.9025157232704402	0.9105202973127502	0.007313105525589252
25	0.9018867924528301	0.907661520869068	0.00610306925374176
30	0.9049170954831333	0.9073756432246999	0.0021590860592909373
35	0.9053173241852488	0.9073756432246999	0.001975660668172796
40	0.9044596912521442	0.9056603773584906	0.0009635391392997614

### Car Data Accuracy:

# of perceptron	Average	Max	Standard Deviation
0	0.745	0.745	0.0
5	0.9640000000000001	0.975	0.009165151389911688
10	0.978	0.995	0.012083045973594584
15	0.9789999999999999	0.985	0.0037416573867739447
20	0.9810000000000001	0.99	0.007348469228349541
25	0.9829999999999999	0.99	0.00509901951359279
30	0.9800000000000001	0.995	0.011832159566199244
35	0.9789999999999999	0.98	0.002000000000000018
40	0.978	0.985	0.007483314773547889



As we can see in the chart, the neuro network accuracy for both datasets starts to increase when the number of perceptrons in the hidden layer increases. While the accuracy of the NN trained on both datasets significantly increases from 0 perceptrons to 5 perceptrons, the accuracy only slightly increases after having 5 perceptrons to more and eventually fluctuates as the number of perceptrons continues to increase. It is also worth noting that the NN trained on Pen data does not perform when there is zero hidden layer perceptron, while the NN trained on Car data does perform acceptably well when there is zero hidden layer perceptron.

### Question 7 (2 points Extra Credit): Learning XOR

When I tried to run the NN with 0 hidden layers the training error and weight change basically does not change, as expected, but the final average accuracy over 5 rounds of training was 0.4 which is greater than 0. Then I ran the NN with weight change threshold = 0.0001 and max iteration = 2000 and the number of hidden layer perceptrons increasing starting from 1 until the average accuracy become 1.0, the result is quite as expected: the average accuracy increases when we add more hidden layer perceptrons.

Number of hidden layer perceptrons	Average accuracy
1	0.500000
2	0.650000
3	0.600000
4	0.600000
5	0.750000

6	0.750000
7	0.800000
8	0.900000
9	0.900000
10	0.850000
11	0.950000
12	1.000000

When I went ahead to increase the max number of perceptrons to a large number, in this case 50, I can observe the average accuracy increases rather steadily and stays to be 1.0 when the number of perceptrons is above 15 (I will not include the results after running 50 times to avoid being lengthy.)