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1. (30 pts) Based on the previous homework, replace the first convolutional layer with autoencoder layers. Train the new network and report the result.

Starting training...
Epoch 1 of 10 took 33.396s
  training loss: 0.790575
  validation loss: 0.289153
  validation accuracy: 91.56 %
Epoch 2 of 10 took 33.136s
  training loss: 0.279753
  validation loss: 0.222340
  validation accuracy: 93.57 %
Epoch 3 of 10 took 33.263s
  training loss: 0.219145
  validation loss: 0.184917
  validation accuracy: 94.81 %
Epoch 4 of 10 took 32.999s
  training loss: 0.180731
  validation loss: 0.157279
  validation accuracy: 95.68 %
Epoch 5 of 10 took 33.224s
  training loss: 0.153128
  validation loss: 0.136613
  validation accuracy: 96.29 %
Epoch 6 of 10 took 33.276s
  training loss: 0.132902
  validation loss: 0.123466
  validation accuracy: 96.54 %
Epoch 7 of 10 took 33.379s
  training loss: 0.117299
  validation loss: 0.112524
  validation accuracy: 96.96 %
Epoch 8 of 10 took 33.488s
  training loss: 0.104507
  validation loss: 0.104547
  validation accuracy: 97.34 %
Epoch 9 of 10 took 33.841s
  training loss: 0.094433
  validation loss: 0.097371
  validation accuracy: 97.34 %
Epoch 10 of 10 took 33.748s
  training loss: 0.086560
  validation loss: 0.089848
  validation accuracy: 97.56 %
Final results:
  test loss: 0.083940

test accuracy: 97.36 %

2. (30 pts) Based on the previous homework, replace the first convolutional layer with Restricted Boltzmann Machine layers (convert the pixels to black/white first). Train the new network and report the result.

((70000, 784)
[BernoulliRBM] Iteration 1, pseudo-likelihood = -93.26, time = 45.28s
[BernoulliRBM] Iteration 2, pseudo-likelihood = -80.08, time = 50.53s
[BernoulliRBM] Iteration 3, pseudo-likelihood = -72.46, time = 52.43s
[BernoulliRBM] Iteration 4, pseudo-likelihood = -69.83, time = 52.41s
[BernoulliRBM] Iteration 5, pseudo-likelihood = -70.28, time = 52.74s
[BernoulliRBM] Iteration 6, pseudo-likelihood = -65.30, time = 51.39s
[BernoulliRBM] Iteration 7, pseudo-likelihood = -65.25, time = 50.82s
[BernoulliRBM] Iteration 8, pseudo-likelihood = -63.77, time = 56.70s
[BernoulliRBM] Iteration 9, pseudo-likelihood = -65.99, time = 54.55s
[BernoulliRBM] Iteration 10, pseudo-likelihood = -65.27, time = 56.79s

Initializing neural network with 3 layers, 400 inputs and 10 outputs.
- Convl: #[1;97mTanh #[0m Output: #[1;97m(16, 16) #[0m Channels: #[1;97m20#[0m
- Dense: #[1;97mSigmoid #[0m Units: #[1;97m100 #[0m
- Dense: #[1;97mSoftmax #[0m Units: #[1;97m10 #[0m
Training on dataset of 56,000 samples with 22,960,000 total size.
- Reshaping input array from (56000, 400) to (44800, 20, 20, 1).
- Train: 44,800 Valid: 11,200
- Early termination after 5 stable iterations.

Epoch	Training Error	Validation Error	Time
1	N/A	#[0;32m 2.666e+00#[0m	135.2s
2	N/A	2.767e+00	128.0s
3	N/A	2.873e+00	124.7s
4	N/A	2.985e+00	143.7s
5	N/A	3.160e+00	128.2s
6	N/A	3.224e+00	124.8s

Early termination condition fired at 6 iterations.

Score:	precision	recall	f1-score	support
0.0	0.98	0.99	0.98	1312
1.0	0.98	0.98	0.98	1604
2.0	0.95	0.97	0.96	1348
3.0	0.95	0.96	0.96	1427
4.0	0.95	0.97	0.96	1362
5.0	0.97	0.94	0.95	1280
6.0	0.97	0.99	0.98	1397
7.0	0.98	0.96	0.97	1461
8.0	0.94	0.95	0.95	1390
9.0	0.95	0.94	0.94	1419
avg / total	0.96	0.96	0.96	14000