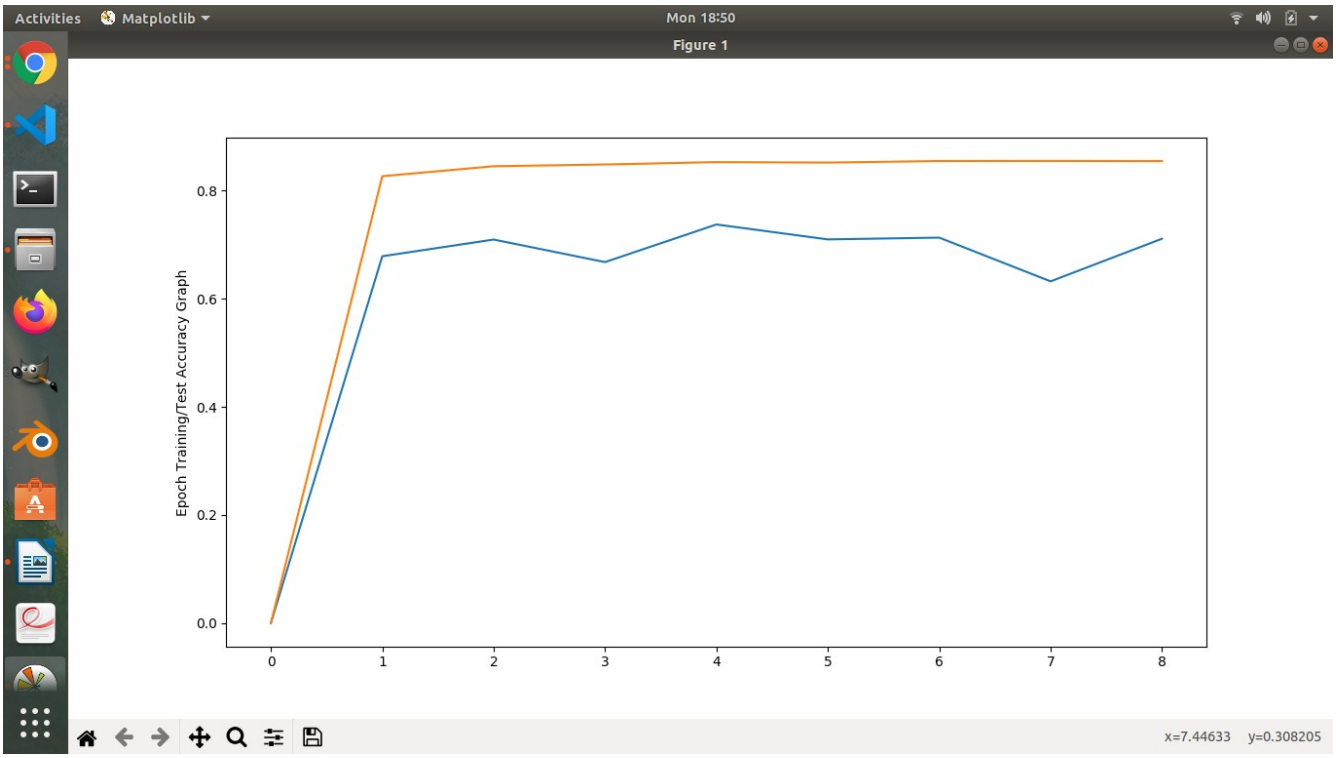
Berin Hadziabdic

The target accuracy for all learning rates in this report is 0.855. The network seemed to be incapable of exceeding 0.86 as a threshold, in most cases. The report for all three learning rates is consolidated into one report for the sake of brevity.

**Learning Rate = 0.1**




**Confusion Matrices:**

**Training Matrix**

[[4.9649e+04 1.3000e+01 5.3400e+02 2.8800e+02 1.4000e+02 1.1960e+03
5.5700e+02 1.5400e+02 5.8700e+02 1.8900e+02]
[2.2000e+01 5.6058e+04 1.0200e+03 5.9700e+02 1.2100e+02 4.4900e+02
9.8000e+01 3.6000e+02 1.7890e+03 1.6400e+02]
[4.7500e+02 8.2100e+02 4.4983e+04 1.7870e+03 6.9900e+02 4.8200e+02
1.0480e+03 7.4700e+02 2.1850e+03 3.9500e+02]
[3.5700e+02 3.4800e+02 1.8690e+03 4.5357e+04 1.3800e+02 3.1860e+03
3.0400e+02 6.6800e+02 1.9310e+03 1.0210e+03]
[1.7800e+02 2.4500e+02 5.1400e+02 2.3200e+02 4.5167e+04 5.1700e+02
7.5000e+02 5.9800e+02 9.6300e+02 3.4140e+03]
[7.2600e+02 3.1700e+02 6.7100e+02 2.7950e+03 8.5100e+02 3.8118e+04
1.1220e+03 2.9700e+02 2.9650e+03 9.2700e+02]
[5.0900e+02 2.1500e+02 1.2910e+03 1.0900e+02 7.0600e+02 1.2110e+03
4.8255e+04 1.0300e+02 7.4700e+02 1.1600e+02]
[2.3600e+02 2.5700e+02 8.0400e+02 8.1700e+02 6.9500e+02 3.4300e+02

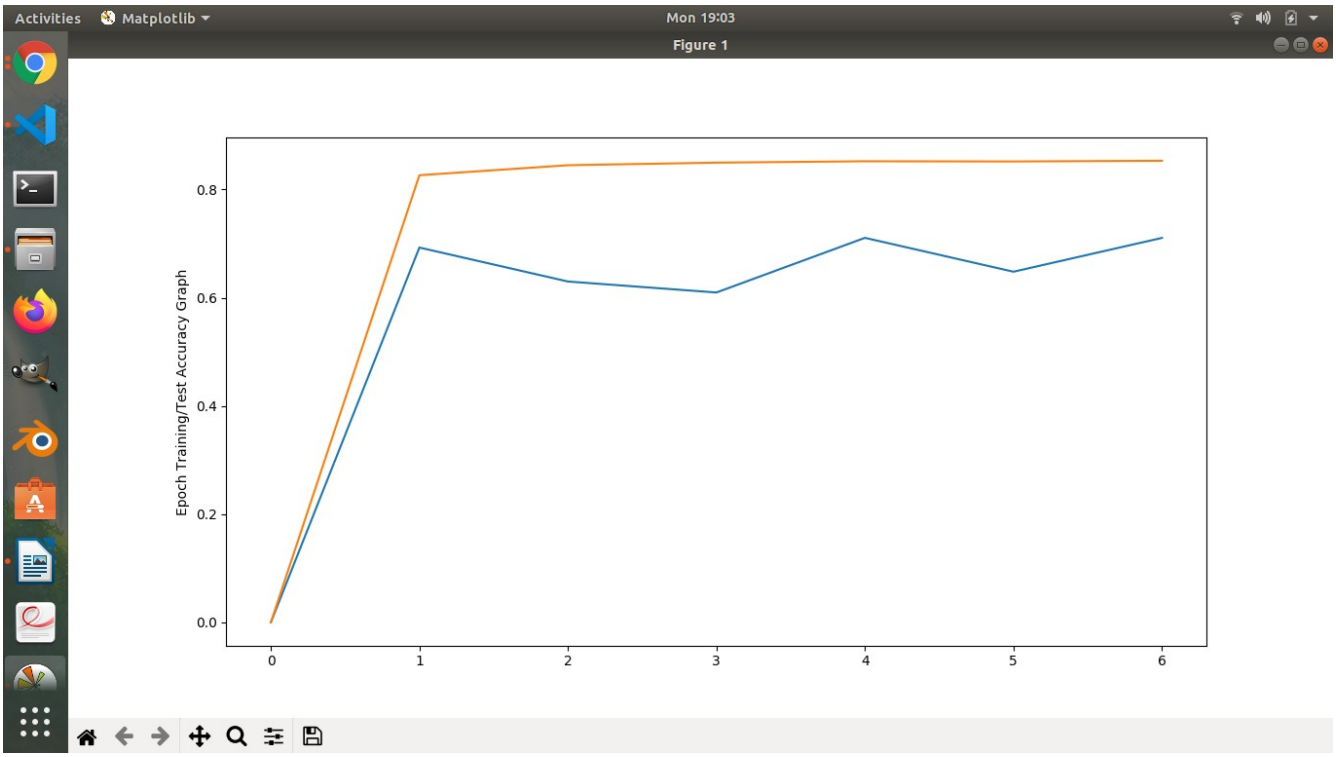
5.1000e+01 4.8917e+04 3.2600e+02 3.9390e+03]
[4.9000e+02 1.3200e+03 1.8200e+03 2.2860e+03 6.5200e+02 3.0070e+03
6.2800e+02 3.6900e+02 4.0393e+04 1.6940e+03]
[3.1100e+02 3.7300e+02 3.5400e+02 1.1810e+03 3.1610e+03 1.0860e+03
6.4000e+01 3.5480e+03 1.5700e+03 4.1893e+04]]

## Testing Matrix

[[8.561e+03 0.000e+00 1.000e+00 2.000e+01 0.000e+00 0.000e+00 4.300e+01
2.000e+00 1.830e+02 1.000e+01]
[1.000e+00 5.918e+03 4.000e+00 4.790e+02 1.200e+01 0.000e+00 3.100e+01
2.000e+00 3.543e+03 2.250e+02]
[1.930e+02 1.900e+02 5.204e+03 1.225e+03 3.200e+01 4.000e+00 4.910e+02
1.000e+01 1.810e+03 1.290e+02]
[1.040e+02 5.000e+00 4.500e+01 8.260e+03 5.000e+00 2.100e+01 5.600e+01
3.200e+01 4.470e+02 1.150e+02]
[9.400e+01 1.000e+00 2.400e+01 4.600e+01 5.492e+03 0.000e+00 3.680e+02
1.000e+00 1.070e+03 1.742e+03]
[3.920e+02 9.000e+00 1.600e+01 1.243e+03 9.100e+01 1.331e+03 2.600e+02
4.800e+01 4.241e+03 3.970e+02]
[1.480e+02 1.400e+01 2.000e+00 7.000e+00 9.000e+00 6.000e+00 8.116e+03
1.000e+00 3.170e+02 2.000e+00]
[1.230e+02 1.800e+01 8.200e+01 4.640e+02 8.900e+01 1.000e+00 2.200e+01
5.173e+03 1.021e+03 2.259e+03]
[8.300e+01 2.300e+01 1.500e+01 5.350e+02 6.900e+01 1.000e+00 9.100e+01
1.100e+01 7.737e+03 2.010e+02]
[9.200e+01 1.000e+00 6.000e+00 1.820e+02 4.000e+01 0.000e+00 3.500e+01
3.500e+01 7.260e+02 7.964e+03]]

Berin Hadziabdic

## Learning Rate = 0.01




## Training Matrix

[[3.8581e+04 9.0000e+00 4.1200e+02 2.3400e+02 1.1100e+02 9.5100e+02
  4.0100e+02 1.1600e+02 4.7800e+02 1.6800e+02]
 [1.7000e+01 4.3508e+04 7.9800e+02 4.9000e+02 8.6000e+01 3.6500e+02
  8.8000e+01 2.9400e+02 1.4330e+03 1.1500e+02]
 [3.9000e+02 6.4300e+02 3.4955e+04 1.4500e+03 5.4600e+02 3.7700e+02
  8.4000e+02 5.8300e+02 1.6250e+03 2.9700e+02]
 [2.4500e+02 2.8300e+02 1.5040e+03 3.5256e+04 1.0500e+02 2.5030e+03
  2.3100e+02 5.1400e+02 1.5300e+03 7.4600e+02]
 [1.4400e+02 1.8300e+02 4.3400e+02 2.1700e+02 3.4998e+04 3.8000e+02
  5.8900e+02 4.5300e+02 7.3600e+02 2.7600e+03]
 [5.8500e+02 2.6600e+02 5.2300e+02 2.1850e+03 6.5400e+02 2.9511e+04
  9.1100e+02 2.4400e+02 2.3550e+03 7.1300e+02]
 [4.0900e+02 1.7500e+02 9.6500e+02 1.0000e+02 5.6000e+02 9.7000e+02
  3.7512e+04 7.8000e+01 5.5500e+02 1.0200e+02]
 [1.9200e+02 2.4300e+02 5.9900e+02 6.3900e+02 5.4400e+02 2.6400e+02
  4.3000e+01 3.8019e+04 2.8400e+02 3.0280e+03]
 [3.9200e+02 1.0800e+03 1.3800e+03 1.8600e+03 4.8400e+02 2.3400e+03
  4.9400e+02 2.6500e+02 3.1289e+04 1.3730e+03]
 [2.4700e+02 2.9000e+02 2.4900e+02 9.4400e+02 2.4950e+03 8.1500e+02
  4.9000e+01 2.7920e+03 1.2970e+03 3.2465e+04]]

## Testing Matrix

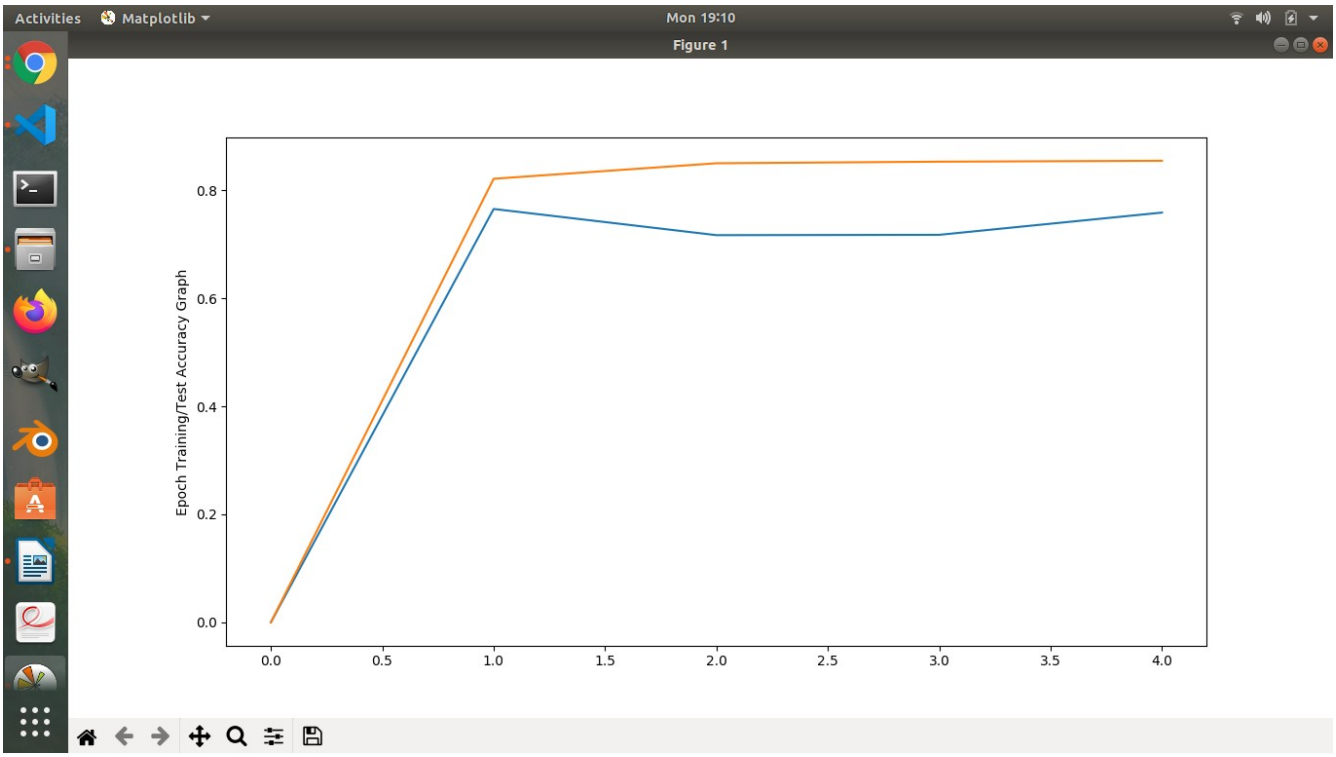
[[6.586e+03 0.000e+00 2.000e+00 1.600e+01 0.000e+00 0.000e+00 4.300e+01
  2.000e+00 2.060e+02 5.000e+00]

Berin Hadziabdic

[1.000e+00 3.694e+03 2.000e+00 4.850e+02 2.000e+00 0.000e+00 2.600e+01
 1.000e+00 3.639e+03 9.500e+01]
[1.840e+02 1.000e+02 3.778e+03 1.013e+03 1.000e+01 3.000e+00 4.170e+02
 7.000e+00 1.629e+03 8.300e+01]
[7.300e+01 2.000e+00 2.900e+01 6.360e+03 1.000e+00 4.000e+00 4.000e+01
 2.100e+01 4.200e+02 1.200e+02]
[8.400e+01 0.000e+00 2.400e+01 8.300e+01 3.184e+03 0.000e+00 4.380e+02
 0.000e+00 1.203e+03 1.858e+03]
[2.210e+02 5.000e+00 1.300e+01 8.810e+02 3.900e+01 8.170e+02 2.120e+02
 3.000e+01 3.679e+03 3.470e+02]
[1.220e+02 6.000e+00 3.000e+00 3.000e+00 2.000e+00 4.000e+00 6.251e+03
 0.000e+00 3.100e+02 5.000e+00]
[8.400e+01 1.200e+01 4.200e+01 4.230e+02 3.200e+01 1.000e+00 1.900e+01
 3.995e+03 9.890e+02 1.599e+03]
[4.400e+01 1.100e+01 1.000e+00 4.080e+02 3.100e+01 0.000e+00 7.200e+01
 2.000e+00 6.144e+03 1.050e+02]
[5.900e+01 1.000e+00 1.000e+00 1.580e+02 3.000e+00 1.000e+00 2.800e+01
 1.400e+01 6.700e+02 6.128e+03]]

Berin Hadziabdic

## Learning Rate = 0.001




## Confusion Matrices

## Training  Matrix:

[[2.7450e+04 1.1000e+01 3.2300e+02 1.7400e+02 7.1000e+01 6.8600e+02
  3.0900e+02 9.5000e+01 3.5900e+02 1.3700e+02]
 [1.8000e+01 3.1219e+04 5.5700e+02 2.9700e+02 7.0000e+01 2.5200e+02
  6.4000e+01 2.1600e+02 9.3900e+02 7.8000e+01]
 [2.9500e+02 4.2400e+02 2.4764e+04 1.0250e+03 4.0500e+02 3.2600e+02
  6.3300e+02 4.2200e+02 1.2430e+03 2.5300e+02]
 [2.0900e+02 1.7300e+02 1.0540e+03 2.5165e+04 7.3000e+01 1.7720e+03
  1.5200e+02 3.8500e+02 1.0620e+03 6.1000e+02]
 [1.1000e+02 1.2500e+02 3.3400e+02 1.6700e+02 2.5007e+04 2.7800e+02
  4.6200e+02 2.9600e+02 5.4100e+02 1.8900e+03]
 [4.8700e+02 1.5000e+02 3.9100e+02 1.5350e+03 4.9900e+02 2.1021e+04
  6.4200e+02 1.9000e+02 1.6540e+03 5.3600e+02]
 [2.8900e+02 1.1600e+02 7.3300e+02 9.6000e+01 4.1300e+02 6.9400e+02
  2.6655e+04 5.1000e+01 4.5100e+02 9.2000e+01]
 [1.5400e+02 1.9100e+02 4.3700e+02 4.8800e+02 3.5200e+02 2.5700e+02
  3.5000e+01 2.7160e+04 2.4500e+02 2.0060e+03]
 [2.7100e+02 6.5700e+02 9.8200e+02 1.3390e+03 2.8500e+02 1.7440e+03
  3.3100e+02 2.0200e+02 2.2451e+04 9.9300e+02]

Berin Hadziabdic

[1.9000e+02 1.9000e+02 2.2300e+02 6.8500e+02 1.7430e+03 6.1700e+02
4.1000e+01 1.8070e+03 9.5400e+02 2.3295e+04]]

**Test Matrix:**

[[4.765e+03 0.000e+00 0.000e+00 1.100e+01 0.000e+00 1.000e+00 2.000e+01
5.000e+00 9.400e+01 4.000e+00]
[1.000e+00 3.931e+03 3.000e+00 4.100e+01 0.000e+00 0.000e+00 1.500e+01
1.000e+00 1.683e+03 0.000e+00]
[1.270e+02 1.150e+02 3.000e+03 3.820e+02 4.100e+01 2.000e+00 2.310e+02
4.000e+00 1.215e+03 4.300e+01]
[5.100e+01 9.000e+00 2.400e+01 4.378e+03 3.000e+00 9.000e+00 2.800e+01
2.800e+01 4.820e+02 3.800e+01]
[3.100e+01 5.000e+00 2.000e+01 9.000e+00 3.571e+03 0.000e+00 1.080e+02
1.000e+00 6.380e+02 5.270e+02]
[1.630e+02 1.100e+01 1.200e+01 5.040e+02 7.600e+01 4.990e+02 1.330e+02
1.800e+01 2.906e+03 1.380e+02]
[1.180e+02 1.000e+01 7.000e+00 6.000e+00 2.000e+01 4.000e+00 4.298e+03
1.000e+00 3.200e+02 6.000e+00]
[7.600e+01 2.100e+01 6.800e+01 2.550e+02 6.300e+01 2.000e+00 1.200e+01
2.934e+03 8.590e+02 8.500e+02]
[2.600e+01 2.800e+01 5.000e+00 1.280e+02 3.900e+01 0.000e+00 3.400e+01
8.000e+00 4.579e+03 2.300e+01]
[5.600e+01 1.000e+01 7.000e+00 7.200e+01 5.200e+01 0.000e+00 1.300e+01
1.100e+01 8.530e+02 3.971e+03]]

Report:

**The network reached 0.855 accuracy in eight epochs for learning parameter of 0.1. The network reached 0.855 accuracy in six epochs for learning of 0.01. The network reached 0.855 accuracy in four epochs with a training parameter of size 0.001. Though not shown in the data and plots above, the network reached 0.855 accuracy in ten epochs with a training parameter of size 0.0001. Given the enumerated gradient step scaling options, it seems 0.001 is the optimal scaling parameter for the set of all error surfaces of this specific problem.**

**The batch sizes for weight updates were of size one. The testing accuracy is observably higher than the training accuracy by an approximate average delta of 0.1. A quick glance at the rows of the confusion matrices reinforces the idea that the network is correctly classifying labels as corresponding label columns are orders of magnitude higher than their very envious row neighbors. Network classification performance skyrockets during the first epoch but tapers off asymptotically in succeeding epochs. Number Pie, yumm, was used to build, train, and test the network.**