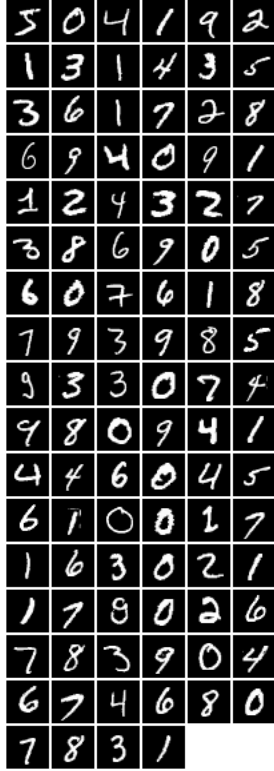


Computer Vision Assignment-2

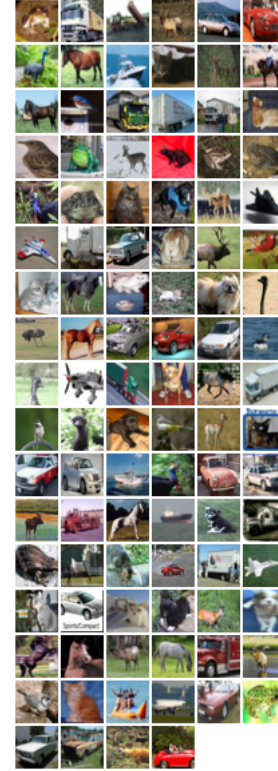
Abhinav Gupta (NetID-ag5799)

November 3, 2016

2. The images for the MNIST and CIFAR training data are as follows:



(a) MNIST-100



(b) CIFAR-100

3.(a) The output after training, validating and testing on 1000 examples.

```
train | epoch = 1 | lr = 0.1000 | loss: 29293.0637 | error: 668.0000 - valid | validloss: 10181.8040 | validerror: 419.0000 | s/iter: 0.2010
train | epoch = 2 | lr = 0.1000 | loss: 3712.8518 | error: 244.0000 - valid | validloss: 2766.7456 | validerror: 228.0000 | s/iter: 0.1829
train | epoch = 3 | lr = 0.1000 | loss: 1273.6265 | error: 133.0000 - valid | validloss: 2527.4130 | validerror: 226.0000 | s/iter: 0.1890
train | epoch = 4 | lr = 0.1000 | loss: 1601.3950 | error: 156.0000 - valid | validloss: 2233.3753 | validerror: 201.0000 | s/iter: 0.1794
train | epoch = 5 | lr = 0.1000 | loss: 713.4778 | error: 88.0000 - valid | validloss: 1746.5079 | validerror: 171.0000 | s/iter: 0.1855
train | epoch = 6 | lr = 0.1000 | loss: 527.5201 | error: 86.0000 - valid | validloss: 1993.9952 | validerror: 211.0000 | s/iter: 0.1890
train | epoch = 7 | lr = 0.1000 | loss: 464.6825 | error: 92.0000 - valid | validloss: 1802.6563 | validerror: 193.0000 | s/iter: 0.1854
train | epoch = 8 | lr = 0.1000 | loss: 238.6802 | error: 54.0000 - valid | validloss: 1765.2389 | validerror: 198.0000 | s/iter: 0.1821
train | epoch = 9 | lr = 0.1000 | loss: 746.3244 | error: 100.0000 - valid | validloss: 3751.9471 | validerror: 274.0000 | s/iter: 0.1822
train | epoch = 10 | lr = 0.1000 | loss: 354.2497 | error: 62.0000 - valid | validloss: 1854.9411 | validerror: 195.0000 | s/iter: 0.1804
| test | error: 191.0000
```

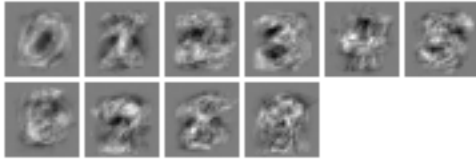
Figure 2

(b) The output after training on 50 examples and using the full validation and test set.

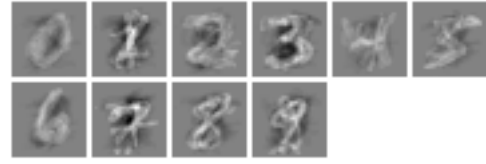
train	epoch = 1	lr = 0.1000	loss: 64.8796	error: 43.0000 - valid	validloss: 20685.1468	validerror: 6954.0000	s/iter: 0.9792
train	epoch = 2	lr = 0.1000	loss: 14671.3541	error: 26.0000 - valid	validloss: 22151.6520	validerror: 6878.0000	s/iter: 0.9875
train	epoch = 3	lr = 0.1000	loss: 19053.0497	error: 28.0000 - valid	validloss: 20575.2377	validerror: 5673.0000	s/iter: 0.9006
train	epoch = 4	lr = 0.1000	loss: 12373.6498	error: 18.0000 - valid	validloss: 16194.0607	validerror: 5246.0000	s/iter: 0.9659
train	epoch = 5	lr = 0.1000	loss: 9386.8868	error: 12.0000 - valid	validloss: 15390.5190	validerror: 6269.0000	s/iter: 0.9032
train	epoch = 6	lr = 0.1000	loss: 7582.5734	error: 22.0000 - valid	validloss: 25863.8462	validerror: 7828.0000	s/iter: 0.8917
train	epoch = 7	lr = 0.1000	loss: 14390.5032	error: 24.0000 - valid	validloss: 18583.1501	validerror: 6385.0000	s/iter: 0.8922
train	epoch = 8	lr = 0.1000	loss: 14692.9140	error: 20.0000 - valid	validloss: 4741.7797	validerror: 4068.0000	s/iter: 0.8963
train	epoch = 9	lr = 0.1000	loss: 188.3231	error: 1.0000 - valid	validloss: 4642.1204	validerror: 3873.0000	s/iter: 0.8996
train	epoch = 10	lr = 0.1000	loss: 0.0000	error: 0.0000 - valid	validloss: 4642.1204	validerror: 3873.0000	s/iter: 0.8960
test	error: 4095.0000						

Figure 3

Visualization of the network weights for both models:



(a) With 1000 training examples



(b) With 50 training examples

train	epoch = 1	lr = 0.1000	loss: 73.5349	error: 47.0000 - valid	validloss: 27484.5521	validerror: 895.0000	s/iter: 0.1747
train	epoch = 2	lr = 0.1000	loss: 22035.7225	error: 42.0000 - valid	validloss: 35853.7824	validerror: 749.0000	s/iter: 0.1443
train	epoch = 3	lr = 0.1000	loss: 40857.0383	error: 29.0000 - valid	validloss: 27193.6502	validerror: 602.0000	s/iter: 0.1237
train	epoch = 4	lr = 0.1000	loss: 29051.9468	error: 22.0000 - valid	validloss: 18001.1229	validerror: 695.0000	s/iter: 0.1164
train	epoch = 5	lr = 0.1000	loss: 12262.9761	error: 21.0000 - valid	validloss: 10213.0758	validerror: 536.0000	s/iter: 0.1145
train	epoch = 6	lr = 0.1000	loss: 1500.9622	error: 7.0000 - valid	validloss: 7618.1303	validerror: 468.0000	s/iter: 0.1500
train	epoch = 7	lr = 0.1000	loss: 644.9726	error: 6.0000 - valid	validloss: 7345.0219	validerror: 483.0000	s/iter: 0.1533
train	epoch = 8	lr = 0.1000	loss: 18.0922	error: 2.0000 - valid	validloss: 5935.0690	validerror: 443.0000	s/iter: 0.1334
train	epoch = 9	lr = 0.1000	loss: 0.0000	error: 0.0000 - valid	validloss: 5935.0690	validerror: 443.0000	s/iter: 0.1152
train	epoch = 10	lr = 0.1000	loss: 0.0000	error: 0.0000 - valid	validloss: 5935.0690	validerror: 443.0000	s/iter: 0.1176
test	error: 449.0000						

Figure 5: Training on 50 examples and using 1000 instances in validation and test set.

Training with just 50 examples leads to overfitting. The model converges very early as it has very less features to learn. On the other hand, the valid and test error are huge, since the model does not generalize to different inputs. As we see that the test error in case of 1000 instances is less than using the full test set since the model is able to generalize to some instances present in the smaller test set.

4.(a)

train	epoch = 1	lr = 0.1000	loss: 5.5752	error: 698.0000 - valid	validloss: 7.7601	validerror: 548.0000	s/iter: 0.4165
train	epoch = 2	lr = 0.1000	loss: 9.9345	error: 709.0000 - valid	validloss: 13.7427	validerror: 660.0000	s/iter: 0.3681
train	epoch = 3	lr = 0.1000	loss: 12.0517	error: 695.0000 - valid	validloss: 13.0474	validerror: 813.0000	s/iter: 0.4952
train	epoch = 4	lr = 0.1000	loss: 12.0060	error: 694.0000 - valid	validloss: 9.1808	validerror: 849.0000	s/iter: 0.4278
train	epoch = 5	lr = 0.1000	loss: 11.2823	error: 653.0000 - valid	validloss: 5.7648	validerror: 575.0000	s/iter: 0.4284
train	epoch = 6	lr = 0.1000	loss: 8.3635	error: 613.0000 - valid	validloss: 9.6513	validerror: 685.0000	s/iter: 0.3523
train	epoch = 7	lr = 0.1000	loss: 8.6425	error: 635.0000 - valid	validloss: 10.3998	validerror: 557.0000	s/iter: 0.3504
train	epoch = 8	lr = 0.1000	loss: 6.7254	error: 552.0000 - valid	validloss: 8.9408	validerror: 760.0000	s/iter: 0.3328
train	epoch = 9	lr = 0.1000	loss: 9.8200	error: 623.0000 - valid	validloss: 12.0858	validerror: 618.0000	s/iter: 0.3492
train	epoch = 10	lr = 0.1000	loss: 9.8584	error: 621.0000 - valid	validloss: 7.9613	validerror: 561.0000	s/iter: 0.3476
test	error: 517.0000						

Figure 6

(b)

train	epoch = 1	lr = 10.0000	loss: 3139.2579	error: 909.0000 - valid	validloss: 6168.4628	validerror: 893.0000	s/iter: 0.3713
train	epoch = 2	lr = 10.0000	loss: 3969.0109	error: 888.0000 - valid	validloss: 5060.6471	validerror: 893.0000	s/iter: 0.3302
train	epoch = 3	lr = 10.0000	loss: 3671.6374	error: 883.0000 - valid	validloss: 3582.3952	validerror: 860.0000	s/iter: 0.3334
train	epoch = 4	lr = 10.0000	loss: 3246.8756	error: 846.0000 - valid	validloss: 4519.9848	validerror: 896.0000	s/iter: 0.3614
train	epoch = 5	lr = 10.0000	loss: 3840.3475	error: 883.0000 - valid	validloss: 3816.6018	validerror: 861.0000	s/iter: 0.3451
train	epoch = 6	lr = 10.0000	loss: 3966.5387	error: 885.0000 - valid	validloss: 4403.5726	validerror: 893.0000	s/iter: 0.4450
train	epoch = 7	lr = 10.0000	loss: 3445.2636	error: 850.0000 - valid	validloss: 3715.3545	validerror: 818.0000	s/iter: 0.3811
train	epoch = 8	lr = 10.0000	loss: 3907.3177	error: 887.0000 - valid	validloss: 3977.0998	validerror: 895.0000	s/iter: 0.3700
train	epoch = 9	lr = 10.0000	loss: 3435.8520	error: 885.0000 - valid	validloss: 2674.8150	validerror: 837.0000	s/iter: 0.3752
train	epoch = 10	lr = 10.0000	loss: 2420.2164	error: 783.0000 - valid	validloss: 2469.2453	validerror: 746.0000	s/iter: 0.3648
test				error: 745.0000			

Figure 7

Due to high learning rate (10), the model keeps on jumping back and forth in the "well" by taking large steps and it will take very far more epochs to converge near the minima. If we compare the answer with (a) where the learning rate is 0.1, we see that it gradually progress towards the minima by taking small steps.

5.(a)

train	epoch = 1	lr = 0.1000	loss: 2.2465	error: 10378.0000 - valid	validloss: 2.1111	validerror: 2294.0000	s/iter: 33.8550
train	epoch = 2	lr = 0.1000	loss: 2.0919	error: 9353.0000 - valid	validloss: 2.1079	validerror: 2388.0000	s/iter: 36.6925
train	epoch = 3	lr = 0.1000	loss: 2.0346	error: 9157.0000 - valid	validloss: 1.9103	validerror: 2136.0000	s/iter: 33.2089
train	epoch = 4	lr = 0.1000	loss: 1.9257	error: 8463.0000 - valid	validloss: 1.7753	validerror: 1955.0000	s/iter: 32.0502
train	epoch = 5	lr = 0.1000	loss: 1.8210	error: 7948.0000 - valid	validloss: 1.7924	validerror: 1973.0000	s/iter: 27.6897
train	epoch = 6	lr = 0.1000	loss: 1.8046	error: 7880.0000 - valid	validloss: 1.7019	validerror: 1899.0000	s/iter: 27.6299
train	epoch = 7	lr = 0.1000	loss: 1.7199	error: 7563.0000 - valid	validloss: 1.6981	validerror: 1868.0000	s/iter: 28.3324
train	epoch = 8	lr = 0.1000	loss: 1.6815	error: 7426.0000 - valid	validloss: 1.6792	validerror: 1849.0000	s/iter: 27.4099
train	epoch = 9	lr = 0.1000	loss: 1.6296	error: 7111.0000 - valid	validloss: 1.6116	validerror: 1791.0000	s/iter: 32.0081
train	epoch = 10	lr = 0.1000	loss: 1.5846	error: 6908.0000 - valid	validloss: 1.5687	validerror: 1727.0000	s/iter: 26.6563
train	epoch = 11	lr = 0.1000	loss: 1.5979	error: 6947.0000 - valid	validloss: 1.6024	validerror: 1761.0000	s/iter: 26.3530
train	epoch = 12	lr = 0.1000	loss: 1.5056	error: 6591.0000 - valid	validloss: 1.5264	validerror: 1702.0000	s/iter: 26.6905
train	epoch = 13	lr = 0.1000	loss: 1.4802	error: 6424.0000 - valid	validloss: 1.5710	validerror: 1726.0000	s/iter: 26.4441
train	epoch = 14	lr = 0.1000	loss: 1.4580	error: 6359.0000 - valid	validloss: 1.5500	validerror: 1701.0000	s/iter: 26.5862
train	epoch = 15	lr = 0.1000	loss: 1.4465	error: 6298.0000 - valid	validloss: 1.5099	validerror: 1637.0000	s/iter: 26.7205
train	epoch = 16	lr = 0.1000	loss: 1.4242	error: 6187.0000 - valid	validloss: 1.5105	validerror: 1680.0000	s/iter: 26.9464
train	epoch = 17	lr = 0.1000	loss: 1.4533	error: 6282.0000 - valid	validloss: 1.5728	validerror: 1724.0000	s/iter: 26.4836
train	epoch = 18	lr = 0.1000	loss: 1.4234	error: 6176.0000 - valid	validloss: 1.5235	validerror: 1673.0000	s/iter: 26.8015
train	epoch = 19	lr = 0.1000	loss: 1.3263	error: 5714.0000 - valid	validloss: 1.4950	validerror: 1636.0000	s/iter: 25.5398
train	epoch = 20	lr = 0.1000	loss: 1.2868	error: 5519.0000 - valid	validloss: 1.5082	validerror: 1665.0000	s/iter: 25.3900
test				error: 1634.0000			

Figure 8

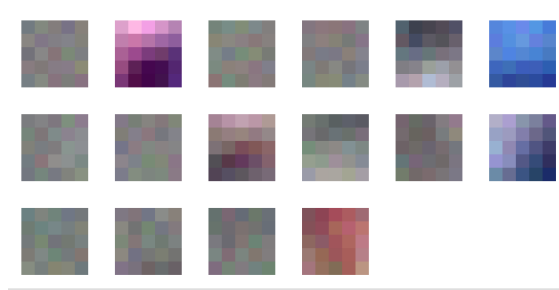


Figure 9: Image of first layer filters

(b) The parameters of the model are as follows:

1. Convolutional Layer ($16((5 \times 5 \times 3) + 1)$) for 16 filters of $5 \times 5 \times 3$ and 1 bias for each = 1216
2. NonLinearity Layer-Tanh (No parameters) = 0
3. MaxPooling Layer (No parameters) = 0
4. Convolutional Layer ($128((5 \times 5 \times 16) + 1)$) for 128 filters of $5 \times 5 \times 16$ and 1 bias for each = 51328

5. NonLinearity Layer-Tanh (No parameters) = 0
 6. MaxPooling Layer (No parameters) = 0
 7. Linear Layer ($64((128 \times 5 \times 5) + 1)$) for 3200 units connected to 64 units each output having 1 bias = 204864
 8. Linear Layer ($10(64 + 1)$) for 64 units connected to 10 units each output having 1 bias = 650
- So, total number of parameters = 258058