CS 3600 Project 4b Analysis
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Question 5: Learning With Restart

Table 1. Results of Random Restart

Dataset	Average of Accuracy	Max of Accuracy	Std of Accuracy
Pen	0.9038	0.9117	0.0087
Cars	0.8501	0.8704	0.0129

Question 6: Varying The Hidden Layer

Table 2. Results of Varying Hidden Layer

| Number of Neurons	Pen-Avg	Pen-Max	Pen-Std	Car-Avg	Car-Max	Car-Std
0	0	0	0	0.7022	0.7022	0.0000
5	0.8573	0.8759	0.0113	0.8623	0.8894	0.0198
10	0.8815	0.8868	0.0046	0.8843	0.8966	0.0095
15	0.9059	0.9102	0.0046	0.8668	0.8802	0.0095
20	0.8991	0.9111	0.0105	0.8695	0.9103	0.0228
25	0.9046	0.9071	0.0026	0.8619	0.8914	0.0152
30	0.9041	0.9082	0.0027	0.8649	0.8848	0.0127
35	0.9030	0.9082	0.0072	0.8541	0.8717	0.0136
40	0.9013	0.9028	0.0013	0.8487	0.8619	0.0072
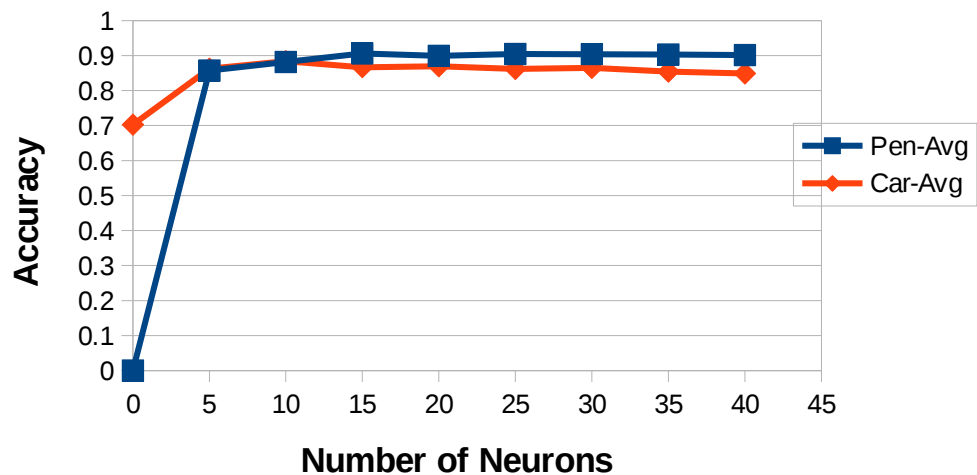
Figure 1. Trends Related to increasing number of neurons

Answer:
As number of neurons increasing, average accuracies of both datasets have a rapid increase when number of neurons is 5. After that, both accuracies have a slight increase along with the increasing of number of neurons. Ultimately, both accuracies remain unchanged and reach a plateau.
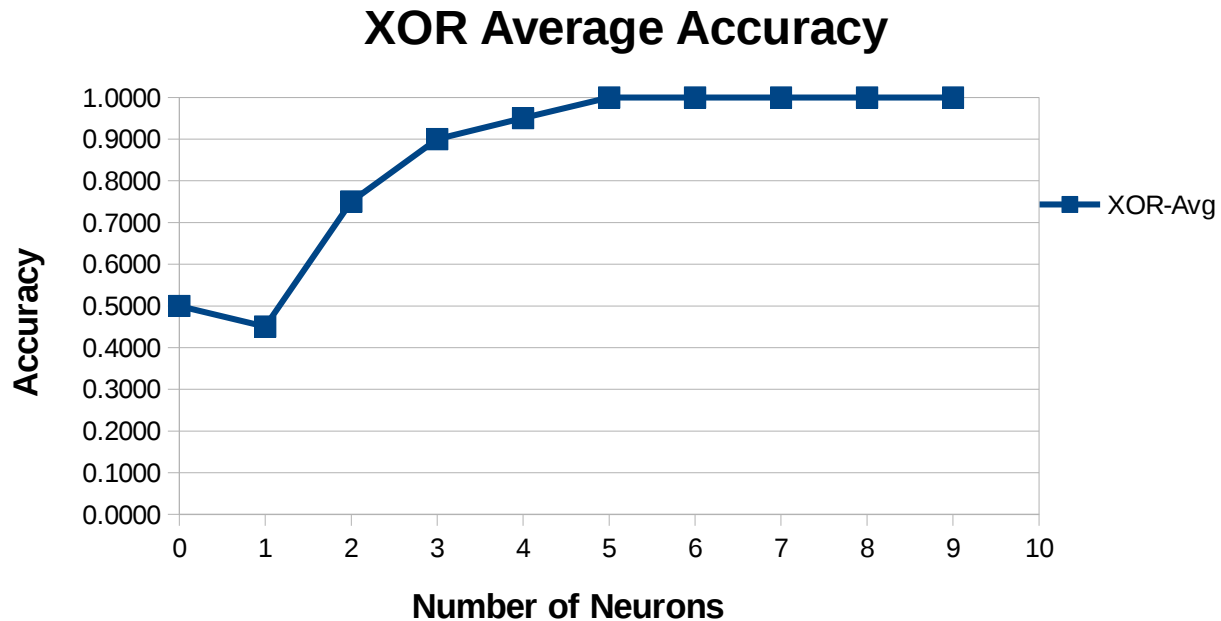
Question 7: Learning XOR

Figure 2. Relation between Accuracy and Number of Neurons in XOR dataset
* Note: maximum iteration is set to 500.

Answer:
According to Figure 2, we can easily conclude that:
(1) When there is no neurons in the hidden layer, the average accuracy is 50%. Accuracy trend grows gradually along with the number of neurons increasing. Ultimately, average accuracy reaches 100% and remains unchanged.
(2) There is a trade off between number of neurons and number of maximum iterations. I used to set maximum iteration as default, but this will easily lead to a local optimal. Therefore, with a higher maximum iteration, the algorithm can comes out a more reasonable result faster with less number of neurons.
(3) This trend meets my expectation, because as the number of neurons increases, neural network can perform nonlinear classification to the dataset and it can classify the nonlinear XOR dataset more accurately. Otherwise, there will be linear classification if there is no hidden layer, and accuracy will be 50% just like the first point shows.

Question 8: Novel Dataset

Table 3. Results of Random Restart

Dataset	Average of Accuracy	Max of Accuracy	Std of Accuracy
Nursery	0.9645	0.9681	0.0025

*Note: Training set size: 2500, testing set size: 10460; 15 neurons in a hidden layer.

Appendix:
Question 5 Raw Output:
(1) Car dataset result:
Starting training at time 23:11:25.973360 with 21 inputs, 4 outputs, [10] hidden layers, size of training set 200, and size of test set 1528
Finished after 200 iterations at time 23:11:46.322942 with training error 0.005171 and weight change 0.000000
Feed Forward Test correctly classified 1343, incorrectly classified 185, test percent error 12.107330

Starting training at time 23:11:46.525276 with 21 inputs, 4 outputs, [10] hidden layers, size of training set 200, and size of test set 1528
Finished after 200 iterations at time 23:12:13.441703 with training error 0.004843 and weight change 0.000000
Feed Forward Test correctly classified 1336, incorrectly classified 192, test percent error 12.565445

Starting training at time 23:12:13.786070 with 21 inputs, 4 outputs, [10] hidden layers, size of training set 200, and size of test set 1528
Finished after 200 iterations at time 23:12:46.598273 with training error 0.004116 and weight change 0.000000
Feed Forward Test correctly classified 1343, incorrectly classified 185, test percent error 12.107330

Starting training at time 23:12:46.945580 with 21 inputs, 4 outputs, [10] hidden layers, size of training set 200, and size of test set 1528
Finished after 200 iterations at time 23:13:19.187645 with training error 0.005708 and weight change 0.000000
Feed Forward Test correctly classified 1332, incorrectly classified 196, test percent error 12.827225

Starting training at time 23:13:19.549192 with 21 inputs, 4 outputs, [10] hidden layers, size of training set 200, and size of test set 1528
Finished after 200 iterations at time 23:13:52.249817 with training error 0.003780 and weight change 0.000000
Feed Forward Test correctly classified 1351, incorrectly classified 177, test percent error 11.583770

(2) Pen dataset result:
Starting training at time 23:17:14.080217 with 16 inputs, 10 outputs, [24] hidden layers, size of training set 7494, and size of test set 3498
Finished after 58 iterations at time 23:26:31.607868 with training error 0.003059 and weight change 0.000000
Feed Forward Test correctly classified 3102, incorrectly classified 396, test percent error 11.320755

Starting training at time 23:26:32.464969 with 16 inputs, 10 outputs, [24] hidden layers, size of training set 7494, and size of test set 3498
Finished after 82 iterations at time 23:35:31.371308 with training error 0.002659 and weight change 0.000000
Feed Forward Test correctly classified 3169, incorrectly classified 329, test percent error 9.405374

Starting training at time 23:35:32.162332 with 16 inputs, 10 outputs, [24] hidden layers, size of training set 7494, and size of test set 3498

Finished after 66 iterations at time 23:42:31.372954 with training error 0.002827 and weight change 0.000000
Feed Forward Test correctly classified 3175, incorrectly classified 323, test percent error 9.233848

Starting training at time 23:42:32.147292 with 16 inputs, 10 outputs, [24] hidden layers, size of training set 7494, and size of test set 3498
Finished after 69 iterations at time 23:49:15.500853 with training error 0.002632 and weight change 0.000000
Feed Forward Test correctly classified 3172, incorrectly classified 326, test percent error 9.319611

Starting training at time 23:49:16.182353 with 16 inputs, 10 outputs, [24] hidden layers, size of training set 7494, and size of test set 3498
Finished after 70 iterations at time 23:56:16.655337 with training error 0.002633 and weight change 0.000000
Feed Forward Test correctly classified 3189, incorrectly classified 309, test percent error 8.833619

Question 8 Raw Output:
Extra dataset result:
Starting training at time 22:52:44.694619 with 27 inputs, 5 outputs, [15] hidden layers, size of training set 2500, and size of test set 10460
Finished after 66 iterations at time 22:54:07.883711 with training error 0.003293 and weight change 0.000000
Feed Forward Test correctly classified 10049, incorrectly classified 411, test percent error 3.929254

Starting training at time 22:54:08.973429 with 27 inputs, 5 outputs, [15] hidden layers, size of training set 2500, and size of test set 10460
Finished after 64 iterations at time 22:55:32.870480 with training error 0.003443 and weight change 0.000000
Feed Forward Test correctly classified 10093, incorrectly classified 367, test percent error 3.508604

Starting training at time 22:55:34.518837 with 27 inputs, 5 outputs, [15] hidden layers, size of training set 2500, and size of test set 10460
Finished after 69 iterations at time 22:57:22.462992 with training error 0.003523 and weight change 0.000000
Feed Forward Test correctly classified 10075, incorrectly classified 385, test percent error 3.680688

Starting training at time 22:57:24.161340 with 27 inputs, 5 outputs, [15] hidden layers, size of training set 2500, and size of test set 10460
Finished after 53 iterations at time 22:58:47.652710 with training error 0.003398 and weight change 0.000000
Feed Forward Test correctly classified 10126, incorrectly classified 334, test percent error 3.193117

Starting training at time 22:58:49.277120 with 27 inputs, 5 outputs, [15] hidden layers, size of training set 2500, and size of test set 10460
Finished after 66 iterations at time 23:00:33.917866 with training error 0.003333 and weight change 0.000000
Feed Forward Test correctly classified 10102, incorrectly classified 358, test percent error 3.422562