Homework 2: Perceptron Learning

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The following is an analysis of the results of using a perceptron classifier written in google Dart on the optdigits dataset located at http://ftp.ics.uci.edu/pub/machine-learning-databases/optdigits/.

1 Setup

The source code for this program was written in Dart, and can be found on my github account at https://github.com/arik181/perceptron_classifier. In order to run this experiment, you will have to have the latest version of Google Dart installed (Release M4 or above).
The simplest way to run the experiment is as follows:

1. Download and install the Dart Editor at http://www.dartlang.org/tools for Windows or Linux.

2. Retrieve the source code from https://github.com/arik181/perceptron_classifier

3. In the Dart Editor, go to file → open existing folder (or type Ctrl-O)

4. Navigate to the source directory

5. Click the Run button (or type Ctrl-R)

The output from the classifier will appear in the console window.

2 Overview

Experiment 1

Training Statistics		Test Statistics	
Learning rate	0.2	Learning rate	0.2
Training runs	20	Training runs	20
Total successes	8520	Total successes	16387
Total failures	480	Total failures	1019
Precision	98%	Precision	97%
Recall	92%	Recall	92%
Accuracy	94%	Accuracy	94%

	Training Confusion Matrix									
	0	1	2	3	4	5	6	7	8	9
0	X	8	4	0	2	0	6	0	0	0
1	0	X	6	0	0	0	4	0	0	0
2	0	16	X	0	0	0	0	4	0	6
3	0	122	28	X	2	4	2	34	12	28
4	0	66	0	0	X	0	6	16	2	4
5	4	82	20	6	0	X	4	12	4	24
6	0	2	0	0	0	0	X	0	0	0
7	0	4	0	0	0	0	0	X	0	0
8	0	152	18	0	10	2	30	32	X	16
9	0	110	4	0	8	2	0	30	2	X

	Test Confusion Matrix									
	0	1	2	3	4	5	6	7	8	9
0	X	14	4	0	5	0	12	1	1	2
1	0	X	6	0	0	0	7	2	0	0
2	0	27	X	0	0	0	1	8	1	7
3	0	182	36	X	2	4	2	55	16	39
4	0	108	6	2	X	6	10	38	12	12
5	4	129	26	8	1	X	9	26	7	34
6	0	4	1	0	0	0	X	0	0	0
7	0	4	0	0	0	0	0	X	0	0
8	0	226	27	1	12	4	37	58	X	19
9	0	155	6	1	11	3	0	53	5	X

Experiment 2

Training Statistics		Test Statistics	
Learning rate	0.8	Learning rate	0.8
Training runs	20	Training runs	20
Total successes	8520	Total successes	16387
Total failures	480	Total failures	1019
Precision	98%	Precision	97%
Recall	92%	Recall	92%
Accuracy	94%	Accuracy	94%

	Training Confusion Matrix									
	0	1	2	3	4	5	6	7	8	9
0	X	8	4	0	2	0	6	0	0	0
1	0	X	6	0	0	0	4	0	0	0
2	0	16	X	0	0	0	0	4	0	6
3	0	122	28	X	2	4	2	34	12	28
4	0	66	0	0	X	0	6	16	2	4
5	4	82	20	6	0	X	4	12	4	24
6	0	2	0	0	0	0	X	0	0	0
7	0	4	0	0	0	0	0	X	0	0
8	0	152	18	0	10	2	30	32	X	16
9	0	110	4	0	8	2	0	30	2	X

	Test Confusion Matrix									
	0	1	2	3	4	5	6	7	8	9
0	X	14	4	0	5	0	12	1	1	2
1	0	X	6	0	0	0	7	2	0	0
2	0	27	X	0	0	0	1	8	1	7
3	0	182	36	X	2	4	2	55	16	39
4	0	108	6	2	X	6	10	38	12	12
5	4	129	26	8	1	X	9	26	7	34
6	0	4	1	0	0	0	X	0	0	0
7	0	4	0	0	0	0	0	X	0	0
8	0	226	27	1	12	4	37	58	X	19
9	0	155	6	1	11	3	0	53	5	X

Experiment 3

Training Statistics		Test Statistics	
Learning rate	0.05	Learning rate	0.05
Training runs	20	Training runs	20
Total successes	8519	Total successes	16385
Total failures	481	Total failures	1021
Precision	98%	Precision	97%
Recall	92%	Recall	92%
Accuracy	94%	Accuracy	94%

	Training Confusion Matrix									
	0	1	2	3	4	5	6	7	8	9
0	X	8	4	0	2	0	6	0	0	0
1	0	X	6	0	0	0	4	0	0	0
2	0	16	X	0	0	0	0	4	0	6
3	0	122	28	X	2	4	2	34	12	28
4	0	66	0	0	X	0	6	16	2	4
5	4	82	20	6	0	X	4	12	4	24
6	0	2	0	0	0	0	X	0	0	0
7	0	4	0	0	0	0	0	X	0	0
8	0	152	18	0	10	2	30	32	X	16
9	0	112	4	0	8	2	0	30	2	X

	Test Confusion Matrix									
	0	1	2	3	4	5	6	7	8	9
0	X	14	4	0	5	0	12	1	1	2
1	0	X	6	0	0	0	7	2	0	0
2	0	27	X	0	0	0	1	8	1	7
3	0	182	36	X	2	4	2	55	16	39
4	0	108	6	2	X	6	10	38	12	12
5	4	129	26	8	1	X	9	26	7	34
6	0	4	1	0	0	0	X	0	0	0
7	0	4	0	0	0	0	0	X	0	0
8	0	227	27	1	12	4	37	58	X	19
9	0	157	6	1	11	3	0	53	5	X

3   Summary

The three experiments produced very similar results. The first experiment produced identical results from the second experiment. I believe that this is due to the fact that I used the same number of training epochs across all perceptrons for all three experiments. It is possible that if I had allowed the experiments to run for much longer periods of time, there would be more of a divergence. There is some variation in the confusion matrix for the third experiment, with a slightly higher number of false classifications. There is also variation between the test runs and the training runs in each experiment, with the test runs containing a slightly higher failure rate overall, as expected.

The number 1 was the most commonly misclassified digit by a considerable margin, having the highest number of false negatives, but very few false positives, it seems to have been mistaken for other numbers quite regularly, and these errors accounted for 1075 of the 1377 false negatives over the test data in experiment two, or approximately 78%. The other experiments resulted in very similar classification errors on this digit.

4   Classifier Output - Experiment 1

```
start
reading files
creating perceptron classifiers
training classifiers
reporting training data
-----------------------------------------------
Learning rate          : 0.2
Training runs          : 20
Total successes        : 8520
Total failures         : 480
Precision              : 0.98%
Recall                 : 0.92%
Accuracy               : 0.94%

-----------------------------------------------
      0    1    2    3    4    5    6    7    8    9

-----------------------------------------------
0 |   X    8    4    0    2    0    6    0    0    0

1 |   0    X    6    0    0    0    4    0    0    0

2 |   0   16    X    0    0    0    0    4    0    6

3 |   0  122   28    X    2    4    2   34   12   28

4 |   0   66    0    0    X    0    6   16    2    4
```

```
5 |    4  82  20   6   0   X   4  12   4  24

6 |    0   2   0   0   0   0   X   0   0   0

7 |    0   4   0   0   0   0   0   X   0   0

8 |    0 152  18   0  10   2  30  32   X  16

9 |    0 110   4   0   8   2   0  30   2   X
```

----
running classifiers

(0, 1)
Successes   : 180
Failures   : 6
False Positives : 6
False Negatives : 0

Learning rate   : 0.2
Training runs   : 20
Total successes   : 180
Total failures   : 6
Precision   : 0.94%
Recall   : 1.0%
Accuracy   : 0.97%

(0, 2)
Successes   : 189
Failures   : 0
False Positives : 0
False Negatives : 0

Learning rate   : 0.2
Training runs   : 20
Total successes   : 189
Total failures   : 0
Precision   : 1.0%
Recall   : 1.0%
Accuracy   : 1.0%

(0, 3)
Successes   : 200

```
Failures        : 0
False Positives : 0
False Negatives : 0

------------------------------
Learning rate        : 0.2
Training runs        : 20
Total successes      : 200
Total failures       : 0
Precision            : 1.0%
Recall               : 1.0%
Accuracy             : 1.0%
---------------------------------------------

---------------------------------------------
( 0, 4 )
Successes       : 176
Failures        : 3
False Positives : 3
False Negatives : 0

------------------------------
Learning rate        : 0.2
Training runs        : 20
Total successes      : 176
Total failures       : 3
Precision            : 0.97%
Recall               : 1.0%
Accuracy             : 0.98%
---------------------------------------------

---------------------------------------------
( 0, 5 )
Successes       : 183
Failures        : 0
False Positives : 0
False Negatives : 0

------------------------------
Learning rate        : 0.2
Training runs        : 20
Total successes      : 183
Total failures       : 0
Precision            : 1.0%
Recall               : 1.0%
Accuracy             : 1.0%
---------------------------------------------

---------------------------------------------
( 0, 6 )
Successes       : 180
```

```
Failures        : 6
False Positives : 6
False Negatives : 0

------------------------------
Learning rate         : 0.2
Training runs         : 20
Total successes       : 180
Total failures        : 6
Precision             : 0.94%
Recall                : 1.0%
Accuracy              : 0.97%
---------------------------------------------
---------------------------------------------
( 0, 7 )
Successes       : 188
Failures        : 1
False Positives : 1
False Negatives : 0

------------------------------
Learning rate         : 0.2
Training runs         : 20
Total successes       : 188
Total failures        : 1
Precision             : 0.99%
Recall                : 1.0%
Accuracy              : 0.99%
---------------------------------------------
---------------------------------------------
( 0, 8 )
Successes       : 182
Failures        : 1
False Positives : 1
False Negatives : 0

------------------------------
Learning rate         : 0.2
Training runs         : 20
Total successes       : 182
Total failures        : 1
Precision             : 0.99%
Recall                : 1.0%
Accuracy              : 0.99%
---------------------------------------------
---------------------------------------------
( 0, 9 )
Successes       : 197
```

```
Failures        : 2
False Positives : 2
False Negatives : 0

-------------------------------
Learning rate         : 0.2
Training runs         : 20
Total successes       : 197
Total failures        : 2
Precision             : 0.98%
Recall                : 1.0%
Accuracy              : 0.99%
---------------------------------------------
---------------------------------------------
( 1, 2 )
Successes       : 174
Failures        : 11
False Positives : 0
False Negatives : 11

-------------------------------
Learning rate         : 0.2
Training runs         : 20
Total successes       : 174
Total failures        : 11
Precision             : 1.0%
Recall                : 0.89%
Accuracy              : 0.94%
---------------------------------------------
---------------------------------------------
( 1, 3 )
Successes       : 136
Failures        : 60
False Positives : 0
False Negatives : 60

-------------------------------
Learning rate         : 0.2
Training runs         : 20
Total successes       : 136
Total failures        : 60
Precision             : 1.0%
Recall                : 0.60%
Accuracy              : 0.56%
---------------------------------------------
---------------------------------------------
( 1, 4 )
Successes       : 133
```

```
Failures        : 42
False Positives : 0
False Negatives : 42

------------------------------
Learning rate        : 0.2
Training runs        : 20
Total successes      : 133
Total failures       : 42
Precision            : 1.0%
Recall               : 0.68%
Accuracy             : 0.68%
----------------------------------------------
----------------------------------------------
( 1, 5 )
Successes       : 132
Failures        : 47
False Positives : 0
False Negatives : 47

------------------------------
Learning rate        : 0.2
Training runs        : 20
Total successes      : 132
Total failures       : 47
Precision            : 1.0%
Recall               : 0.66%
Accuracy             : 0.64%
----------------------------------------------
----------------------------------------------
( 1, 6 )
Successes       : 177
Failures        : 5
False Positives : 3
False Negatives : 2

------------------------------
Learning rate        : 0.2
Training runs        : 20
Total successes      : 177
Total failures       : 5
Precision            : 0.97%
Recall               : 0.98%
Accuracy             : 0.97%
----------------------------------------------
----------------------------------------------
( 1, 7 )
Successes       : 183
```

```
Failures        : 2
False Positives : 2
False Negatives : 0

------------------------------
Learning rate        : 0.2
Training runs        : 20
Total successes      : 183
Total failures       : 2
Precision            : 0.98%
Recall               : 1.0%
Accuracy             : 0.99%
---------------------------------------------
---------------------------------------------
( 1, 8 )
Successes       : 105
Failures        : 74
False Positives : 0
False Negatives : 74

------------------------------
Learning rate        : 0.2
Training runs        : 20
Total successes      : 105
Total failures       : 74
Precision            : 1.0%
Recall               : 0.55%
Accuracy             : 0.30%
---------------------------------------------
---------------------------------------------
( 1, 9 )
Successes       : 150
Failures        : 45
False Positives : 0
False Negatives : 45

------------------------------
Learning rate        : 0.2
Training runs        : 20
Total successes      : 150
Total failures       : 45
Precision            : 1.0%
Recall               : 0.67%
Accuracy             : 0.70%
---------------------------------------------
---------------------------------------------
( 2, 3 )
Successes       : 191
```

```
Failures        : 8
False Positives : 0
False Negatives : 8

------------------------------
Learning rate        : 0.2
Training runs        : 20
Total successes      : 191
Total failures       : 8
Precision            : 1.0%
Recall               : 0.92%
Accuracy             : 0.96%
---------------------------------------------
---------------------------------------------
( 2, 4 )
Successes       : 172
Failures        : 6
False Positives : 0
False Negatives : 6

------------------------------
Learning rate        : 0.2
Training runs        : 20
Total successes      : 172
Total failures       : 6
Precision            : 1.0%
Recall               : 0.94%
Accuracy             : 0.97%
---------------------------------------------
---------------------------------------------
( 2, 5 )
Successes       : 176
Failures        : 6
False Positives : 0
False Negatives : 6

------------------------------
Learning rate        : 0.2
Training runs        : 20
Total successes      : 176
Total failures       : 6
Precision            : 1.0%
Recall               : 0.94%
Accuracy             : 0.97%
---------------------------------------------
---------------------------------------------
( 2, 6 )
Successes       : 183
```

```
Failures        : 2
False Positives : 1
False Negatives : 1
------------------------------
Learning rate        : 0.2
Training runs        : 20
Total successes      : 183
Total failures       : 2
Precision            : 0.99%
Recall               : 0.99%
Accuracy             : 0.99%
---------------------------------------------
---------------------------------------------
( 2, 7 )
Successes       : 184
Failures        : 4
False Positives : 4
False Negatives : 0
------------------------------
Learning rate        : 0.2
Training runs        : 20
Total successes      : 184
Total failures       : 4
Precision            : 0.96%
Recall               : 1.0%
Accuracy             : 0.98%
---------------------------------------------
---------------------------------------------
( 2, 8 )
Successes       : 172
Failures        : 10
False Positives : 1
False Negatives : 9
------------------------------
Learning rate        : 0.2
Training runs        : 20
Total successes      : 172
Total failures       : 10
Precision            : 0.99%
Recall               : 0.91%
Accuracy             : 0.94%
---------------------------------------------
---------------------------------------------
( 2, 9 )
Successes       : 195
```

```
Failures        : 3
False Positives : 1
False Negatives : 2

------------------------------
Learning rate         : 0.2
Training runs         : 20
Total successes       : 195
Total failures        : 3
Precision             : 0.99%
Recall                : 0.98%
Accuracy              : 0.98%
---------------------------------------------
---------------------------------------------
( 3, 4 )
Successes       : 187
Failures        : 2
False Positives : 0
False Negatives : 2

------------------------------
Learning rate         : 0.2
Training runs         : 20
Total successes       : 187
Total failures        : 2
Precision             : 1.0%
Recall                : 0.98%
Accuracy              : 0.99%
---------------------------------------------
---------------------------------------------
( 3, 5 )
Successes       : 191
Failures        : 2
False Positives : 0
False Negatives : 2

------------------------------
Learning rate         : 0.2
Training runs         : 20
Total successes       : 191
Total failures        : 2
Precision             : 1.0%
Recall                : 0.98%
Accuracy              : 0.99%
---------------------------------------------
---------------------------------------------
( 3, 6 )
Successes       : 196
```

```
Failures        : 0
False Positives : 0
False Negatives : 0

------------------------------
Learning rate       : 0.2
Training runs       : 20
Total successes     : 196
Total failures      : 0
Precision           : 1.0%
Recall              : 1.0%
Accuracy            : 1.0%
--------------------------------------------

--------------------------------------------
( 3, 7 )
Successes       : 178
Failures        : 21
False Positives : 21
False Negatives : 0

------------------------------
Learning rate       : 0.2
Training runs       : 20
Total successes     : 178
Total failures      : 21
Precision           : 0.80%
Recall              : 1.0%
Accuracy            : 0.88%
--------------------------------------------

--------------------------------------------
( 3, 8 )
Successes       : 188
Failures        : 5
False Positives : 4
False Negatives : 1

------------------------------
Learning rate       : 0.2
Training runs       : 20
Total successes     : 188
Total failures      : 5
Precision           : 0.96%
Recall              : 0.99%
Accuracy            : 0.97%
--------------------------------------------

--------------------------------------------
( 3, 9 )
Successes       : 197
```

```
Failures         : 12
False Positives : 11
False Negatives : 1

------------------------------
Learning rate          : 0.2
Training runs          : 20
Total successes        : 197
Total failures         : 12
Precision              : 0.90%
Recall                 : 0.99%
Accuracy               : 0.94%
---------------------------------------------
---------------------------------------------
( 4, 5 )
Successes       : 165
Failures         : 7
False Positives : 6
False Negatives : 1

------------------------------
Learning rate          : 0.2
Training runs          : 20
Total successes        : 165
Total failures         : 7
Precision              : 0.93%
Recall                 : 0.99%
Accuracy               : 0.96%
---------------------------------------------
---------------------------------------------
( 4, 6 )
Successes       : 171
Failures         : 4
False Positives : 4
False Negatives : 0

------------------------------
Learning rate          : 0.2
Training runs          : 20
Total successes        : 171
Total failures         : 4
Precision              : 0.95%
Recall                 : 1.0%
Accuracy               : 0.98%
---------------------------------------------
---------------------------------------------
( 4, 7 )
Successes       : 156
```

```
Failures        : 22
False Positives : 22
False Negatives : 0

------------------------------
Learning rate         : 0.2
Training runs         : 20
Total successes       : 156
Total failures        : 22
Precision             : 0.74%
Recall                : 1.0%
Accuracy              : 0.86%
---------------------------------------------
---------------------------------------------
( 4, 8 )
Successes       : 160
Failures        : 12
False Positives : 10
False Negatives : 2

------------------------------
Learning rate         : 0.2
Training runs         : 20
Total successes       : 160
Total failures        : 12
Precision             : 0.88%
Recall                : 0.97%
Accuracy              : 0.93%
---------------------------------------------
---------------------------------------------
( 4, 9 )
Successes       : 177
Failures        : 11
False Positives : 8
False Negatives : 3

------------------------------
Learning rate         : 0.2
Training runs         : 20
Total successes       : 177
Total failures        : 11
Precision             : 0.90%
Recall                : 0.96%
Accuracy              : 0.94%
---------------------------------------------
---------------------------------------------
( 5, 6 )
Successes       : 174
```

```
Failures        : 5
False Positives : 5
False Negatives : 0

------------------------------
Learning rate        : 0.2
Training runs        : 20
Total successes      : 174
Total failures       : 5
Precision            : 0.94%
Recall               : 1.0%
Accuracy             : 0.97%
------------------------------------------

------------------------------------------
( 5, 7 )
Successes       : 168
Failures        : 14
False Positives : 14
False Negatives : 0

------------------------------
Learning rate        : 0.2
Training runs        : 20
Total successes      : 168
Total failures       : 14
Precision            : 0.84%
Recall               : 1.0%
Accuracy             : 0.92%
------------------------------------------

------------------------------------------
( 5, 8 )
Successes       : 171
Failures        : 5
False Positives : 3
False Negatives : 2

------------------------------
Learning rate        : 0.2
Training runs        : 20
Total successes      : 171
Total failures       : 5
Precision            : 0.97%
Recall               : 0.98%
Accuracy             : 0.97%
------------------------------------------

------------------------------------------
( 5, 9 )
Successes       : 181
```

```
Failures         : 11
False Positives : 10
False Negatives : 1

------------------------------
Learning rate        : 0.2
Training runs        : 20
Total successes      : 181
Total failures       : 11
Precision            : 0.89%
Recall               : 0.99%
Accuracy             : 0.94%
----------------------------------------------

----------------------------------------------
( 6, 7 )
Successes       : 185
Failures        : 0
False Positives : 0
False Negatives : 0

------------------------------
Learning rate        : 0.2
Training runs        : 20
Total successes      : 185
Total failures       : 0
Precision            : 1.0%
Recall               : 1.0%
Accuracy             : 1.0%
----------------------------------------------

----------------------------------------------
( 6, 8 )
Successes       : 172
Failures        : 7
False Positives : 0
False Negatives : 7

------------------------------
Learning rate        : 0.2
Training runs        : 20
Total successes      : 172
Total failures       : 7
Precision            : 1.0%
Recall               : 0.93%
Accuracy             : 0.96%
----------------------------------------------

----------------------------------------------
( 6, 9 )
Successes       : 195
```

```
Failures        : 0
False Positives : 0
False Negatives : 0

-------------------------------
Learning rate       : 0.2
Training runs       : 20
Total successes     : 195
Total failures      : 0
Precision           : 1.0%
Recall              : 1.0%
Accuracy            : 1.0%
---------------------------------------------
---------------------------------------------
( 7, 8 )
Successes       : 156
Failures        : 26
False Positives : 0
False Negatives : 26

-------------------------------
Learning rate       : 0.2
Training runs       : 20
Total successes     : 156
Total failures      : 26
Precision           : 1.0%
Recall              : 0.78%
Accuracy            : 0.83%
---------------------------------------------
---------------------------------------------
( 7, 9 )
Successes       : 175
Failures        : 23
False Positives : 0
False Negatives : 23

-------------------------------
Learning rate       : 0.2
Training runs       : 20
Total successes     : 175
Total failures      : 23
Precision           : 1.0%
Recall              : 0.80%
Accuracy            : 0.87%
---------------------------------------------
---------------------------------------------
( 8, 9 )
Successes       : 186
```

```
Failures        : 6
False Positives : 3
False Negatives : 3

-------------------------------
Learning rate         : 0.2
Training runs         : 20
Total successes       : 186
Total failures        : 6
Precision             : 0.97%
Recall                : 0.97%
Accuracy              : 0.97%
----------------------------------------------
reporting test data
----------------------------------------------
Learning rate         : 0.2
Training runs         : 20
Total successes       : 16387
Total failures        : 1019
Precision             : 0.97%
Recall                : 0.92%
Accuracy              : 0.94%

----------------------------------------------
       0    1    2    3    4    5    6    7    8    9

----------------------------------------------
0 |    X   14    4    0    5    0   12    1    1    2

1 |    0    X    6    0    0    0    7    2    0    0

2 |    0   27    X    0    0    0    1    8    1    7

3 |    0  182   36    X    2    4    2   55   16   39

4 |    0  108    6    2    X    6   10   38   12   12

5 |    4  129   26    8    1    X    9   26    7   34

6 |    0    4    1    0    0    0    X    0    0    0

7 |    0    4    0    0    0    0    0    X    0    0

8 |    0  226   27    1   12    4   37   58    X   19

9 |    0  155    6    1   11    3    0   53    5    X

----------------------------------------------
```

4.1 Classifier Output - Experiment 2

```
start
reading files
creating perceptron classifiers
training classifiers
reporting training data

------------------------------------------------
Learning rate          : 0.8
Training runs          : 20
Total successes        : 8520
Total failures         : 480
Precision              : 0.98%
Recall                 : 0.92%
Accuracy               : 0.94%

------------------------------------------------
      0    1    2    3    4    5    6    7    8    9

------------------------------------------------
0 |   X    8    4    0    2    0    6    0    0    0

1 |   0    X    6    0    0    0    4    0    0    0

2 |   0   16    X    0    0    0    0    4    0    6

3 |   0  122   28    X    2    4    2   34   12   28

4 |   0   66    0    0    X    0    6   16    2    4

5 |   4   82   20    6    0    X    4   12    4   24

6 |   0    2    0    0    0    0    X    0    0    0

7 |   0    4    0    0    0    0    0    X    0    0

8 |   0  152   18    0   10    2   30   32    X   16

9 |   0  110    4    0    8    2    0   30    2    X

------------------------------------------------
running classifiers
------------------------------------------------
( 0, 1 )
Successes        : 180
Failures         : 6
False Positives  : 6
False Negatives  : 0
```

```
------------------------------
Learning rate        : 0.8
Training runs        : 20
Total successes      : 180
Total failures       : 6
Precision            : 0.94%
Recall               : 1.0%
Accuracy             : 0.97%
----------------------------------------

----------------------------------------
( 0, 2 )
Successes       : 189
Failures        : 0
False Positives : 0
False Negatives : 0

------------------------------
Learning rate        : 0.8
Training runs        : 20
Total successes      : 189
Total failures       : 0
Precision            : 1.0%
Recall               : 1.0%
Accuracy             : 1.0%
----------------------------------------

----------------------------------------
( 0, 3 )
Successes       : 200
Failures        : 0
False Positives : 0
False Negatives : 0

------------------------------
Learning rate        : 0.8
Training runs        : 20
Total successes      : 200
Total failures       : 0
Precision            : 1.0%
Recall               : 1.0%
Accuracy             : 1.0%
----------------------------------------

----------------------------------------
( 0, 4 )
Successes       : 176
Failures        : 3
False Positives : 3
False Negatives : 0
```

```
------------------------------
Learning rate        : 0.8
Training runs        : 20
Total successes      : 176
Total failures       : 3
Precision            : 0.97%
Recall               : 1.0%
Accuracy             : 0.98%
---------------------------------------------

---------------------------------------------
( 0, 5 )
Successes      : 183
Failures       : 0
False Positives : 0
False Negatives : 0

------------------------------
Learning rate        : 0.8
Training runs        : 20
Total successes      : 183
Total failures       : 0
Precision            : 1.0%
Recall               : 1.0%
Accuracy             : 1.0%
---------------------------------------------

---------------------------------------------
( 0, 6 )
Successes      : 180
Failures       : 6
False Positives : 6
False Negatives : 0

------------------------------
Learning rate        : 0.8
Training runs        : 20
Total successes      : 180
Total failures       : 6
Precision            : 0.94%
Recall               : 1.0%
Accuracy             : 0.97%
---------------------------------------------

---------------------------------------------
( 0, 7 )
Successes      : 188
Failures       : 1
False Positives : 1
False Negatives : 0
```

```
------------------------------
Learning rate          : 0.8
Training runs          : 20
Total successes        : 188
Total failures         : 1
Precision              : 0.99%
Recall                 : 1.0%
Accuracy               : 0.99%
---------------------------------------------
---------------------------------------------
( 0, 8 )
Successes        : 182
Failures         : 1
False Positives : 1
False Negatives : 0

------------------------------
Learning rate          : 0.8
Training runs          : 20
Total successes        : 182
Total failures         : 1
Precision              : 0.99%
Recall                 : 1.0%
Accuracy               : 0.99%
---------------------------------------------
---------------------------------------------
( 0, 9 )
Successes        : 197
Failures         : 2
False Positives : 2
False Negatives : 0

------------------------------
Learning rate          : 0.8
Training runs          : 20
Total successes        : 197
Total failures         : 2
Precision              : 0.98%
Recall                 : 1.0%
Accuracy               : 0.99%
---------------------------------------------
---------------------------------------------
( 1, 2 )
Successes        : 174
Failures         : 11
False Positives : 0
False Negatives : 11
```

```
------------------------------
Learning rate          : 0.8
Training runs          : 20
Total successes        : 174
Total failures         : 11
Precision              : 1.0%
Recall                 : 0.89%
Accuracy               : 0.94%
-----------------------------------------

-----------------------------------------
( 1, 3 )
Successes       : 136
Failures        : 60
False Positives : 0
False Negatives : 60

------------------------------
Learning rate          : 0.8
Training runs          : 20
Total successes        : 136
Total failures         : 60
Precision              : 1.0%
Recall                 : 0.60%
Accuracy               : 0.56%
-----------------------------------------

-----------------------------------------
( 1, 4 )
Successes       : 133
Failures        : 42
False Positives : 0
False Negatives : 42

------------------------------
Learning rate          : 0.8
Training runs          : 20
Total successes        : 133
Total failures         : 42
Precision              : 1.0%
Recall                 : 0.68%
Accuracy               : 0.68%
-----------------------------------------

-----------------------------------------
( 1, 5 )
Successes       : 132
Failures        : 47
False Positives : 0
False Negatives : 47
```

```
--------------------------------
Learning rate         : 0.8
Training runs         : 20
Total successes       : 132
Total failures        : 47
Precision             : 1.0%
Recall                : 0.66%
Accuracy              : 0.64%
--------------------------------------------

--------------------------------------------
( 1, 6 )
Successes       : 177
Failures        : 5
False Positives : 3
False Negatives : 2

--------------------------------
Learning rate         : 0.8
Training runs         : 20
Total successes       : 177
Total failures        : 5
Precision             : 0.97%
Recall                : 0.98%
Accuracy              : 0.97%
--------------------------------------------

--------------------------------------------
( 1, 7 )
Successes       : 183
Failures        : 2
False Positives : 2
False Negatives : 0

--------------------------------
Learning rate         : 0.8
Training runs         : 20
Total successes       : 183
Total failures        : 2
Precision             : 0.98%
Recall                : 1.0%
Accuracy              : 0.99%
--------------------------------------------

--------------------------------------------
( 1, 8 )
Successes       : 105
Failures        : 74
False Positives : 0
False Negatives : 74
```

```
-------------------------------
Learning rate        : 0.8
Training runs        : 20
Total successes      : 105
Total failures       : 74
Precision            : 1.0%
Recall               : 0.55%
Accuracy             : 0.30%
-------------------------------------------
-------------------------------------------
( 1, 9 )
Successes       : 150
Failures        : 45
False Positives : 0
False Negatives : 45

-------------------------------
Learning rate        : 0.8
Training runs        : 20
Total successes      : 150
Total failures       : 45
Precision            : 1.0%
Recall               : 0.67%
Accuracy             : 0.70%
-------------------------------------------
-------------------------------------------
( 2, 3 )
Successes       : 191
Failures        : 8
False Positives : 0
False Negatives : 8

-------------------------------
Learning rate        : 0.8
Training runs        : 20
Total successes      : 191
Total failures       : 8
Precision            : 1.0%
Recall               : 0.92%
Accuracy             : 0.96%
-------------------------------------------
-------------------------------------------
( 2, 4 )
Successes       : 172
Failures        : 6
False Positives : 0
False Negatives : 6
```

```
------------------------------
Learning rate       : 0.8
Training runs       : 20
Total successes     : 172
Total failures      : 6
Precision           : 1.0%
Recall              : 0.94%
Accuracy            : 0.97%
--------------------------------------------
--------------------------------------------
( 2, 5 )
Successes       : 176
Failures        : 6
False Positives : 0
False Negatives : 6
------------------------------
Learning rate       : 0.8
Training runs       : 20
Total successes     : 176
Total failures      : 6
Precision           : 1.0%
Recall              : 0.94%
Accuracy            : 0.97%
--------------------------------------------
--------------------------------------------
( 2, 6 )
Successes       : 183
Failures        : 2
False Positives : 1
False Negatives : 1
------------------------------
Learning rate       : 0.8
Training runs       : 20
Total successes     : 183
Total failures      : 2
Precision           : 0.99%
Recall              : 0.99%
Accuracy            : 0.99%
--------------------------------------------
--------------------------------------------
( 2, 7 )
Successes       : 184
Failures        : 4
False Positives : 4
False Negatives : 0
```

```
--------------------------------
Learning rate       : 0.8
Training runs       : 20
Total successes     : 184
Total failures      : 4
Precision           : 0.96%
Recall              : 1.0%
Accuracy            : 0.98%
--------------------------------------------
--------------------------------------------
( 2, 8 )
Successes      : 172
Failures       : 10
False Positives : 1
False Negatives : 9

--------------------------------
Learning rate       : 0.8
Training runs       : 20
Total successes     : 172
Total failures      : 10
Precision           : 0.99%
Recall              : 0.91%
Accuracy            : 0.94%
--------------------------------------------
--------------------------------------------
( 2, 9 )
Successes      : 195
Failures       : 3
False Positives : 1
False Negatives : 2

--------------------------------
Learning rate       : 0.8
Training runs       : 20
Total successes     : 195
Total failures      : 3
Precision           : 0.99%
Recall              : 0.98%
Accuracy            : 0.98%
--------------------------------------------
--------------------------------------------
( 3, 4 )
Successes      : 187
Failures       : 2
False Positives : 0
False Negatives : 2
```

```
------------------------------
Learning rate        : 0.8
Training runs        : 20
Total successes      : 187
Total failures       : 2
Precision            : 1.0%
Recall               : 0.98%
Accuracy             : 0.99%
---------------------------------------------

---------------------------------------------
( 3, 5 )
Successes        : 191
Failures         : 2
False Positives : 0
False Negatives : 2

------------------------------
Learning rate        : 0.8
Training runs        : 20
Total successes      : 191
Total failures       : 2
Precision            : 1.0%
Recall               : 0.98%
Accuracy             : 0.99%
---------------------------------------------

---------------------------------------------
( 3, 6 )
Successes        : 196
Failures         : 0
False Positives : 0
False Negatives : 0

------------------------------
Learning rate        : 0.8
Training runs        : 20
Total successes      : 196
Total failures       : 0
Precision            : 1.0%
Recall               : 1.0%
Accuracy             : 1.0%
---------------------------------------------

---------------------------------------------
( 3, 7 )
Successes        : 178
Failures         : 21
False Positives : 21
False Negatives : 0
```

```
------------------------------
Learning rate        : 0.8
Training runs        : 20
Total successes      : 178
Total failures       : 21
Precision            : 0.80%
Recall               : 1.0%
Accuracy             : 0.88%
----------------------------------------

----------------------------------------
( 3, 8 )
Successes       : 188
Failures        : 5
False Positives : 4
False Negatives : 1

------------------------------
Learning rate        : 0.8
Training runs        : 20
Total successes      : 188
Total failures       : 5
Precision            : 0.96%
Recall               : 0.99%
Accuracy             : 0.97%
----------------------------------------

----------------------------------------
( 3, 9 )
Successes       : 197
Failures        : 12
False Positives : 11
False Negatives : 1

------------------------------
Learning rate        : 0.8
Training runs        : 20
Total successes      : 197
Total failures       : 12
Precision            : 0.90%
Recall               : 0.99%
Accuracy             : 0.94%
----------------------------------------

----------------------------------------
( 4, 5 )
Successes       : 165
Failures        : 7
False Positives : 6
False Negatives : 1
```

```
------------------------------
Learning rate        : 0.8
Training runs        : 20
Total successes      : 165
Total failures       : 7
Precision            : 0.93%
Recall               : 0.99%
Accuracy             : 0.96%
------------------------------------------

------------------------------------------
( 4, 6 )
Successes       : 171
Failures        : 4
False Positives : 4
False Negatives : 0

------------------------------
Learning rate        : 0.8
Training runs        : 20
Total successes      : 171
Total failures       : 4
Precision            : 0.95%
Recall               : 1.0%
Accuracy             : 0.98%
------------------------------------------

------------------------------------------
( 4, 7 )
Successes       : 156
Failures        : 22
False Positives : 22
False Negatives : 0

------------------------------
Learning rate        : 0.8
Training runs        : 20
Total successes      : 156
Total failures       : 22
Precision            : 0.74%
Recall               : 1.0%
Accuracy             : 0.86%
------------------------------------------

------------------------------------------
( 4, 8 )
Successes       : 160
Failures        : 12
False Positives : 10
False Negatives : 2
```

```
------------------------------
Learning rate        : 0.8
Training runs        : 20
Total successes      : 160
Total failures       : 12
Precision            : 0.88%
Recall               : 0.97%
Accuracy             : 0.93%
----------------------------------------------
----------------------------------------------
( 4, 9 )
Successes       : 177
Failures        : 11
False Positives : 8
False Negatives : 3
------------------------------
Learning rate        : 0.8
Training runs        : 20
Total successes      : 177
Total failures       : 11
Precision            : 0.90%
Recall               : 0.96%
Accuracy             : 0.94%
----------------------------------------------
----------------------------------------------
( 5, 6 )
Successes       : 174
Failures        : 5
False Positives : 5
False Negatives : 0
------------------------------
Learning rate        : 0.8
Training runs        : 20
Total successes      : 174
Total failures       : 5
Precision            : 0.94%
Recall               : 1.0%
Accuracy             : 0.97%
----------------------------------------------
----------------------------------------------
( 5, 7 )
Successes       : 168
Failures        : 14
False Positives : 14
False Negatives : 0
```

```
-------------------------------
Learning rate        : 0.8
Training runs        : 20
Total successes      : 168
Total failures       : 14
Precision            : 0.84%
Recall               : 1.0%
Accuracy             : 0.92%
-------------------------------------------

-------------------------------------------
( 5, 8 )
Successes      : 171
Failures       : 5
False Positives : 3
False Negatives : 2
-------------------------------
Learning rate        : 0.8
Training runs        : 20
Total successes      : 171
Total failures       : 5
Precision            : 0.97%
Recall               : 0.98%
Accuracy             : 0.97%
-------------------------------------------

-------------------------------------------
( 5, 9 )
Successes      : 181
Failures       : 11
False Positives : 10
False Negatives : 1
-------------------------------
Learning rate        : 0.8
Training runs        : 20
Total successes      : 181
Total failures       : 11
Precision            : 0.89%
Recall               : 0.99%
Accuracy             : 0.94%
-------------------------------------------

-------------------------------------------
( 6, 7 )
Successes      : 185
Failures       : 0
False Positives : 0
False Negatives : 0
```

```
------------------------------
Learning rate         : 0.8
Training runs         : 20
Total successes       : 185
Total failures        : 0
Precision             : 1.0%
Recall                : 1.0%
Accuracy              : 1.0%
----------------------------------------------

----------------------------------------------
( 6, 8 )
Successes       : 172
Failures        : 7
False Positives : 0
False Negatives : 7

------------------------------
Learning rate         : 0.8
Training runs         : 20
Total successes       : 172
Total failures        : 7
Precision             : 1.0%
Recall                : 0.93%
Accuracy              : 0.96%
----------------------------------------------

----------------------------------------------
( 6, 9 )
Successes       : 195
Failures        : 0
False Positives : 0
False Negatives : 0

------------------------------
Learning rate         : 0.8
Training runs         : 20
Total successes       : 195
Total failures        : 0
Precision             : 1.0%
Recall                : 1.0%
Accuracy              : 1.0%
----------------------------------------------

----------------------------------------------
( 7, 8 )
Successes       : 156
Failures        : 26
False Positives : 0
False Negatives : 26
```

```
---------------------------------
Learning rate         : 0.8
Training runs         : 20
Total successes       : 156
Total failures        : 26
Precision             : 1.0%
Recall                : 0.78%
Accuracy              : 0.83%
---------------------------------------------

---------------------------------------------
( 7, 9 )
Successes       : 175
Failures        : 23
False Positives : 0
False Negatives : 23
---------------------------------
Learning rate         : 0.8
Training runs         : 20
Total successes       : 175
Total failures        : 23
Precision             : 1.0%
Recall                : 0.80%
Accuracy              : 0.87%
---------------------------------------------

---------------------------------------------
( 8, 9 )
Successes       : 186
Failures        : 6
False Positives : 3
False Negatives : 3
---------------------------------
Learning rate         : 0.8
Training runs         : 20
Total successes       : 186
Total failures        : 6
Precision             : 0.97%
Recall                : 0.97%
Accuracy              : 0.97%
---------------------------------------------
reporting test data

---------------------------------------------
Learning rate         : 0.8
Training runs         : 20
Total successes       : 16387
Total failures        : 1019
```

```
Precision              : 0.97%
Recall                 : 0.92%
Accuracy               : 0.94%

------------------------------------------------
      0    1    2    3    4    5    6    7    8    9
------------------------------------------------
0 |   X   14    4    0    5    0   12    1    1    2

1 |   0    X    6    0    0    0    7    2    0    0

2 |   0   27    X    0    0    0    1    8    1    7

3 |   0  182   36    X    2    4    2   55   16   39

4 |   0  108    6    2    X    6   10   38   12   12

5 |   4  129   26    8    1    X    9   26    7   34

6 |   0    4    1    0    0    0    X    0    0    0

7 |   0    4    0    0    0    0    0    X    0    0

8 |   0  226   27    1   12    4   37   58    X   19

9 |   0  155    6    1   11    3    0   53    5    X


------------------------------------------------
```

4.2   Classifier Output - Experiment 3

```
start
reading files
creating perceptron classifiers
training classifiers
reporting training data

------------------------------------------------
Learning rate          : 0.05
Training runs          : 20
Total successes        : 8519
Total failures         : 481
Precision              : 0.98%
Recall                 : 0.92%
Accuracy               : 0.94%

------------------------------------------------
      0    1    2    3    4    5    6    7    8    9
------------------------------------------------
```

```
0 |   X   8   4   0   2   0   6   0   0   0

1 |   0   X   6   0   0   0   4   0   0   0

2 |   0  16   X   0   0   0   0   4   0   6

3 |   0 122  28   X   2   4   2  34  12  28

4 |   0  66   0   0   X   0   6  16   2   4

5 |   4  82  20   6   0   X   4  12   4  24

6 |   0   2   0   0   0   0   X   0   0   0

7 |   0   4   0   0   0   0   0   X   0   0

8 |   0 152  18   0  10   2  30  32   X  16

9 |   0 112   4   0   8   2   0  30   2   X

-----------------------------------------------
running classifiers
-----------------------------------------------
( 0, 1 )
Successes        : 180
Failures         : 6
False Positives  : 6
False Negatives  : 0
-------------------------------
Learning rate         : 0.05
Training runs         : 20
Total successes       : 180
Total failures        : 6
Precision             : 0.94%
Recall                : 1.0%
Accuracy              : 0.97%
-----------------------------------------------
-----------------------------------------------
( 0, 2 )
Successes        : 189
Failures         : 0
False Positives  : 0
False Negatives  : 0
-------------------------------
Learning rate         : 0.05
```

```
Training runs        : 20
Total successes      : 189
Total failures       : 0
Precision            : 1.0%
Recall               : 1.0%
Accuracy             : 1.0%
------------------------------------------
------------------------------------------
( 0, 3 )
Successes       : 200
Failures        : 0
False Positives : 0
False Negatives : 0

------------------------------
Learning rate        : 0.05
Training runs        : 20
Total successes      : 200
Total failures       : 0
Precision            : 1.0%
Recall               : 1.0%
Accuracy             : 1.0%
------------------------------------------
------------------------------------------
( 0, 4 )
Successes       : 176
Failures        : 3
False Positives : 3
False Negatives : 0

------------------------------
Learning rate        : 0.05
Training runs        : 20
Total successes      : 176
Total failures       : 3
Precision            : 0.97%
Recall               : 1.0%
Accuracy             : 0.98%
------------------------------------------
------------------------------------------
( 0, 5 )
Successes       : 183
Failures        : 0
False Positives : 0
False Negatives : 0

------------------------------
Learning rate        : 0.05
```

```
Training runs       : 20
Total successes     : 183
Total failures      : 0
Precision           : 1.0%
Recall              : 1.0%
Accuracy            : 1.0%
------------------------------------------
------------------------------------------
( 0, 6 )
Successes       : 180
Failures        : 6
False Positives : 6
False Negatives : 0
------------------------------
Learning rate       : 0.05
Training runs       : 20
Total successes     : 180
Total failures      : 6
Precision           : 0.94%
Recall              : 1.0%
Accuracy            : 0.97%
------------------------------------------
------------------------------------------
( 0, 7 )
Successes       : 188
Failures        : 1
False Positives : 1
False Negatives : 0
------------------------------
Learning rate       : 0.05
Training runs       : 20
Total successes     : 188
Total failures      : 1
Precision           : 0.99%
Recall              : 1.0%
Accuracy            : 0.99%
------------------------------------------
------------------------------------------
( 0, 8 )
Successes       : 182
Failures        : 1
False Positives : 1
False Negatives : 0
------------------------------
Learning rate       : 0.05
```

```
Training runs        : 20
Total successes      : 182
Total failures       : 1
Precision            : 0.99%
Recall               : 1.0%
Accuracy             : 0.99%
-------------------------------------------
-------------------------------------------
( 0, 9 )
Successes       : 197
Failures        : 2
False Positives : 2
False Negatives : 0
------------------------------
Learning rate        : 0.05
Training runs        : 20
Total successes      : 197
Total failures       : 2
Precision            : 0.98%
Recall               : 1.0%
Accuracy             : 0.99%
-------------------------------------------
-------------------------------------------
( 1, 2 )
Successes       : 174
Failures        : 11
False Positives : 0
False Negatives : 11
------------------------------
Learning rate        : 0.05
Training runs        : 20
Total successes      : 174
Total failures       : 11
Precision            : 1.0%
Recall               : 0.89%
Accuracy             : 0.94%
-------------------------------------------
-------------------------------------------
( 1, 3 )
Successes       : 136
Failures        : 60
False Positives : 0
False Negatives : 60
------------------------------
Learning rate        : 0.05
```

```
Training runs       : 20
Total successes     : 136
Total failures      : 60
Precision           : 1.0%
Recall              : 0.60%
Accuracy            : 0.56%
----------------------------------------
----------------------------------------
( 1, 4 )
Successes       : 133
Failures        : 42
False Positives : 0
False Negatives : 42
------------------------------
Learning rate       : 0.05
Training runs       : 20
Total successes     : 133
Total failures      : 42
Precision           : 1.0%
Recall              : 0.68%
Accuracy            : 0.68%
----------------------------------------
----------------------------------------
( 1, 5 )
Successes       : 132
Failures        : 47
False Positives : 0
False Negatives : 47
------------------------------
Learning rate       : 0.05
Training runs       : 20
Total successes     : 132
Total failures      : 47
Precision           : 1.0%
Recall              : 0.66%
Accuracy            : 0.64%
----------------------------------------
----------------------------------------
( 1, 6 )
Successes       : 177
Failures        : 5
False Positives : 3
False Negatives : 2
------------------------------
Learning rate       : 0.05
```

```
Training runs      : 20
Total successes    : 177
Total failures     : 5
Precision          : 0.97%
Recall             : 0.98%
Accuracy           : 0.97%
------------------------------------------
------------------------------------------
( 1, 7 )
Successes       : 183
Failures        : 2
False Positives : 2
False Negatives : 0

------------------------------
Learning rate      : 0.05
Training runs      : 20
Total successes    : 183
Total failures     : 2
Precision          : 0.98%
Recall             : 1.0%
Accuracy           : 0.99%
------------------------------------------
------------------------------------------
( 1, 8 )
Successes       : 104
Failures        : 75
False Positives : 0
False Negatives : 75

------------------------------
Learning rate      : 0.05
Training runs      : 20
Total successes    : 104
Total failures     : 75
Precision          : 1.0%
Recall             : 0.55%
Accuracy           : 0.28%
------------------------------------------
------------------------------------------
( 1, 9 )
Successes       : 150
Failures        : 45
False Positives : 0
False Negatives : 45

------------------------------
Learning rate      : 0.05
```

```
Training runs       : 20
Total successes     : 150
Total failures      : 45
Precision           : 1.0%
Recall              : 0.67%
Accuracy            : 0.70%
-------------------------------------------
-------------------------------------------
( 2, 3 )
Successes       : 191
Failures        : 8
False Positives : 0
False Negatives : 8
------------------------------
Learning rate       : 0.05
Training runs       : 20
Total successes     : 191
Total failures      : 8
Precision           : 1.0%
Recall              : 0.92%
Accuracy            : 0.96%
-------------------------------------------
-------------------------------------------
( 2, 4 )
Successes       : 172
Failures        : 6
False Positives : 0
False Negatives : 6
------------------------------
Learning rate       : 0.05
Training runs       : 20
Total successes     : 172
Total failures      : 6
Precision           : 1.0%
Recall              : 0.94%
Accuracy            : 0.97%
-------------------------------------------
-------------------------------------------
( 2, 5 )
Successes       : 176
Failures        : 6
False Positives : 0
False Negatives : 6
------------------------------
Learning rate       : 0.05
```

```
Training runs        : 20
Total successes      : 176
Total failures       : 6
Precision            : 1.0%
Recall               : 0.94%
Accuracy             : 0.97%
---------------------------------------
---------------------------------------
( 2, 6 )
Successes       : 183
Failures        : 2
False Positives : 1
False Negatives : 1
-----------------------------
Learning rate        : 0.05
Training runs        : 20
Total successes      : 183
Total failures       : 2
Precision            : 0.99%
Recall               : 0.99%
Accuracy             : 0.99%
---------------------------------------
---------------------------------------
( 2, 7 )
Successes       : 184
Failures        : 4
False Positives : 4
False Negatives : 0
-----------------------------
Learning rate        : 0.05
Training runs        : 20
Total successes      : 184
Total failures       : 4
Precision            : 0.96%
Recall               : 1.0%
Accuracy             : 0.98%
---------------------------------------
---------------------------------------
( 2, 8 )
Successes       : 172
Failures        : 10
False Positives : 1
False Negatives : 9
-----------------------------
Learning rate        : 0.05
```

```
Training runs       : 20
Total successes     : 172
Total failures      : 10
Precision           : 0.99%
Recall              : 0.91%
Accuracy            : 0.94%
------------------------------------------
------------------------------------------
( 2, 9 )
Successes       : 195
Failures        : 3
False Positives : 1
False Negatives : 2
------------------------------
Learning rate       : 0.05
Training runs       : 20
Total successes     : 195
Total failures      : 3
Precision           : 0.99%
Recall              : 0.98%
Accuracy            : 0.98%
------------------------------------------
------------------------------------------
( 3, 4 )
Successes       : 187
Failures        : 2
False Positives : 0
False Negatives : 2
------------------------------
Learning rate       : 0.05
Training runs       : 20
Total successes     : 187
Total failures      : 2
Precision           : 1.0%
Recall              : 0.98%
Accuracy            : 0.99%
------------------------------------------
------------------------------------------
( 3, 5 )
Successes       : 191
Failures        : 2
False Positives : 0
False Negatives : 2
------------------------------
Learning rate       : 0.05
```

```
Training runs        : 20
Total successes      : 191
Total failures       : 2
Precision            : 1.0%
Recall               : 0.98%
Accuracy             : 0.99%
------------------------------------------
------------------------------------------
( 3, 6 )
Successes       : 196
Failures        : 0
False Positives : 0
False Negatives : 0

------------------------------
Learning rate        : 0.05
Training runs        : 20
Total successes      : 196
Total failures       : 0
Precision            : 1.0%
Recall               : 1.0%
Accuracy             : 1.0%
------------------------------------------
------------------------------------------
( 3, 7 )
Successes       : 178
Failures        : 21
False Positives : 21
False Negatives : 0

------------------------------
Learning rate        : 0.05
Training runs        : 20
Total successes      : 178
Total failures       : 21
Precision            : 0.80%
Recall               : 1.0%
Accuracy             : 0.88%
------------------------------------------
------------------------------------------
( 3, 8 )
Successes       : 188
Failures        : 5
False Positives : 4
False Negatives : 1

------------------------------
Learning rate        : 0.05
```

```
Training runs       : 20
Total successes     : 188
Total failures      : 5
Precision           : 0.96%
Recall              : 0.99%
Accuracy            : 0.97%
----------------------------------------
----------------------------------------
( 3, 9 )
Successes       : 197
Failures        : 12
False Positives : 11
False Negatives : 1
------------------------------
Learning rate       : 0.05
Training runs       : 20
Total successes     : 197
Total failures      : 12
Precision           : 0.90%
Recall              : 0.99%
Accuracy            : 0.94%
----------------------------------------
----------------------------------------
( 4, 5 )
Successes       : 165
Failures        : 7
False Positives : 6
False Negatives : 1
------------------------------
Learning rate       : 0.05
Training runs       : 20
Total successes     : 165
Total failures      : 7
Precision           : 0.93%
Recall              : 0.99%
Accuracy            : 0.96%
----------------------------------------
----------------------------------------
( 4, 6 )
Successes       : 171
Failures        : 4
False Positives : 4
False Negatives : 0
------------------------------
Learning rate       : 0.05
```

```
Training runs         : 20
Total successes       : 171
Total failures        : 4
Precision             : 0.95%
Recall                : 1.0%
Accuracy              : 0.98%
------------------------------------------
------------------------------------------
( 4, 7 )
Successes      : 156
Failures       : 22
False Positives : 22
False Negatives : 0
------------------------------
Learning rate         : 0.05
Training runs         : 20
Total successes       : 156
Total failures        : 22
Precision             : 0.74%
Recall                : 1.0%
Accuracy              : 0.86%
------------------------------------------
------------------------------------------
( 4, 8 )
Successes      : 160
Failures       : 12
False Positives : 10
False Negatives : 2
------------------------------
Learning rate         : 0.05
Training runs         : 20
Total successes       : 160
Total failures        : 12
Precision             : 0.88%
Recall                : 0.97%
Accuracy              : 0.93%
------------------------------------------
------------------------------------------
( 4, 9 )
Successes      : 177
Failures       : 11
False Positives : 8
False Negatives : 3
------------------------------
Learning rate         : 0.05
```

```
Training runs        : 20
Total successes      : 177
Total failures       : 11
Precision            : 0.90%
Recall               : 0.96%
Accuracy             : 0.94%
------------------------------------------
------------------------------------------
( 5, 6 )
Successes       : 174
Failures        : 5
False Positives : 5
False Negatives : 0
------------------------------
Learning rate        : 0.05
Training runs        : 20
Total successes      : 174
Total failures       : 5
Precision            : 0.94%
Recall               : 1.0%
Accuracy             : 0.97%
------------------------------------------
------------------------------------------
( 5, 7 )
Successes       : 168
Failures        : 14
False Positives : 14
False Negatives : 0
------------------------------
Learning rate        : 0.05
Training runs        : 20
Total successes      : 168
Total failures       : 14
Precision            : 0.84%
Recall               : 1.0%
Accuracy             : 0.92%
------------------------------------------
------------------------------------------
( 5, 8 )
Successes       : 171
Failures        : 5
False Positives : 3
False Negatives : 2
------------------------------
Learning rate        : 0.05
```

```
Training runs         : 20
Total successes       : 171
Total failures        : 5
Precision             : 0.97%
Recall                : 0.98%
Accuracy              : 0.97%
------------------------------------------
------------------------------------------
( 5, 9 )
Successes       : 181
Failures        : 11
False Positives : 10
False Negatives : 1
------------------------------
Learning rate         : 0.05
Training runs         : 20
Total successes       : 181
Total failures        : 11
Precision             : 0.89%
Recall                : 0.99%
Accuracy              : 0.94%
------------------------------------------
------------------------------------------
( 6, 7 )
Successes       : 185
Failures        : 0
False Positives : 0
False Negatives : 0
------------------------------
Learning rate         : 0.05
Training runs         : 20
Total successes       : 185
Total failures        : 0
Precision             : 1.0%
Recall                : 1.0%
Accuracy              : 1.0%
------------------------------------------
------------------------------------------
( 6, 8 )
Successes       : 172
Failures        : 7
False Positives : 0
False Negatives : 7
------------------------------
Learning rate         : 0.05
```

```
Training runs       : 20
Total successes     : 172
Total failures      : 7
Precision           : 1.0%
Recall              : 0.93%
Accuracy            : 0.96%
-------------------------------------------
-------------------------------------------
( 6, 9 )
Successes       : 195
Failures        : 0
False Positives : 0
False Negatives : 0
------------------------------
Learning rate       : 0.05
Training runs       : 20
Total successes     : 195
Total failures      : 0
Precision           : 1.0%
Recall              : 1.0%
Accuracy            : 1.0%
-------------------------------------------
-------------------------------------------
( 7, 8 )
Successes       : 156
Failures        : 26
False Positives : 0
False Negatives : 26
------------------------------
Learning rate       : 0.05
Training runs       : 20
Total successes     : 156
Total failures      : 26
Precision           : 1.0%
Recall              : 0.78%
Accuracy            : 0.83%
-------------------------------------------
-------------------------------------------
( 7, 9 )
Successes       : 175
Failures        : 23
False Positives : 0
False Negatives : 23
------------------------------
Learning rate       : 0.05
```

```
Training runs      : 20
Total successes    : 175
Total failures     : 23
Precision          : 1.0%
Recall             : 0.80%
Accuracy           : 0.87%
----------------------------------------
----------------------------------------
( 8, 9 )
Successes       : 186
Failures        : 6
False Positives : 3
False Negatives : 3

--------------------------------
Learning rate      : 0.05
Training runs      : 20
Total successes    : 186
Total failures     : 6
Precision          : 0.97%
Recall             : 0.97%
Accuracy           : 0.97%
----------------------------------------
reporting test data

----------------------------------------
Learning rate      : 0.05
Training runs      : 20
Total successes    : 16385
Total failures     : 1021
Precision          : 0.97%
Recall             : 0.92%
Accuracy           : 0.94%

----------------------------------------
      0    1    2    3    4    5    6    7    8    9

----------------------------------------
0 |   X   14    4    0    5    0   12    1    1    2

1 |   0    X    6    0    0    0    7    2    0    0

2 |   0   27    X    0    0    0    1    8    1    7

3 |   0  182   36    X    2    4    2   55   16   39

4 |   0  108    6    2    X    6   10   38   12   12

5 |   4  129   26    8    1    X    9   26    7   34
```

```
6 |   0   4   1   0   0   0   X   0   0   0

7 |   0   4   0   0   0   0   0   X   0   0

8 |   0 227  27   1  12   4  37  58   X  19

9 |   0 157   6   1  11   3   0  53   5   X

---------------------------------------------
```