

week_1_solution_19_4

March 15, 2018

```
In [1]: import mnist_loader
import numpy as np
import pandas as pd
```

```
training_data, validation_data, test_data = mnist_loader.load_data_wrapper()
print("Training data, validation data and test data loaded.")
```

Training data, validation data and test data loaded.

```
In [10]: import network2
```

```
network2 = reload(network2)
```

```
net2_all_train = network2.Network([784,30, 30, 30, 30, 10], cost=network2.CrossEntropy)
net2_all_train.large_weight_initializer()
```

```
evaluation_cost_all_train, evaluation_accuracy_all_train, training_cost_all_train, tr
    training_data=training_data,
    epochs=30,
    mini_batch_size=10,
    eta=0.0001,
    evaluation_data=test_data,
    lambda=5.0,
    monitor_evaluation_cost=True,
    monitor_evaluation_accuracy=True,
    monitor_training_cost=True,
    monitor_training_accuracy=True
)
```

Epoch 0 training complete

Cost on training data: 2.17971532554

Accuracy on training data: 4814 / 50000

Cost on evaluation data: 7.41736507717

Accuracy on evaluation data: 944 / 10000

Epoch 1 training complete

Cost on training data: 2.52284313722

Accuracy on training data: 5266 / 50000

Cost on evaluation data: 7.73436578679
Accuracy on evaluation data: 1044 / 10000

Epoch 2 training complete
Cost on training data: 2.93264188598
Accuracy on training data: 5453 / 50000
Cost on evaluation data: 8.10973923812
Accuracy on evaluation data: 1052 / 10000

Epoch 3 training complete
Cost on training data: 3.44048667269
Accuracy on training data: 5469 / 50000
Cost on evaluation data: 8.63507449196
Accuracy on evaluation data: 1075 / 10000

Epoch 4 training complete
Cost on training data: 4.09595712395
Accuracy on training data: 5340 / 50000
Cost on evaluation data: 9.28977521597
Accuracy on evaluation data: 1066 / 10000

Epoch 5 training complete
Cost on training data: 4.72141380623
Accuracy on training data: 5396 / 50000
Cost on evaluation data: 9.91649000849
Accuracy on evaluation data: 1089 / 10000

Epoch 6 training complete
Cost on training data: 4.93081909031
Accuracy on training data: 5724 / 50000
Cost on evaluation data: 10.1150933693
Accuracy on evaluation data: 1135 / 10000

Epoch 7 training complete
Cost on training data: 4.83292904002
Accuracy on training data: 5872 / 50000
Cost on evaluation data: 10.0133304704
Accuracy on evaluation data: 1214 / 10000

Epoch 8 training complete
Cost on training data: 4.70336328164
Accuracy on training data: 6194 / 50000
Cost on evaluation data: 9.88046604005
Accuracy on evaluation data: 1264 / 10000

Epoch 9 training complete
Cost on training data: 4.60231133219
Accuracy on training data: 6464 / 50000

Cost on evaluation data: 9.78358083297
Accuracy on evaluation data: 1353 / 10000

Epoch 10 training complete
Cost on training data: 4.4904320701
Accuracy on training data: 6859 / 50000
Cost on evaluation data: 9.67512386394
Accuracy on evaluation data: 1430 / 10000

Epoch 11 training complete
Cost on training data: 4.41928280993
Accuracy on training data: 7727 / 50000
Cost on evaluation data: 9.61802856425
Accuracy on evaluation data: 1624 / 10000

Epoch 12 training complete
Cost on training data: 4.35562572494
Accuracy on training data: 8564 / 50000
Cost on evaluation data: 9.56046508351
Accuracy on evaluation data: 1799 / 10000

Epoch 13 training complete
Cost on training data: 4.33875126426
Accuracy on training data: 8962 / 50000
Cost on evaluation data: 9.53415201847
Accuracy on evaluation data: 1884 / 10000

Epoch 14 training complete
Cost on training data: 4.33668843766
Accuracy on training data: 9391 / 50000
Cost on evaluation data: 9.53346610201
Accuracy on evaluation data: 1962 / 10000

Epoch 15 training complete
Cost on training data: 4.31041866607
Accuracy on training data: 9775 / 50000
Cost on evaluation data: 9.51205968697
Accuracy on evaluation data: 2057 / 10000

Epoch 16 training complete
Cost on training data: 4.3052143865
Accuracy on training data: 10027 / 50000
Cost on evaluation data: 9.48041392611
Accuracy on evaluation data: 2130 / 10000

Epoch 17 training complete
Cost on training data: 4.31148230237
Accuracy on training data: 10420 / 50000

Cost on evaluation data: 9.49608127236
Accuracy on evaluation data: 2214 / 10000

Epoch 18 training complete
Cost on training data: 4.30239025651
Accuracy on training data: 10577 / 50000
Cost on evaluation data: 9.48619734971
Accuracy on evaluation data: 2250 / 10000

Epoch 19 training complete
Cost on training data: 4.30984197081
Accuracy on training data: 10782 / 50000
Cost on evaluation data: 9.48606569389
Accuracy on evaluation data: 2265 / 10000

Epoch 20 training complete
Cost on training data: 4.31400568097
Accuracy on training data: 10889 / 50000
Cost on evaluation data: 9.4949570211
Accuracy on evaluation data: 2261 / 10000

Epoch 21 training complete
Cost on training data: 4.31021233651
Accuracy on training data: 11059 / 50000
Cost on evaluation data: 9.49226165951
Accuracy on evaluation data: 2310 / 10000

Epoch 22 training complete
Cost on training data: 4.30673448448
Accuracy on training data: 11292 / 50000
Cost on evaluation data: 9.48299209405
Accuracy on evaluation data: 2380 / 10000

Epoch 23 training complete
Cost on training data: 4.30928823938
Accuracy on training data: 11451 / 50000
Cost on evaluation data: 9.49010882687
Accuracy on evaluation data: 2384 / 10000

Epoch 24 training complete
Cost on training data: 4.30193215842
Accuracy on training data: 11473 / 50000
Cost on evaluation data: 9.48448183761
Accuracy on evaluation data: 2380 / 10000

Epoch 25 training complete
Cost on training data: 4.30333429687
Accuracy on training data: 11586 / 50000

Cost on evaluation data: 9.47494811464
Accuracy on evaluation data: 2399 / 10000

Epoch 26 training complete
Cost on training data: 4.30264583179
Accuracy on training data: 11674 / 50000
Cost on evaluation data: 9.47620391555
Accuracy on evaluation data: 2403 / 10000

Epoch 27 training complete
Cost on training data: 4.2997244948
Accuracy on training data: 11726 / 50000
Cost on evaluation data: 9.46838922215
Accuracy on evaluation data: 2415 / 10000

Epoch 28 training complete
Cost on training data: 4.30069344476
Accuracy on training data: 11835 / 50000
Cost on evaluation data: 9.46775108168
Accuracy on evaluation data: 2427 / 10000

Epoch 29 training complete
Cost on training data: 4.30392637041
Accuracy on training data: 11864 / 50000
Cost on evaluation data: 9.46621416428
Accuracy on evaluation data: 2419 / 10000

```
In [11]: evaluation_cost_all_train, evaluation_accuracy_all_train, training_cost_all_train, tr
        training_data=training_data,
        epochs=100,
        mini_batch_size=10,
        eta=0.0001,
        evaluation_data=test_data,
        lambda=5.0,
        monitor_evaluation_cost=True,
        monitor_evaluation_accuracy=True,
        monitor_training_cost=True,
        monitor_training_accuracy=True
    )
```

Epoch 0 training complete
Cost on training data: 4.29696942669
Accuracy on training data: 11978 / 50000
Cost on evaluation data: 9.46505333155
Accuracy on evaluation data: 2450 / 10000

Epoch 1 training complete
Cost on training data: 4.29085607386
Accuracy on training data: 12023 / 50000
Cost on evaluation data: 9.45395772865
Accuracy on evaluation data: 2447 / 10000

Epoch 2 training complete
Cost on training data: 4.29755137829
Accuracy on training data: 11959 / 50000
Cost on evaluation data: 9.46226510161
Accuracy on evaluation data: 2437 / 10000

Epoch 3 training complete
Cost on training data: 4.28588793287
Accuracy on training data: 12137 / 50000
Cost on evaluation data: 9.4602965779
Accuracy on evaluation data: 2462 / 10000

Epoch 4 training complete
Cost on training data: 4.28650235854
Accuracy on training data: 12167 / 50000
Cost on evaluation data: 9.46424338734
Accuracy on evaluation data: 2502 / 10000

Epoch 5 training complete
Cost on training data: 4.28655878774
Accuracy on training data: 12248 / 50000
Cost on evaluation data: 9.45677281476
Accuracy on evaluation data: 2506 / 10000

Epoch 6 training complete
Cost on training data: 4.28260631775
Accuracy on training data: 12350 / 50000
Cost on evaluation data: 9.4575776542
Accuracy on evaluation data: 2519 / 10000

Epoch 7 training complete
Cost on training data: 4.28158724257
Accuracy on training data: 12258 / 50000
Cost on evaluation data: 9.44866823356
Accuracy on evaluation data: 2505 / 10000

Epoch 8 training complete
Cost on training data: 4.27970677312
Accuracy on training data: 12364 / 50000
Cost on evaluation data: 9.44733180894
Accuracy on evaluation data: 2542 / 10000

Epoch 9 training complete
Cost on training data: 4.27573327893
Accuracy on training data: 12538 / 50000
Cost on evaluation data: 9.44194569419
Accuracy on evaluation data: 2581 / 10000

Epoch 10 training complete
Cost on training data: 4.27760080985
Accuracy on training data: 12481 / 50000
Cost on evaluation data: 9.43973370686
Accuracy on evaluation data: 2533 / 10000

Epoch 11 training complete
Cost on training data: 4.27404409588
Accuracy on training data: 12527 / 50000
Cost on evaluation data: 9.43997137645
Accuracy on evaluation data: 2538 / 10000

Epoch 12 training complete
Cost on training data: 4.26747756307
Accuracy on training data: 12553 / 50000
Cost on evaluation data: 9.4287428546
Accuracy on evaluation data: 2581 / 10000

Epoch 13 training complete
Cost on training data: 4.27398926938
Accuracy on training data: 12458 / 50000
Cost on evaluation data: 9.43544615437
Accuracy on evaluation data: 2564 / 10000

Epoch 14 training complete
Cost on training data: 4.2703292679
Accuracy on training data: 12645 / 50000
Cost on evaluation data: 9.43243273059
Accuracy on evaluation data: 2581 / 10000

Epoch 15 training complete
Cost on training data: 4.27125354698
Accuracy on training data: 12580 / 50000
Cost on evaluation data: 9.42715298087
Accuracy on evaluation data: 2600 / 10000

Epoch 16 training complete
Cost on training data: 4.27023730564
Accuracy on training data: 12680 / 50000
Cost on evaluation data: 9.42708615404
Accuracy on evaluation data: 2543 / 10000

Epoch 17 training complete
Cost on training data: 4.2665917798
Accuracy on training data: 12756 / 50000
Cost on evaluation data: 9.42141638109
Accuracy on evaluation data: 2601 / 10000

Epoch 18 training complete
Cost on training data: 4.2680779051
Accuracy on training data: 12690 / 50000
Cost on evaluation data: 9.42344148628
Accuracy on evaluation data: 2585 / 10000

Epoch 19 training complete
Cost on training data: 4.27010832103
Accuracy on training data: 12752 / 50000
Cost on evaluation data: 9.42468355338
Accuracy on evaluation data: 2590 / 10000

Epoch 20 training complete
Cost on training data: 4.26860054924
Accuracy on training data: 12676 / 50000
Cost on evaluation data: 9.42645335405
Accuracy on evaluation data: 2587 / 10000

Epoch 21 training complete
Cost on training data: 4.2656870279
Accuracy on training data: 12867 / 50000
Cost on evaluation data: 9.42882020241
Accuracy on evaluation data: 2633 / 10000

Epoch 22 training complete
Cost on training data: 4.26868469731
Accuracy on training data: 12764 / 50000
Cost on evaluation data: 9.43075269712
Accuracy on evaluation data: 2589 / 10000

Epoch 23 training complete
Cost on training data: 4.27493257901
Accuracy on training data: 12677 / 50000
Cost on evaluation data: 9.43353008217
Accuracy on evaluation data: 2577 / 10000

Epoch 24 training complete
Cost on training data: 4.26520358781
Accuracy on training data: 12734 / 50000
Cost on evaluation data: 9.42455784966
Accuracy on evaluation data: 2628 / 10000

Epoch 25 training complete
Cost on training data: 4.261925152
Accuracy on training data: 12873 / 50000
Cost on evaluation data: 9.4211178519
Accuracy on evaluation data: 2614 / 10000

Epoch 26 training complete
Cost on training data: 4.25911383339
Accuracy on training data: 13047 / 50000
Cost on evaluation data: 9.42097600105
Accuracy on evaluation data: 2664 / 10000

Epoch 27 training complete
Cost on training data: 4.26043283779
Accuracy on training data: 12900 / 50000
Cost on evaluation data: 9.4147989307
Accuracy on evaluation data: 2651 / 10000

Epoch 28 training complete
Cost on training data: 4.25514251513
Accuracy on training data: 12930 / 50000
Cost on evaluation data: 9.41067105008
Accuracy on evaluation data: 2681 / 10000

Epoch 29 training complete
Cost on training data: 4.25313034476
Accuracy on training data: 12991 / 50000
Cost on evaluation data: 9.41116436558
Accuracy on evaluation data: 2691 / 10000

Epoch 30 training complete
Cost on training data: 4.25658915789
Accuracy on training data: 12954 / 50000
Cost on evaluation data: 9.40840037281
Accuracy on evaluation data: 2664 / 10000

Epoch 31 training complete
Cost on training data: 4.26227057345
Accuracy on training data: 12924 / 50000
Cost on evaluation data: 9.41448588375
Accuracy on evaluation data: 2668 / 10000

Epoch 32 training complete
Cost on training data: 4.25423525987
Accuracy on training data: 12907 / 50000
Cost on evaluation data: 9.40646027508
Accuracy on evaluation data: 2674 / 10000

Epoch 33 training complete
Cost on training data: 4.25145035239
Accuracy on training data: 13117 / 50000
Cost on evaluation data: 9.40506438796
Accuracy on evaluation data: 2694 / 10000

Epoch 34 training complete
Cost on training data: 4.25011400708
Accuracy on training data: 13130 / 50000
Cost on evaluation data: 9.40122640766
Accuracy on evaluation data: 2690 / 10000

Epoch 35 training complete
Cost on training data: 4.25442433913
Accuracy on training data: 13035 / 50000
Cost on evaluation data: 9.40606113668
Accuracy on evaluation data: 2647 / 10000

Epoch 36 training complete
Cost on training data: 4.2509678864
Accuracy on training data: 13053 / 50000
Cost on evaluation data: 9.4038054889
Accuracy on evaluation data: 2678 / 10000

Epoch 37 training complete
Cost on training data: 4.25103803248
Accuracy on training data: 13106 / 50000
Cost on evaluation data: 9.3992016486
Accuracy on evaluation data: 2667 / 10000

Epoch 38 training complete
Cost on training data: 4.24594113915
Accuracy on training data: 13054 / 50000
Cost on evaluation data: 9.40402050914
Accuracy on evaluation data: 2687 / 10000

Epoch 39 training complete
Cost on training data: 4.25179060135
Accuracy on training data: 13082 / 50000
Cost on evaluation data: 9.40236373239
Accuracy on evaluation data: 2671 / 10000

Epoch 40 training complete
Cost on training data: 4.24938016477
Accuracy on training data: 13123 / 50000
Cost on evaluation data: 9.39900448144
Accuracy on evaluation data: 2664 / 10000

Epoch 41 training complete
Cost on training data: 4.2498696779
Accuracy on training data: 13056 / 50000
Cost on evaluation data: 9.39875279338
Accuracy on evaluation data: 2641 / 10000

Epoch 42 training complete
Cost on training data: 4.24750845775
Accuracy on training data: 13204 / 50000
Cost on evaluation data: 9.39796434878
Accuracy on evaluation data: 2694 / 10000

Epoch 43 training complete
Cost on training data: 4.2423551647
Accuracy on training data: 13184 / 50000
Cost on evaluation data: 9.39267102437
Accuracy on evaluation data: 2729 / 10000

Epoch 44 training complete
Cost on training data: 4.24629351228
Accuracy on training data: 13228 / 50000
Cost on evaluation data: 9.39647055556
Accuracy on evaluation data: 2701 / 10000

Epoch 45 training complete
Cost on training data: 4.24463944729
Accuracy on training data: 13129 / 50000
Cost on evaluation data: 9.39367394069
Accuracy on evaluation data: 2706 / 10000

Epoch 46 training complete
Cost on training data: 4.24926997938
Accuracy on training data: 13246 / 50000
Cost on evaluation data: 9.39880586521
Accuracy on evaluation data: 2692 / 10000

Epoch 47 training complete
Cost on training data: 4.24478953248
Accuracy on training data: 13150 / 50000
Cost on evaluation data: 9.3927802486
Accuracy on evaluation data: 2718 / 10000

Epoch 48 training complete
Cost on training data: 4.2410002575
Accuracy on training data: 13305 / 50000
Cost on evaluation data: 9.39047448152
Accuracy on evaluation data: 2717 / 10000

Epoch 49 training complete
Cost on training data: 4.24450428666
Accuracy on training data: 13241 / 50000
Cost on evaluation data: 9.39146599669
Accuracy on evaluation data: 2675 / 10000

Epoch 50 training complete
Cost on training data: 4.24137844191
Accuracy on training data: 13218 / 50000
Cost on evaluation data: 9.38882330475
Accuracy on evaluation data: 2687 / 10000

Epoch 51 training complete
Cost on training data: 4.24368721112
Accuracy on training data: 13197 / 50000
Cost on evaluation data: 9.38646867452
Accuracy on evaluation data: 2699 / 10000

Epoch 52 training complete
Cost on training data: 4.24559545765
Accuracy on training data: 13247 / 50000
Cost on evaluation data: 9.39066414647
Accuracy on evaluation data: 2686 / 10000

Epoch 53 training complete
Cost on training data: 4.23535379878
Accuracy on training data: 13275 / 50000
Cost on evaluation data: 9.38273309128
Accuracy on evaluation data: 2715 / 10000

Epoch 54 training complete
Cost on training data: 4.23729351518
Accuracy on training data: 13315 / 50000
Cost on evaluation data: 9.38177839265
Accuracy on evaluation data: 2710 / 10000

Epoch 55 training complete
Cost on training data: 4.23649362721
Accuracy on training data: 13434 / 50000
Cost on evaluation data: 9.37853437252
Accuracy on evaluation data: 2738 / 10000

Epoch 56 training complete
Cost on training data: 4.23091671159
Accuracy on training data: 13276 / 50000
Cost on evaluation data: 9.37286952562
Accuracy on evaluation data: 2726 / 10000

Epoch 57 training complete
Cost on training data: 4.24089173749
Accuracy on training data: 13234 / 50000
Cost on evaluation data: 9.38214689552
Accuracy on evaluation data: 2725 / 10000

Epoch 58 training complete
Cost on training data: 4.23279054289
Accuracy on training data: 13388 / 50000
Cost on evaluation data: 9.37698130745
Accuracy on evaluation data: 2709 / 10000

Epoch 59 training complete
Cost on training data: 4.24079051782
Accuracy on training data: 13261 / 50000
Cost on evaluation data: 9.37778770759
Accuracy on evaluation data: 2722 / 10000

Epoch 60 training complete
Cost on training data: 4.23514801406
Accuracy on training data: 13292 / 50000
Cost on evaluation data: 9.37247845067
Accuracy on evaluation data: 2686 / 10000

Epoch 61 training complete
Cost on training data: 4.22621861467
Accuracy on training data: 13460 / 50000
Cost on evaluation data: 9.37192215093
Accuracy on evaluation data: 2752 / 10000

Epoch 62 training complete
Cost on training data: 4.23037934986
Accuracy on training data: 13382 / 50000
Cost on evaluation data: 9.36962000086
Accuracy on evaluation data: 2738 / 10000

Epoch 63 training complete
Cost on training data: 4.23471075675
Accuracy on training data: 13335 / 50000
Cost on evaluation data: 9.3708789704
Accuracy on evaluation data: 2694 / 10000

Epoch 64 training complete
Cost on training data: 4.23909774078
Accuracy on training data: 13260 / 50000
Cost on evaluation data: 9.36929518182
Accuracy on evaluation data: 2724 / 10000

Epoch 65 training complete
Cost on training data: 4.23137542466
Accuracy on training data: 13228 / 50000
Cost on evaluation data: 9.36678694925
Accuracy on evaluation data: 2723 / 10000

Epoch 66 training complete
Cost on training data: 4.22823059594
Accuracy on training data: 13485 / 50000
Cost on evaluation data: 9.36660384942
Accuracy on evaluation data: 2739 / 10000

Epoch 67 training complete
Cost on training data: 4.22689785985
Accuracy on training data: 13433 / 50000
Cost on evaluation data: 9.36050250862
Accuracy on evaluation data: 2764 / 10000

Epoch 68 training complete
Cost on training data: 4.23832456804
Accuracy on training data: 13360 / 50000
Cost on evaluation data: 9.36610683993
Accuracy on evaluation data: 2732 / 10000

Epoch 69 training complete
Cost on training data: 4.22726682744
Accuracy on training data: 13451 / 50000
Cost on evaluation data: 9.36290290563
Accuracy on evaluation data: 2745 / 10000

Epoch 70 training complete
Cost on training data: 4.22452786973
Accuracy on training data: 13610 / 50000
Cost on evaluation data: 9.36228394391
Accuracy on evaluation data: 2748 / 10000

Epoch 71 training complete
Cost on training data: 4.22171691444
Accuracy on training data: 13437 / 50000
Cost on evaluation data: 9.35669645381
Accuracy on evaluation data: 2739 / 10000

Epoch 72 training complete
Cost on training data: 4.22554809107
Accuracy on training data: 13381 / 50000
Cost on evaluation data: 9.35550052517
Accuracy on evaluation data: 2738 / 10000

Epoch 73 training complete
Cost on training data: 4.22839509378
Accuracy on training data: 13372 / 50000
Cost on evaluation data: 9.3593850318
Accuracy on evaluation data: 2733 / 10000

Epoch 74 training complete
Cost on training data: 4.2203226043
Accuracy on training data: 13375 / 50000
Cost on evaluation data: 9.34766318478
Accuracy on evaluation data: 2757 / 10000

Epoch 75 training complete
Cost on training data: 4.22706723913
Accuracy on training data: 13407 / 50000
Cost on evaluation data: 9.36095618963
Accuracy on evaluation data: 2716 / 10000

Epoch 76 training complete
Cost on training data: 4.23528052499
Accuracy on training data: 13407 / 50000
Cost on evaluation data: 9.36647197694
Accuracy on evaluation data: 2743 / 10000

Epoch 77 training complete
Cost on training data: 4.22152750773
Accuracy on training data: 13571 / 50000
Cost on evaluation data: 9.35189632429
Accuracy on evaluation data: 2756 / 10000

Epoch 78 training complete
Cost on training data: 4.22207087959
Accuracy on training data: 13555 / 50000
Cost on evaluation data: 9.3485735312
Accuracy on evaluation data: 2763 / 10000

Epoch 79 training complete
Cost on training data: 4.22280733065
Accuracy on training data: 13447 / 50000
Cost on evaluation data: 9.35181485709
Accuracy on evaluation data: 2728 / 10000

Epoch 80 training complete
Cost on training data: 4.21563226879
Accuracy on training data: 13505 / 50000
Cost on evaluation data: 9.34777916729
Accuracy on evaluation data: 2745 / 10000

Epoch 81 training complete
Cost on training data: 4.23410646212
Accuracy on training data: 13448 / 50000
Cost on evaluation data: 9.35528652921
Accuracy on evaluation data: 2733 / 10000

Epoch 82 training complete
Cost on training data: 4.21511099923
Accuracy on training data: 13578 / 50000
Cost on evaluation data: 9.34188700342
Accuracy on evaluation data: 2778 / 10000

Epoch 83 training complete
Cost on training data: 4.22182703426
Accuracy on training data: 13456 / 50000
Cost on evaluation data: 9.34966264242
Accuracy on evaluation data: 2727 / 10000

Epoch 84 training complete
Cost on training data: 4.21391755957
Accuracy on training data: 13538 / 50000
Cost on evaluation data: 9.34252594043
Accuracy on evaluation data: 2780 / 10000

Epoch 85 training complete
Cost on training data: 4.20909456802
Accuracy on training data: 13501 / 50000
Cost on evaluation data: 9.33765878339
Accuracy on evaluation data: 2769 / 10000

Epoch 86 training complete
Cost on training data: 4.21443649069
Accuracy on training data: 13644 / 50000
Cost on evaluation data: 9.3402519453
Accuracy on evaluation data: 2777 / 10000

Epoch 87 training complete
Cost on training data: 4.22075317602
Accuracy on training data: 13582 / 50000
Cost on evaluation data: 9.34773298881
Accuracy on evaluation data: 2764 / 10000

Epoch 88 training complete
Cost on training data: 4.2131392178
Accuracy on training data: 13569 / 50000
Cost on evaluation data: 9.33887340761
Accuracy on evaluation data: 2776 / 10000

Epoch 89 training complete
Cost on training data: 4.21010498654
Accuracy on training data: 13648 / 50000
Cost on evaluation data: 9.33876252716
Accuracy on evaluation data: 2803 / 10000

Epoch 90 training complete
Cost on training data: 4.20867119382
Accuracy on training data: 13493 / 50000
Cost on evaluation data: 9.3381210174
Accuracy on evaluation data: 2759 / 10000

Epoch 91 training complete
Cost on training data: 4.21576297009
Accuracy on training data: 13536 / 50000
Cost on evaluation data: 9.339869523
Accuracy on evaluation data: 2763 / 10000

Epoch 92 training complete
Cost on training data: 4.21437604974
Accuracy on training data: 13553 / 50000
Cost on evaluation data: 9.33789387592
Accuracy on evaluation data: 2769 / 10000

Epoch 93 training complete
Cost on training data: 4.21631717038
Accuracy on training data: 13524 / 50000
Cost on evaluation data: 9.34172289968
Accuracy on evaluation data: 2789 / 10000

Epoch 94 training complete
Cost on training data: 4.2069284472
Accuracy on training data: 13641 / 50000
Cost on evaluation data: 9.33495685339
Accuracy on evaluation data: 2807 / 10000

Epoch 95 training complete
Cost on training data: 4.20888000229
Accuracy on training data: 13659 / 50000
Cost on evaluation data: 9.33216043044
Accuracy on evaluation data: 2798 / 10000

Epoch 96 training complete
Cost on training data: 4.21368826044
Accuracy on training data: 13437 / 50000
Cost on evaluation data: 9.33480006675
Accuracy on evaluation data: 2756 / 10000

Epoch 97 training complete
Cost on training data: 4.22319592234
Accuracy on training data: 13480 / 50000
Cost on evaluation data: 9.34122885665
Accuracy on evaluation data: 2728 / 10000

Epoch 98 training complete
Cost on training data: 4.21104988904
Accuracy on training data: 13558 / 50000
Cost on evaluation data: 9.33478357333
Accuracy on evaluation data: 2802 / 10000

Epoch 99 training complete
Cost on training data: 4.21963729058
Accuracy on training data: 13614 / 50000
Cost on evaluation data: 9.33822950689
Accuracy on evaluation data: 2783 / 10000

```
In [12]: evaluation_cost_all_train, evaluation_accuracy_all_train, training_cost_all_train, tr
        training_data=training_data,
        epochs=30,
        mini_batch_size=10,
        eta=0.01,
        evaluation_data=test_data,
        lambda=5.0,
        monitor_evaluation_cost=True,
        monitor_evaluation_accuracy=True,
        monitor_training_cost=True,
        monitor_training_accuracy=True
    )
```

Epoch 0 training complete
Cost on training data: 4.19232739948
Accuracy on training data: 11645 / 50000
Cost on evaluation data: 9.27719005168
Accuracy on evaluation data: 2297 / 10000

Epoch 1 training complete
Cost on training data: 4.12177046783
Accuracy on training data: 11990 / 50000
Cost on evaluation data: 9.14920334416
Accuracy on evaluation data: 2487 / 10000

Epoch 2 training complete
Cost on training data: 4.1438668788
Accuracy on training data: 12081 / 50000

Cost on evaluation data: 9.12647013474
Accuracy on evaluation data: 2456 / 10000

Epoch 3 training complete
Cost on training data: 4.02917453998
Accuracy on training data: 13783 / 50000
Cost on evaluation data: 8.96430966948
Accuracy on evaluation data: 2815 / 10000

Epoch 4 training complete
Cost on training data: 4.02168715083
Accuracy on training data: 13177 / 50000
Cost on evaluation data: 8.88735639182
Accuracy on evaluation data: 2659 / 10000

Epoch 5 training complete
Cost on training data: 3.88894557502
Accuracy on training data: 16062 / 50000
Cost on evaluation data: 8.70415102939
Accuracy on evaluation data: 3291 / 10000

Epoch 6 training complete
Cost on training data: 3.89620290466
Accuracy on training data: 15399 / 50000
Cost on evaluation data: 8.67383572388
Accuracy on evaluation data: 3126 / 10000

Epoch 7 training complete
Cost on training data: 3.87522020268
Accuracy on training data: 16815 / 50000
Cost on evaluation data: 8.6105210978
Accuracy on evaluation data: 3386 / 10000

Epoch 8 training complete
Cost on training data: 3.90614197558
Accuracy on training data: 14629 / 50000
Cost on evaluation data: 8.58923719052
Accuracy on evaluation data: 2950 / 10000

Epoch 9 training complete
Cost on training data: 3.81773480118
Accuracy on training data: 16620 / 50000
Cost on evaluation data: 8.43681879883
Accuracy on evaluation data: 3344 / 10000

Epoch 10 training complete
Cost on training data: 3.72933735426
Accuracy on training data: 17615 / 50000

Cost on evaluation data: 8.31148644219
Accuracy on evaluation data: 3524 / 10000

Epoch 11 training complete
Cost on training data: 3.80707417902
Accuracy on training data: 16910 / 50000
Cost on evaluation data: 8.35413736388
Accuracy on evaluation data: 3364 / 10000

Epoch 12 training complete
Cost on training data: 3.72202764828
Accuracy on training data: 14326 / 50000
Cost on evaluation data: 8.2108819072
Accuracy on evaluation data: 2904 / 10000

Epoch 13 training complete
Cost on training data: 3.64450676986
Accuracy on training data: 19146 / 50000
Cost on evaluation data: 8.09608579465
Accuracy on evaluation data: 3844 / 10000

Epoch 14 training complete
Cost on training data: 3.64236768975
Accuracy on training data: 19409 / 50000
Cost on evaluation data: 8.05719895255
Accuracy on evaluation data: 3912 / 10000

Epoch 15 training complete
Cost on training data: 3.63418209026
Accuracy on training data: 15134 / 50000
Cost on evaluation data: 7.98786763818
Accuracy on evaluation data: 3050 / 10000

Epoch 16 training complete
Cost on training data: 3.57665369305
Accuracy on training data: 19651 / 50000
Cost on evaluation data: 7.90190609054
Accuracy on evaluation data: 3943 / 10000

Epoch 17 training complete
Cost on training data: 3.52662443656
Accuracy on training data: 20993 / 50000
Cost on evaluation data: 7.80101499062
Accuracy on evaluation data: 4226 / 10000

Epoch 18 training complete
Cost on training data: 3.47242486007
Accuracy on training data: 21116 / 50000

Cost on evaluation data: 7.71292749068
Accuracy on evaluation data: 4231 / 10000

Epoch 19 training complete
Cost on training data: 3.4362473712
Accuracy on training data: 21661 / 50000
Cost on evaluation data: 7.62234922031
Accuracy on evaluation data: 4359 / 10000

Epoch 20 training complete
Cost on training data: 3.39802678248
Accuracy on training data: 22482 / 50000
Cost on evaluation data: 7.53499251138
Accuracy on evaluation data: 4535 / 10000

Epoch 21 training complete
Cost on training data: 3.47903293584
Accuracy on training data: 20905 / 50000
Cost on evaluation data: 7.58540977805
Accuracy on evaluation data: 4161 / 10000

Epoch 22 training complete
Cost on training data: 3.36484065347
Accuracy on training data: 22389 / 50000
Cost on evaluation data: 7.44667066352
Accuracy on evaluation data: 4454 / 10000

Epoch 23 training complete
Cost on training data: 3.33162213268
Accuracy on training data: 22937 / 50000
Cost on evaluation data: 7.36409323199
Accuracy on evaluation data: 4625 / 10000

Epoch 24 training complete
Cost on training data: 3.31317414218
Accuracy on training data: 22719 / 50000
Cost on evaluation data: 7.29216933693
Accuracy on evaluation data: 4527 / 10000

Epoch 25 training complete
Cost on training data: 3.21177431671
Accuracy on training data: 22251 / 50000
Cost on evaluation data: 7.17042477016
Accuracy on evaluation data: 4463 / 10000

Epoch 26 training complete
Cost on training data: 3.22296335244
Accuracy on training data: 23879 / 50000

Cost on evaluation data: 7.15331787422
Accuracy on evaluation data: 4760 / 10000

Epoch 27 training complete
Cost on training data: 3.20270499705
Accuracy on training data: 22744 / 50000
Cost on evaluation data: 7.08244978086
Accuracy on evaluation data: 4580 / 10000

Epoch 28 training complete
Cost on training data: 3.17371006131
Accuracy on training data: 23196 / 50000
Cost on evaluation data: 7.00259664787
Accuracy on evaluation data: 4609 / 10000

Epoch 29 training complete
Cost on training data: 3.16664407834
Accuracy on training data: 23888 / 50000
Cost on evaluation data: 6.96811279899
Accuracy on evaluation data: 4810 / 10000

```
In [13]: evaluation_cost_all_train, evaluation_accuracy_all_train, training_cost_all_train, tra
        training_data=training_data,
        epochs=30,
        mini_batch_size=10,
        eta=0.1,
        evaluation_data=test_data,
        lambda=5.0,
        monitor_evaluation_cost=True,
        monitor_evaluation_accuracy=True,
        monitor_training_cost=True,
        monitor_training_accuracy=True
    )
```

Epoch 0 training complete
Cost on training data: 3.65149303125
Accuracy on training data: 15303 / 50000
Cost on evaluation data: 7.11039278219
Accuracy on evaluation data: 3072 / 10000

Epoch 1 training complete
Cost on training data: 3.38856180748
Accuracy on training data: 18013 / 50000
Cost on evaluation data: 6.4846352304
Accuracy on evaluation data: 3588 / 10000

Epoch 2 training complete
Cost on training data: 3.07758487402
Accuracy on training data: 23284 / 50000
Cost on evaluation data: 5.89033311694
Accuracy on evaluation data: 4656 / 10000

Epoch 3 training complete
Cost on training data: 2.50481478925
Accuracy on training data: 30103 / 50000
Cost on evaluation data: 5.04137363078
Accuracy on evaluation data: 6033 / 10000

Epoch 4 training complete
Cost on training data: 2.21751396759
Accuracy on training data: 33559 / 50000
Cost on evaluation data: 4.50116846546
Accuracy on evaluation data: 6819 / 10000

Epoch 5 training complete
Cost on training data: 1.8631822104
Accuracy on training data: 36864 / 50000
Cost on evaluation data: 3.95369037517
Accuracy on evaluation data: 7395 / 10000

Epoch 6 training complete
Cost on training data: 1.87417389294
Accuracy on training data: 34182 / 50000
Cost on evaluation data: 3.73895357733
Accuracy on evaluation data: 6871 / 10000

Epoch 7 training complete
Cost on training data: 1.6375864732
Accuracy on training data: 39610 / 50000
Cost on evaluation data: 3.33065520923
Accuracy on evaluation data: 7943 / 10000

Epoch 8 training complete
Cost on training data: 1.45968257476
Accuracy on training data: 40723 / 50000
Cost on evaluation data: 3.00665487983
Accuracy on evaluation data: 8117 / 10000

Epoch 9 training complete
Cost on training data: 1.25339353086
Accuracy on training data: 41773 / 50000
Cost on evaluation data: 2.64748046749
Accuracy on evaluation data: 8383 / 10000

Epoch 10 training complete
Cost on training data: 1.22987378023
Accuracy on training data: 42469 / 50000
Cost on evaluation data: 2.48914223358
Accuracy on evaluation data: 8517 / 10000

Epoch 11 training complete
Cost on training data: 1.22127016603
Accuracy on training data: 43015 / 50000
Cost on evaluation data: 2.36032919788
Accuracy on evaluation data: 8603 / 10000

Epoch 12 training complete
Cost on training data: 0.997059517608
Accuracy on training data: 43555 / 50000
Cost on evaluation data: 2.03106852877
Accuracy on evaluation data: 8713 / 10000

Epoch 13 training complete
Cost on training data: 1.03180891142
Accuracy on training data: 44015 / 50000
Cost on evaluation data: 1.95907044751
Accuracy on evaluation data: 8782 / 10000

Epoch 14 training complete
Cost on training data: 0.937523272893
Accuracy on training data: 44420 / 50000
Cost on evaluation data: 1.78126022115
Accuracy on evaluation data: 8861 / 10000

Epoch 15 training complete
Cost on training data: 0.876346819366
Accuracy on training data: 44683 / 50000
Cost on evaluation data: 1.64809530295
Accuracy on evaluation data: 8917 / 10000

Epoch 16 training complete
Cost on training data: 0.924274340071
Accuracy on training data: 44919 / 50000
Cost on evaluation data: 1.61586679339
Accuracy on evaluation data: 8935 / 10000

Epoch 17 training complete
Cost on training data: 0.768316702065
Accuracy on training data: 45238 / 50000
Cost on evaluation data: 1.4065806939
Accuracy on evaluation data: 9008 / 10000

Epoch 18 training complete
Cost on training data: 0.758379981298
Accuracy on training data: 45552 / 50000
Cost on evaluation data: 1.33343806047
Accuracy on evaluation data: 9050 / 10000

Epoch 19 training complete
Cost on training data: 0.707865420725
Accuracy on training data: 45848 / 50000
Cost on evaluation data: 1.23024619567
Accuracy on evaluation data: 9112 / 10000

Epoch 20 training complete
Cost on training data: 0.707590517077
Accuracy on training data: 46031 / 50000
Cost on evaluation data: 1.18622871368
Accuracy on evaluation data: 9139 / 10000

Epoch 21 training complete
Cost on training data: 0.724551208891
Accuracy on training data: 46127 / 50000
Cost on evaluation data: 1.16326428536
Accuracy on evaluation data: 9154 / 10000

Epoch 22 training complete
Cost on training data: 0.616778270432
Accuracy on training data: 46318 / 50000
Cost on evaluation data: 1.01222529436
Accuracy on evaluation data: 9203 / 10000

Epoch 23 training complete
Cost on training data: 0.591224943354
Accuracy on training data: 46459 / 50000
Cost on evaluation data: 0.967196483217
Accuracy on evaluation data: 9197 / 10000

Epoch 24 training complete
Cost on training data: 0.579290091045
Accuracy on training data: 46578 / 50000
Cost on evaluation data: 0.920097250051
Accuracy on evaluation data: 9244 / 10000

Epoch 25 training complete
Cost on training data: 0.539146934199
Accuracy on training data: 46755 / 50000
Cost on evaluation data: 0.848639439209
Accuracy on evaluation data: 9277 / 10000

Epoch 26 training complete
Cost on training data: 0.523217774332
Accuracy on training data: 46984 / 50000
Cost on evaluation data: 0.812172773051
Accuracy on evaluation data: 9329 / 10000

Epoch 27 training complete
Cost on training data: 0.610264951041
Accuracy on training data: 47005 / 50000
Cost on evaluation data: 0.867424663119
Accuracy on evaluation data: 9331 / 10000

Epoch 28 training complete
Cost on training data: 0.503864455239
Accuracy on training data: 47097 / 50000
Cost on evaluation data: 0.74684627131
Accuracy on evaluation data: 9348 / 10000

Epoch 29 training complete
Cost on training data: 0.433928954526
Accuracy on training data: 47331 / 50000
Cost on evaluation data: 0.659623254631
Accuracy on evaluation data: 9382 / 10000