raport

December 28, 2023

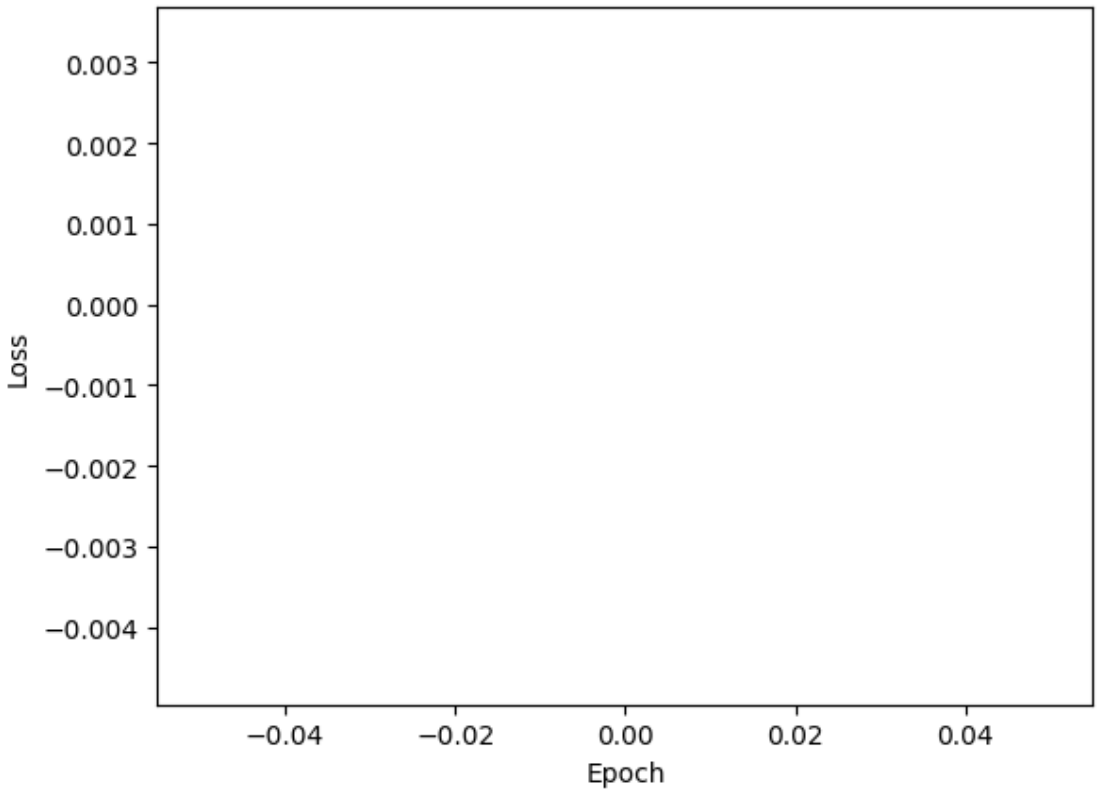
1 Lab 5: Sieci neuronowe

[3]:
```
from sklearn.datasets import load_digits
from sklearn.model_selection import train_test_split
from wsilib.algorithms.nn.nn import NNC, Layer, OutputLayer
import numpy as np
```

1.1 Trenowanie Mnist

[4]:
```
digits = load_digits()
X = digits.data
y = digits.target

# scale the data to be in the range [-1, 1]

X = X / 8 - 1

# make y into a one-hot vector
y = np.eye(10)[y]

X_train, X_test, y_train, y_test = train_test_split(X, y, random_state=0)

clf = NNC(
    layers=[
        Layer(64),
        Layer(32),
        Layer(16),
        OutputLayer(10),
    ],
    learning_rate=0.1,
)

clf.train(X_train, y_train, epochs=100)

result = clf.score(X_test, y_test)
result.plot_confusion_matrix()
print(result)
```

```
EpochLog(epoch=0, loss=array([-4.92049049e-05,  2.76994652e-04, -3.61358262e-03,
1.72942423e-03,
       -4.56730191e-03,  5.06158318e-04,  3.29327653e-03,  1.10064061e-03,
        3.05787253e-03,  2.77795351e-03]))
```




```
EpochLog(epoch=1, loss=array([ 0.00432159,  0.00010845, -0.00089285,
0.00058466, -0.00384397,
        0.00089989, -0.00027503, -0.00023447,  0.00010414, -0.00328755]))
EpochLog(epoch=2, loss=array([ 3.62780273e-03, -3.07975723e-03, -2.34271452e-03,
-9.74851673e-05,
        2.75527021e-03, -9.04258166e-04,  1.82283965e-03, -8.63727453e-04,
        8.95884549e-03,  1.31398537e-03]))
EpochLog(epoch=3, loss=array([ 0.0037993 , -0.00209669,  0.0026293 ,
0.00293705, -0.00066134,
       -0.00309668,  0.00226746,  0.00284967,  0.00018584,  0.00234122]))
EpochLog(epoch=4, loss=array([-0.00240747, -0.00111948, -0.00014587,
0.00310966, -0.00223612,
        0.00099639,  0.00216787, -0.00436914,  0.00185633,  0.00197888]))
EpochLog(epoch=5, loss=array([ 0.00209413, -0.00119234,  0.00481535,
0.00196314, -0.0001322 ,
        0.00325806, -0.00211394,  0.0039804 , -0.00268714,  0.00492634]))
EpochLog(epoch=6, loss=array([-0.00178781,  0.00206071, -0.00251344,
```

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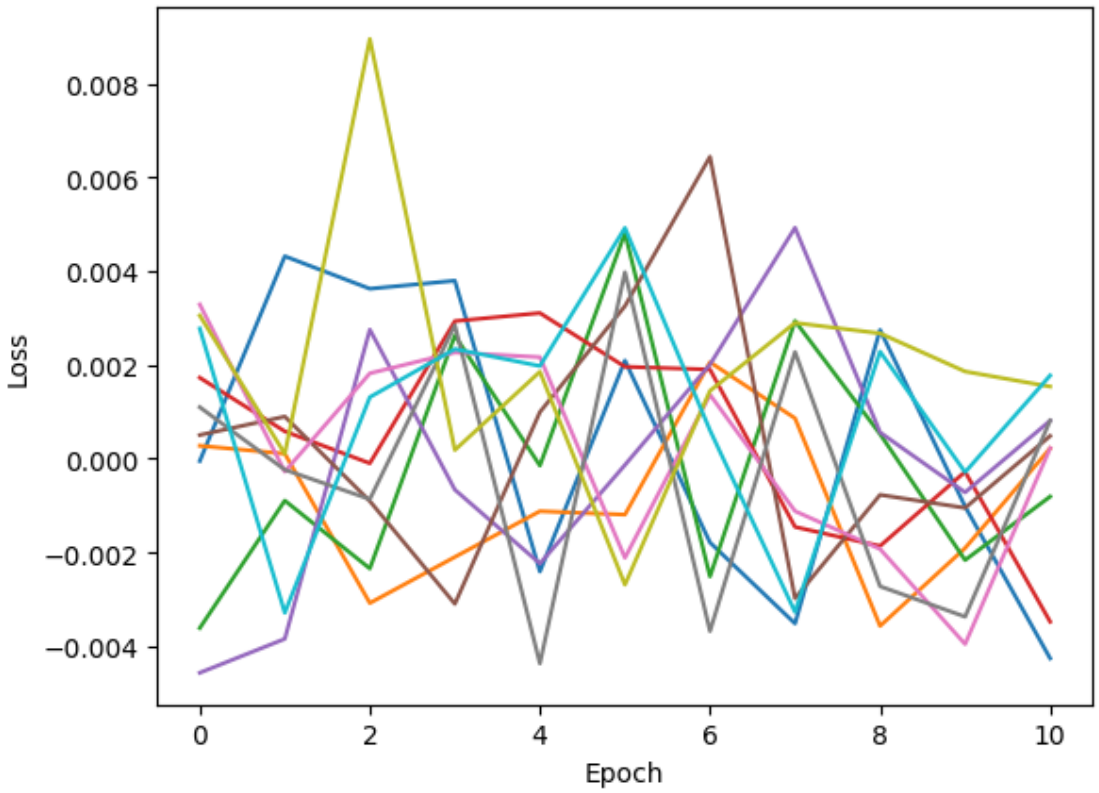
0.00190438,  0.00201197,
        0.00644491,  0.00136726, -0.00368078,  0.00144998,  0.00060643]))
EpochLog(epoch=7, loss=array([-0.00351601,  0.00086437,  0.00294064, -0.0014549
,  0.00493024,
       -0.00297788, -0.00111775,  0.00227951,  0.00289999, -0.00327048]))
EpochLog(epoch=8, loss=array([ 0.00274929, -0.00356819,  0.00052672,
-0.00186212,  0.00056187,
       -0.00077005, -0.00192664, -0.00272245,  0.00267544,  0.00228613]))
EpochLog(epoch=9, loss=array([-0.00101948, -0.00190647, -0.00216293,
-0.00027723, -0.00071735,
       -0.00104921, -0.00395502, -0.0033708 ,  0.00186199, -0.00028727]))
EpochLog(epoch=10, loss=array([-0.00425984,  0.00022222, -0.00080737,
-0.00347722,  0.00081185,
        0.00048612,  0.000226  ,  0.00081492,  0.00154041,  0.00177655]))
```




```
EpochLog(epoch=11, loss=array([ 0.0010528 ,  0.00082844, -0.00413729,
-0.00276403,  0.00010343,
       -0.00106943, -0.00263995, -0.00034722,  0.00034775, -0.00052355]))
EpochLog(epoch=12, loss=array([-0.00056878, -0.00104755, -0.00029422,
-0.00114739,  0.00076506,
       -0.00373635, -0.00267072,  0.00159056, -0.00114393, -0.00231435]))
EpochLog(epoch=13, loss=array([-0.00025165,  0.00109613, -0.00030203,
```

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-0.00190977,  0.00222276,
       -0.00394703,  0.00028202, -0.00094075,  0.00107823,  0.00145146]))
EpochLog(epoch=14, loss=array([ 0.00379314, -0.00188752, -0.00515709,
-0.00152137, -0.00177174,
       -0.00266194, -0.0015674 ,  0.00251264,  0.00125664, -0.00027421]))
EpochLog(epoch=15, loss=array([ 0.00129155, -0.0019231 , -0.00227914,
0.00101645,  0.00118811,
        0.00303858,  0.00243656,  0.00180169,  0.00026323, -0.00251447]))
EpochLog(epoch=16, loss=array([ 0.00167337, -0.00151239,  0.00427578,
0.00069322,  0.00263632,
       -0.00235146, -0.00120246,  0.00174227,  0.00376743,  0.00815937]))
EpochLog(epoch=17, loss=array([ 3.05462714e-03,  2.15432454e-03,
6.97403214e-05, -5.31286170e-04,
       -2.14018670e-03, -4.63994336e-04,  1.78334575e-03,  3.00420183e-03,
       -3.64667334e-03, -1.10414311e-03]))
EpochLog(epoch=18, loss=array([ 0.00211417, -0.00168028, -0.00466875,
-0.00068599, -0.00116214,
        0.00123997,  0.0005792 , -0.00048749, -0.00028811, -0.00144432]))
EpochLog(epoch=19, loss=array([-0.00154591, -0.00098487, -0.00338034,
0.00053181, -0.00234343,
       -0.00377984,  0.00706698,  0.00269623, -0.00111647, -0.0021634 ]))
EpochLog(epoch=20, loss=array([-4.95292610e-04, -3.93081743e-04,
-2.56251146e-03, -4.84085779e-04,
        3.10946002e-03, -1.45888953e-03,  7.28932187e-05, -3.64579277e-03,
       -2.83405030e-03, -3.69014867e-03]))
```

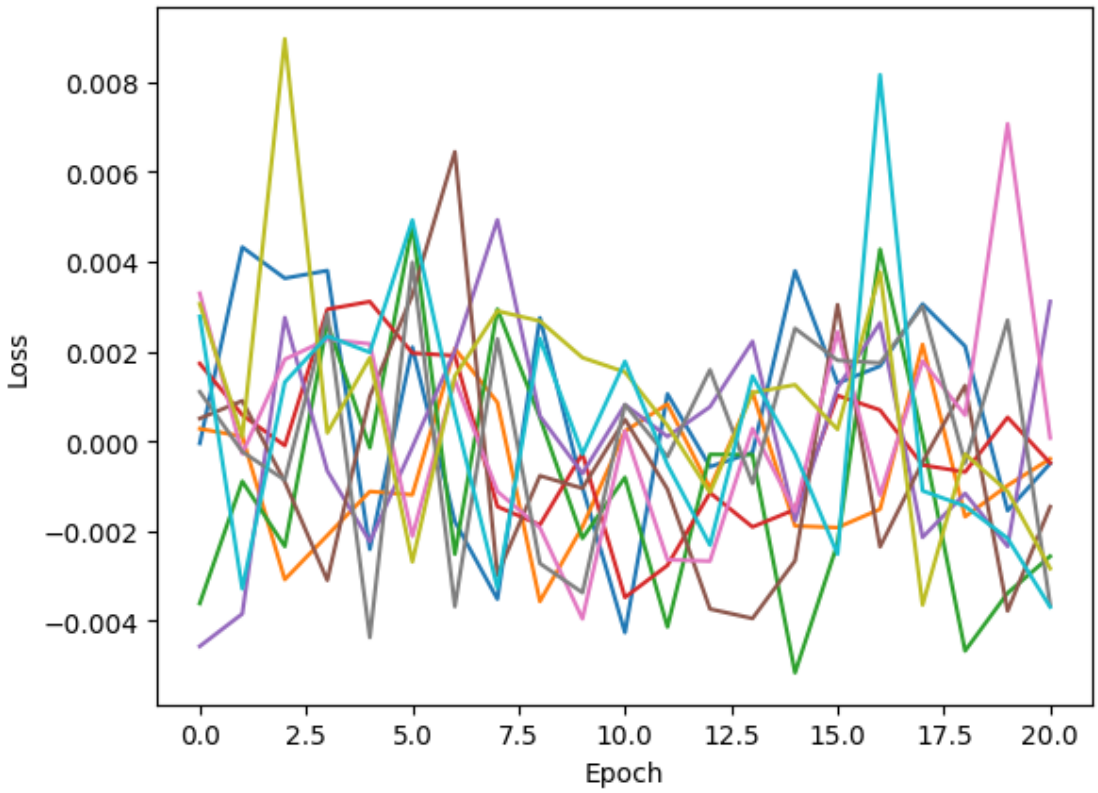


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EpochLog(epoch=21, loss=array([ 0.00248816, -0.00060168,  0.00108222,
0.00084948,  0.00206445,
        0.00089593, -0.00138167,  0.00150978,  0.00062144, -0.0035332 ]))
EpochLog(epoch=22, loss=array([-0.00045215, -0.00010729,  0.00082692,
-0.00364257,  0.00143547,
        0.00280931, -0.00015691, -0.00155249, -0.00383114, -0.00442053]))
EpochLog(epoch=23, loss=array([ 0.00114729, -0.00047017, -0.00366913, -0.0031365
,  0.00194833,
        0.00242076,  0.00154524, -0.00146102, -0.00568575,  0.00090657]))
EpochLog(epoch=24, loss=array([ 0.00042382, -0.0042324 ,  0.00413122,
0.00050264, -0.00238252,
       -0.00055014,  0.00017231,  0.00016291,  0.000865  , -0.0045472 ]))
EpochLog(epoch=25, loss=array([ 1.23674755e-03, -1.83703284e-03,
1.44444403e-03,  6.10870242e-03,
        3.15675805e-04,  3.87968320e-04,  1.99490028e-03, -4.46966219e-03,
        9.18656845e-05,  6.66283043e-04]))
EpochLog(epoch=26, loss=array([ 1.21981420e-03,  4.55234121e-03,
-2.41228817e-04, -7.09215631e-04,
       -4.14117304e-04,  1.75653790e-03,  6.48866340e-04, -7.73328755e-04,
        8.14253153e-04, -6.73505310e-05]))
EpochLog(epoch=27, loss=array([-0.00010156,  0.00255014, -0.00098274,
0.00079434, -0.00021671,
```

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        0.00134606,  0.00058559, -0.00053437, -0.00372546,  0.00125325]))
EpochLog(epoch=28, loss=array([-1.35458538e-03, -1.64768287e-03,
2.57817003e-03,  5.10212649e-05,
       -4.32535179e-03, -1.16048707e-04,  1.36537299e-03, -3.39909465e-03,
        4.66453802e-03,  1.58625003e-03]))
EpochLog(epoch=29, loss=array([-0.00369196,  0.00479237, -0.00077579,
-0.00248944, -0.00181052,
        0.00097019,  0.00173125,  0.00023321, -0.0032679 ,  0.00099221]))
EpochLog(epoch=30, loss=array([ 0.0003442 , -0.00206439,  0.00085312,
0.00047066,  0.00484195,
        0.00117664, -0.00350005,  0.00463401, -0.00083647, -0.00099032]))
```

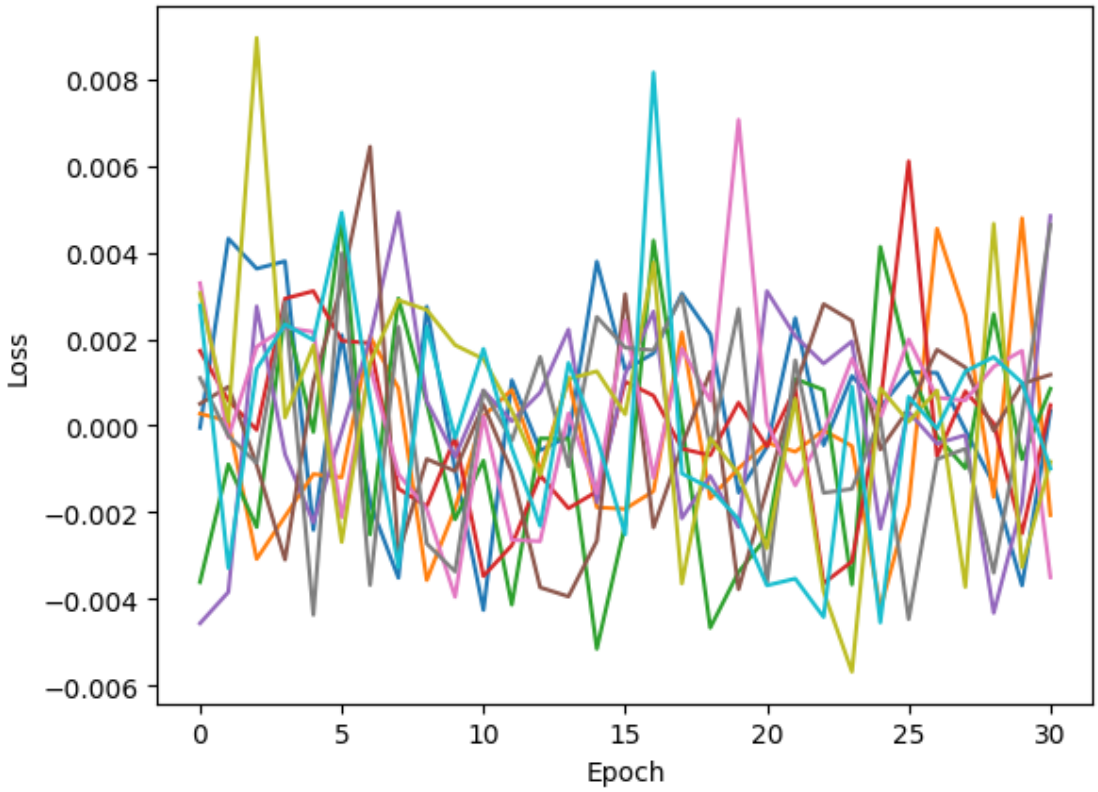


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EpochLog(epoch=31, loss=array([ 0.00013534, -0.00099228, -0.00185123,
-0.00114826,  0.00231753,
        0.00050053,  0.00070332, -0.00156952,  0.00204849, -0.00074731]))
EpochLog(epoch=32, loss=array([ 1.14082936e-03, -2.20761035e-04,
2.35266428e-03, -3.45109595e-03,
        5.36150946e-03, -3.67190758e-03,  1.39702695e-03,  3.17460747e-05,
        6.33600869e-04,  2.03427495e-03]))
EpochLog(epoch=33, loss=array([ 1.73458657e-03, -1.27750315e-03,
4.02568600e-03,  1.01030241e-03,
        6.90126047e-05, -3.61716083e-03, -7.77673583e-03, -2.82062206e-03,
```

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        3.45088929e-03,  2.07318514e-03]))
EpochLog(epoch=34, loss=array([-0.00040212, -0.00231439, -0.0030697 ,
-0.00068746,  0.00775759,
       -0.00021876,  0.00203976, -0.00046017, -0.00338743, -0.00395598]))
EpochLog(epoch=35, loss=array([ 5.14734261e-04,  4.49167558e-03,
4.41884976e-03,  3.79131513e-05,
       -3.33681020e-03,  4.05321302e-04,  1.53320562e-03,  6.83496252e-03,
        4.98952144e-04, -1.09749930e-03]))
EpochLog(epoch=36, loss=array([ 0.00215584,  0.00359262,  0.00223428,
0.00177906,  0.00464421,
        0.00242957, -0.00043838,  0.00051247,  0.00324146, -0.00412808]))
EpochLog(epoch=37, loss=array([ 0.00546369,  0.00031204,  0.0025242 ,
-0.00017446, -0.00021967,
       -0.00424466, -0.00061897,  0.00446373,  0.00021574,  0.00410826]))
EpochLog(epoch=38, loss=array([ 1.40463987e-03,  4.48010827e-03,
-2.79230946e-04, -3.82355383e-03,
       -2.40905921e-03, -2.83247433e-03,  5.20295507e-05,  8.25509688e-04,
       -1.93475501e-03, -9.41883916e-04]))
EpochLog(epoch=39, loss=array([-0.00377921, -0.0007152 , -0.00718428,
-0.00077628,  0.00407802,
        0.0017365 ,  0.00301574, -0.00138706,  0.00208086,  0.00348414]))
EpochLog(epoch=40, loss=array([ 5.14318430e-03, -1.96692993e-03,
3.18754071e-03, -3.11723053e-03,
        2.72904046e-03, -1.76939980e-03, -8.12782599e-04,  2.52577932e-03,
        5.03252291e-03, -1.42386053e-05]))
```

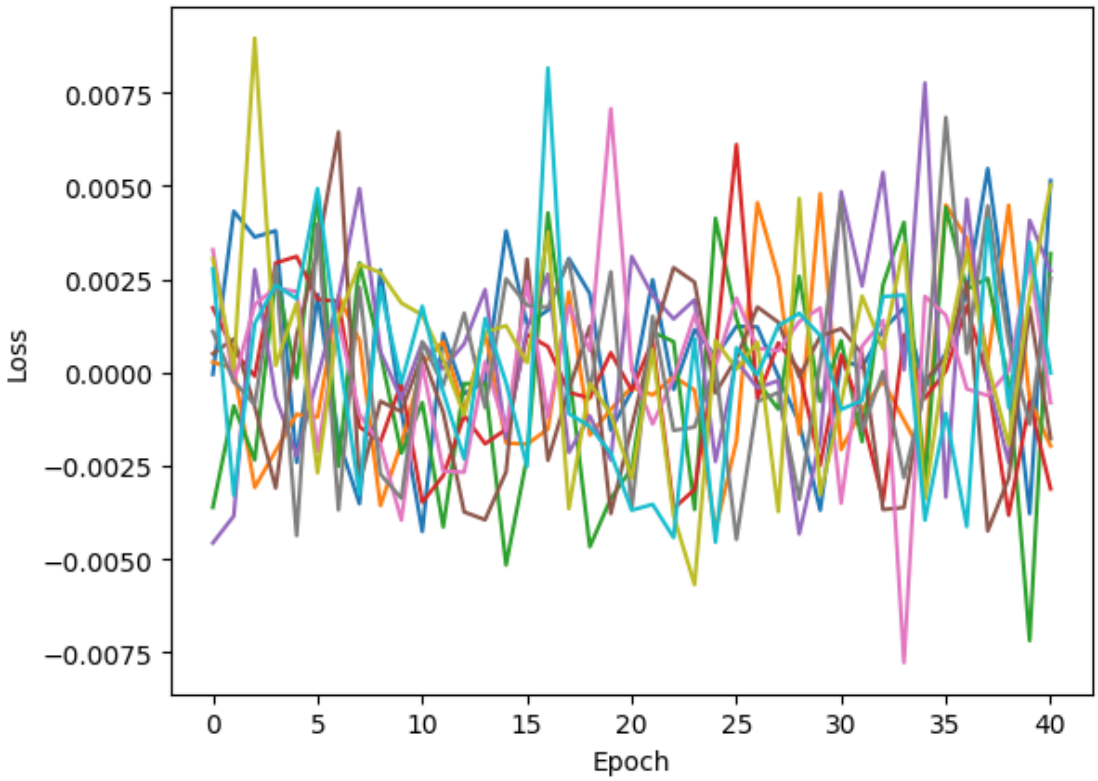


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EpochLog(epoch=41, loss=array([-2.02061319e-05, -5.00127512e-04,
2.11437597e-03,  1.83805702e-04,
       -2.60886232e-03, -1.85092996e-03,  7.85461082e-04, -3.00301759e-03,
        2.36050427e-03,  3.34211785e-03]))
EpochLog(epoch=42, loss=array([-2.12699141e-04, -2.37322963e-03,
2.24329257e-03,  7.60148198e-05,
        1.56295262e-03, -1.05254044e-03,  4.79184610e-04,  2.69476874e-03,
        6.05261737e-03,  1.38862551e-04]))
EpochLog(epoch=43, loss=array([ 2.62676448e-04,  8.19002828e-04,
2.07358771e-03,  2.03310591e-03,
        7.20789257e-04, -4.28907919e-03,  1.28451562e-03, -5.14893744e-05,
        8.75617249e-04,  3.31117782e-03]))
EpochLog(epoch=44, loss=array([ 1.70479394e-03,  2.18474930e-03,
-2.49370687e-03,  3.38983817e-04,
       -7.95226376e-05,  4.87600195e-03,  1.39567135e-04, -1.58026371e-04,
       -2.03420730e-03,  3.85310659e-03]))
EpochLog(epoch=45, loss=array([-0.00239416,  0.00156886,  0.00013007,
-0.00225723,  0.00073043,
        0.0024386 , -0.00173485,  0.00258438, -0.00139729, -0.00114741]))
EpochLog(epoch=46, loss=array([ 0.00012472,  0.00158985,  0.00289383,  0.0030661
, -0.00104136,
       -0.00356309, -0.00077238, -0.00010192,  0.00371982, -0.00186992]))
```

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EpochLog(epoch=47, loss=array([ 2.30081395e-03,  2.81723076e-03,
-7.18858135e-04,  3.14549285e-03,
        2.71157752e-03, -4.71262192e-05, -2.29552728e-03, -2.88030629e-03,
        1.18086865e-03, -1.08198564e-03]))
EpochLog(epoch=48, loss=array([-1.06151875e-03,  7.89355766e-04,
-2.26712294e-03, -1.07972900e-03,
       -2.61317471e-03, -4.03222569e-03,  2.29822687e-03,  6.34568376e-04,
        2.72834597e-03, -4.99572112e-05]))
EpochLog(epoch=49, loss=array([ 0.00216526, -0.00100576, -0.00011588,
0.00192696,  0.0014905 ,
        0.00427834,  0.00255929, -0.00157904, -0.00325477, -0.0001735 ]))
EpochLog(epoch=50, loss=array([ 0.00088559, -0.00170662, -0.00129616,
0.00044801, -0.00028053,
        0.00192817,  0.0023835 ,  0.00308879, -0.00454555,  0.0027836 ]))
```

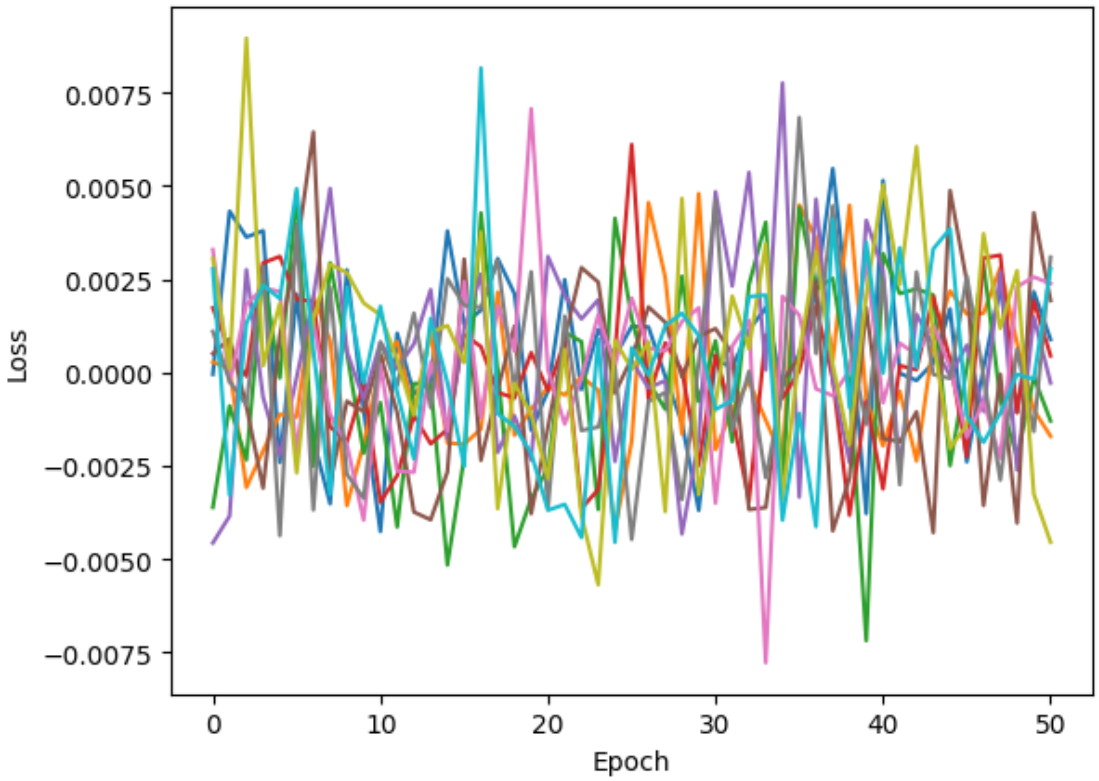


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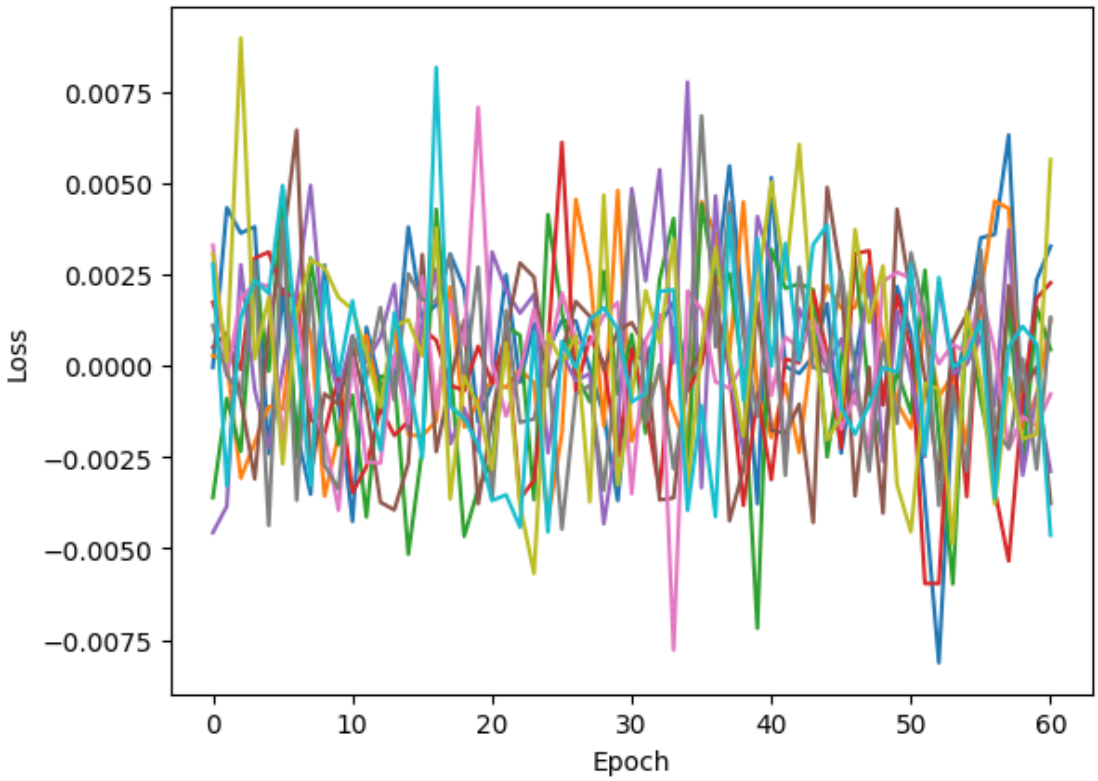
EpochLog(epoch=51, loss=array([-0.00368198,  0.00117543,  0.00260953,
-0.00595941, -0.00248498,
       -0.00033406,  0.00106596,  0.0014051 , -0.000483  , -0.00242696]))
EpochLog(epoch=52, loss=array([-8.12672565e-03, -8.48272775e-04,
-1.94015061e-03, -5.96061978e-03,
        2.25935484e-03, -3.12445157e-03,  5.20904545e-05, -3.82215232e-03,
       -6.48260104e-04,  2.41374211e-03]))
```

```
EpochLog(epoch=53, loss=array([-9.64229852e-04, -2.55323977e-04,
-5.97234903e-03,  6.53064665e-04,
       -2.20841728e-04,  6.63146632e-04,  5.86434899e-04, -5.61542969e-04,
       -4.86825389e-03, -4.86562040e-05]))
EpochLog(epoch=54, loss=array([ 1.06581246e-03, -2.16932639e-03,
1.34082590e-03, -3.58342959e-03,
        4.36715623e-05,  1.39853448e-03,  3.49699026e-04, -2.88457898e-03,
        1.49372059e-03,  2.43615207e-04]))
EpochLog(epoch=55, loss=array([ 0.00349576,  0.00196112, -0.00096827,
0.00277889,  0.00079193,
        0.00257816,  0.00198656,  0.00316466, -0.00038436,  0.00122682]))
EpochLog(epoch=56, loss=array([ 0.00359242,  0.00450439, -0.0027755 ,
-0.00340265, -0.00110118,
       -0.00270941,  0.00043031, -0.00170868, -0.00378802, -0.00362354]))
EpochLog(epoch=57, loss=array([ 0.0063087 ,  0.00429711,  0.0017242 ,
-0.00534303,  0.0037105 ,
        0.00218547, -0.00227458, -0.00226274, -0.00033893,  0.00052149]))
EpochLog(epoch=58, loss=array([-0.00169219, -0.00174491, -0.00284401,
-0.00092321, -0.00299956,
       -0.00073226, -0.0013885 ,  0.00018993, -0.00200107,  0.00107672]))
EpochLog(epoch=59, loss=array([ 2.34639365e-03, -8.01631581e-04,
1.60027847e-03,  1.84182404e-03,
       -7.77333822e-04, -3.05298519e-05, -1.65326275e-03, -2.82912860e-03,
       -1.87464524e-03,  5.86825941e-04]))
EpochLog(epoch=60, loss=array([ 0.00326454,  0.0012405 ,  0.00043872,
0.00226545, -0.00288858,
       -0.00377036, -0.00077788,  0.0013193 ,  0.00563659, -0.0046379 ]))
```

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EpochLog(epoch=61, loss=array([-1.55004246e-03,  7.81584212e-04,
2.50086788e-03, -3.94576720e-03,
        1.23739472e-03,  1.31530825e-03,  1.80009462e-03, -3.53380764e-03,
       -4.51113494e-03, -3.80764436e-05]))
EpochLog(epoch=62, loss=array([-0.00354578,  0.00137223, -0.00331737,
-0.00238765,  0.00391969,
       -0.00382436, -0.00261765, -0.00502057,  0.00163814, -0.0016425 ]))
EpochLog(epoch=63, loss=array([ 0.00242199,  0.00298297,  0.00046925,
-0.00061996, -0.00305574,
       -0.00110709,  0.00673938, -0.0017025 ,  0.00066251, -0.0021042 ]))
EpochLog(epoch=64, loss=array([-2.69788226e-03,  7.08182416e-04,
8.12649574e-05,  2.13122166e-03,
       -1.58053519e-03,  2.77004178e-04, -4.52827608e-03,  7.41452999e-03,
       -2.35120822e-03,  1.34720486e-03]))
EpochLog(epoch=65, loss=array([-0.00110207,  0.00103788,  0.00068491, -0.00053
, -0.00102313,
       -0.00240587, -0.00100001, -0.00391087,  0.00691407, -0.00356085]))
EpochLog(epoch=66, loss=array([-0.00394254,  0.00454425,  0.00056197,
-0.00251474,  0.00206663,
        0.00239457,  0.00066173,  0.00260562,  0.00241128,  0.00193979]))
EpochLog(epoch=67, loss=array([ 2.25358377e-03, -5.95344865e-04,
-5.91002745e-03,  1.83942413e-05,
```
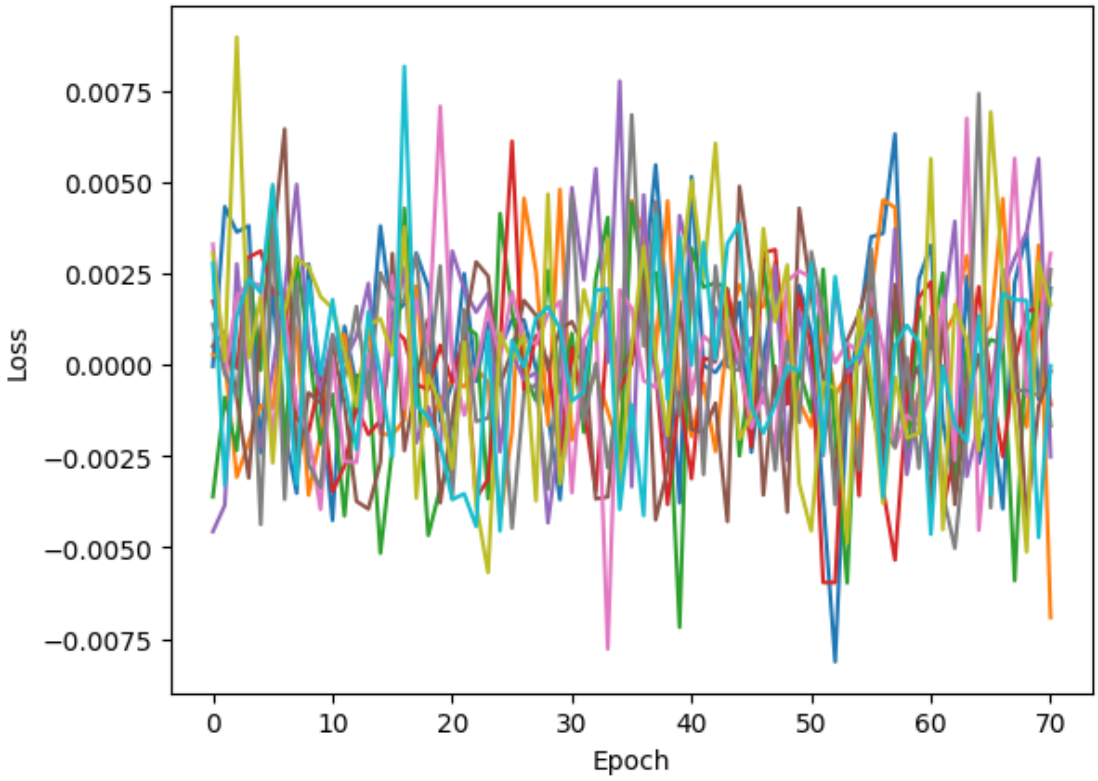
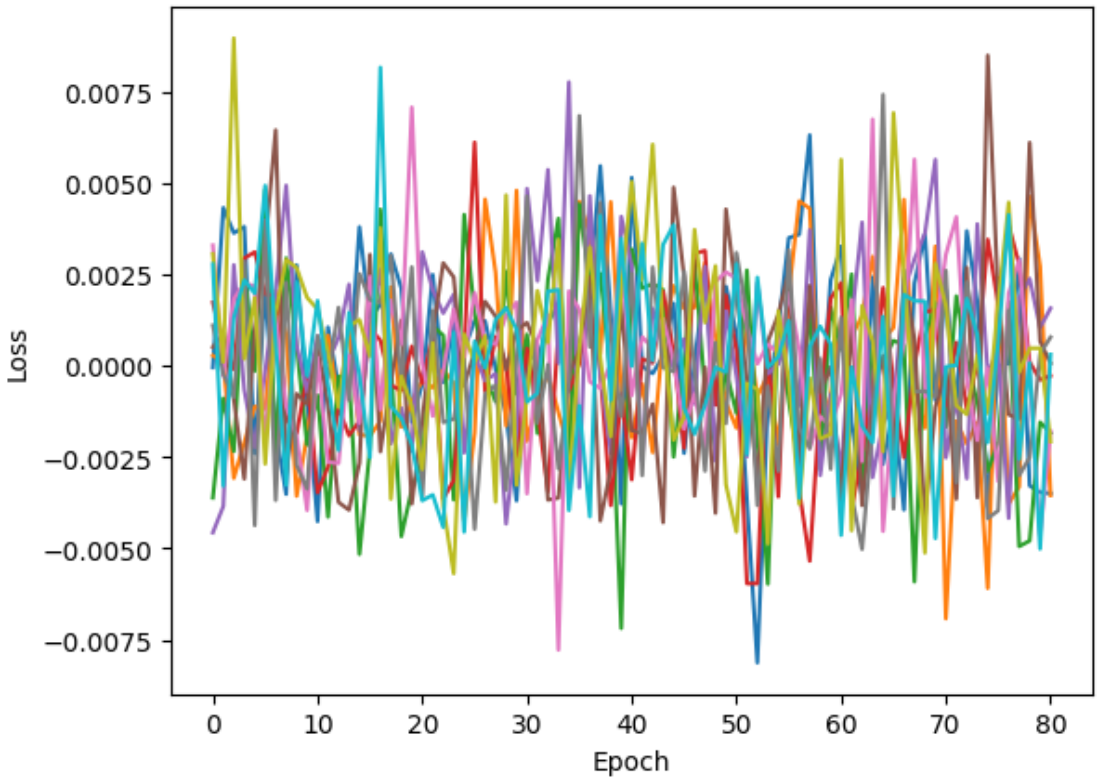

```
        2.91222197e-03,  7.47021016e-04,  5.64249710e-03, -7.17462303e-04,
       -1.23656475e-03,  1.77409519e-03]))
EpochLog(epoch=68, loss=array([ 0.00358956, -0.00170721,  0.00080281,
0.00148022,  0.00361941,
       -0.00419089, -0.00085835, -0.00069527, -0.00512014,  0.00175795]))
EpochLog(epoch=69, loss=array([-0.00094997,  0.00326398,  0.00172167,
0.00151695,  0.00563775,
       -0.00112927,  0.00093605, -0.00085289,  0.00279019, -0.00472343]))
EpochLog(epoch=70, loss=array([ 2.09634140e-03, -6.91922023e-03,
-1.67412256e-03, -1.09108807e-03,
       -2.51679340e-03, -1.80587770e-04,  3.03878588e-03,  2.60064712e-03,
        1.64145882e-03, -3.20884560e-05]))
```



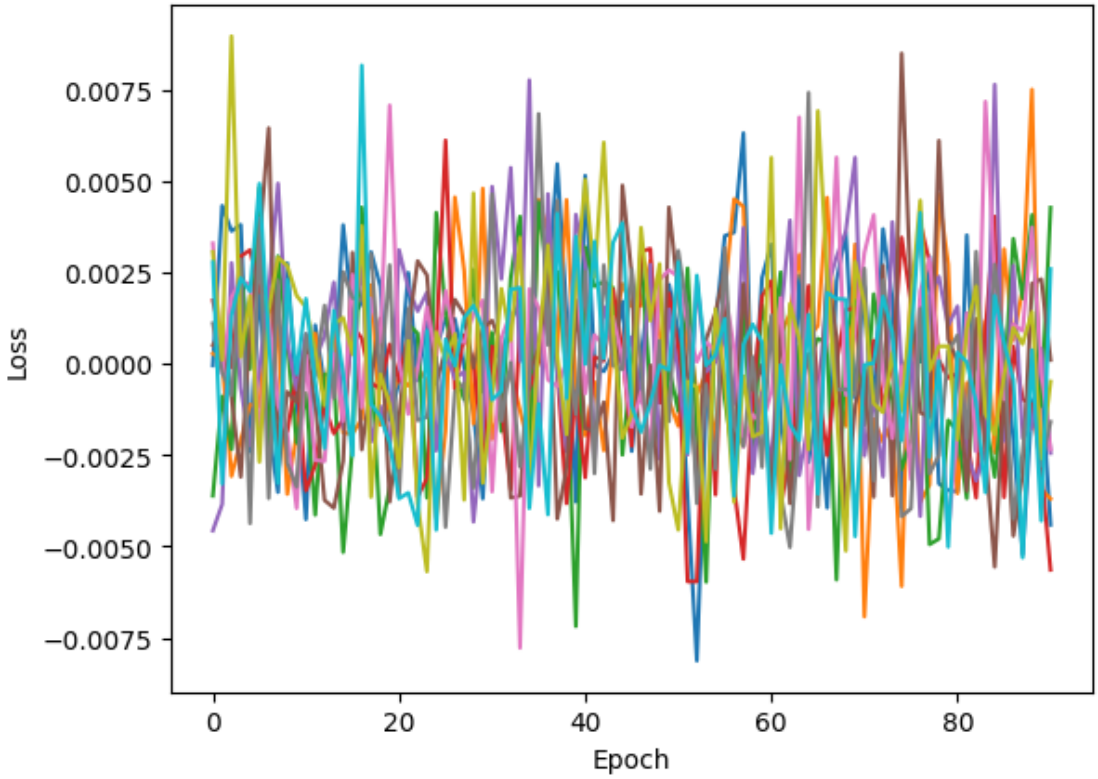

```
EpochLog(epoch=71, loss=array([-1.17043092e-03, -1.51373370e-03,
1.90226666e-03,  6.32160714e-04,
       -9.22647800e-04, -3.64437373e-03,  4.06805426e-03, -3.19369322e-03,
       -1.08972756e-03,  1.44469373e-05]))
EpochLog(epoch=72, loss=array([ 0.0036835 , -0.00214143,  0.00020131,
-0.00118657, -0.00308819,
        0.00268174, -0.0003742 ,  0.0022873 , -0.00133483,  0.00183592]))
EpochLog(epoch=73, loss=array([ 1.75852738e-03, -1.55332635e-03,
-1.00943855e-03,  4.83898758e-05,
```

```
        3.87556632e-03, -3.60848554e-03, -2.04429877e-03,  6.46709454e-04,
        2.97945888e-04,  8.61655603e-04]))
EpochLog(epoch=74, loss=array([-3.85921676e-03, -6.08859817e-03,
-2.88356525e-03,  3.45223605e-03,
       -2.11568940e-04,  8.48811660e-03, -6.25529822e-05, -4.17894445e-03,
       -1.29944964e-03, -2.10434341e-03]))
EpochLog(epoch=75, loss=array([-3.15238189e-06,  2.40201733e-03,
-2.08325399e-03,  1.66928715e-03,
        4.17999227e-04,  1.80045536e-03, -3.16582405e-03, -3.96312972e-03,
        1.71410445e-03,  6.44728969e-04]))
EpochLog(epoch=76, loss=array([ 6.08710918e-05, -3.78258682e-03,
1.75627020e-03,  3.85594004e-03,
       -4.17242195e-03, -1.33780023e-03,  1.97942530e-03,  1.51021667e-03,
        4.46593259e-03,  4.12565475e-03]))
EpochLog(epoch=77, loss=array([ 0.00292368, -0.00331131, -0.0049442 ,
0.00275421,  0.00184513,
       -0.00145734,  0.00289513, -0.00300731, -0.00018497, -0.00255687]))
EpochLog(epoch=78, loss=array([-3.28201219e-03,  4.62507979e-03,
-4.79070605e-03,  9.80646846e-05,
        2.38168252e-03,  6.10222161e-03, -2.94584122e-04, -2.51082340e-03,
        4.76269659e-04,  7.43957036e-05]))
EpochLog(epoch=79, loss=array([-0.00346489,  0.00271239, -0.00154888,
-0.00038628,  0.00104055,
        0.00066454, -0.00463008,  0.00032761,  0.00047759, -0.00501142]))
EpochLog(epoch=80, loss=array([-3.49393839e-03, -3.55021717e-03,
-1.84134632e-03, -2.78966628e-04,
        1.57027970e-03,  6.57779242e-05, -1.79834009e-03,  7.79052444e-04,
       -2.07605028e-03,  3.06324995e-04]))
```



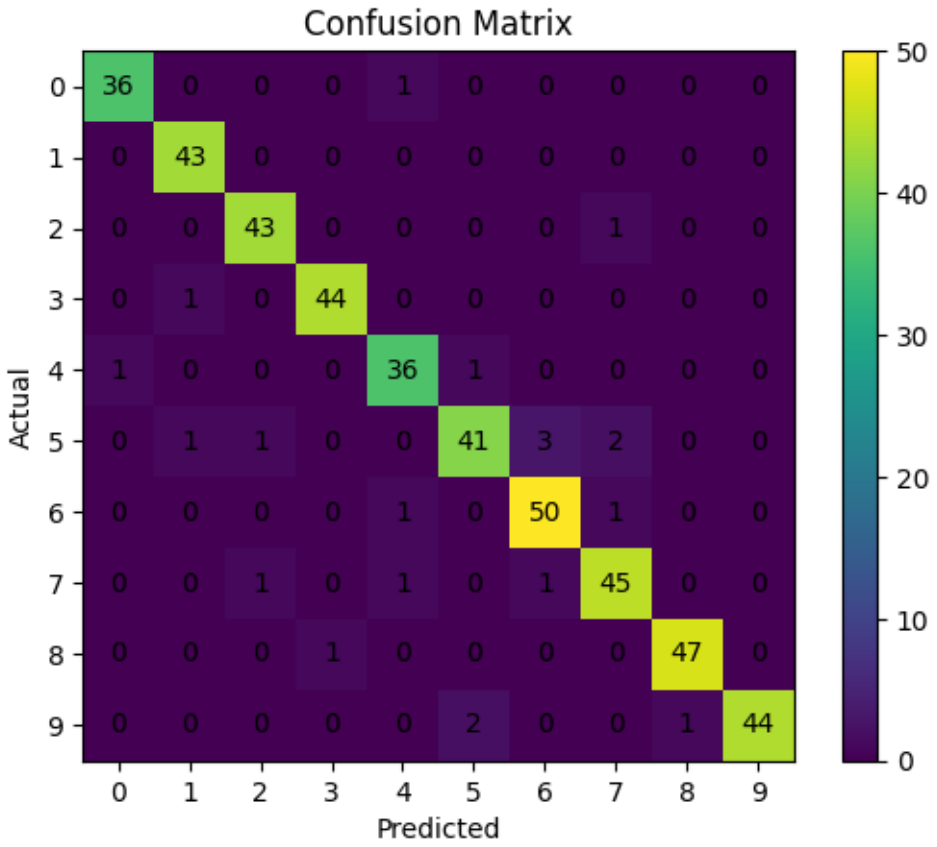

```
EpochLog(epoch=81, loss=array([ 3.51522444e-03, -5.25453086e-04,
-3.68524260e-03, -1.99258838e-03,
       -2.42343458e-03, -3.48586556e-03,  1.38252494e-03, -2.03924903e-03,
        9.23819156e-04,  4.36819724e-05]))
EpochLog(epoch=82, loss=array([-0.00237521, -0.00098268,  0.00038618,
-0.00366907, -0.00320611,
        0.00122672, -0.00240392,  0.00306476,  0.00211853, -0.00105509]))
EpochLog(epoch=83, loss=array([ 0.00098578,  0.00116761, -0.00148415,
0.00092717, -0.0023663 ,
       -0.00238269,  0.00716979, -0.00142251, -0.00136071, -0.00352482]))
EpochLog(epoch=84, loss=array([ 0.00219056, -0.00243186, -0.00309769,
0.00402456,  0.0076362 ,
       -0.00555738,  0.00243427,  0.00271661, -0.00194227,  0.00185926]))
EpochLog(epoch=85, loss=array([ 0.00053451,  0.00313638, -0.00060287,
-0.00365456, -0.00211035,
       -0.00069171, -0.00097688,  0.0004338 , -0.00032606,  0.0005833 ]))
EpochLog(epoch=86, loss=array([-0.00207862,  0.00064168,  0.00341764,
0.00047075,  0.00268338,
       -0.00471063,  0.00107604, -0.00424342,  0.00098217, -0.00044228]))
EpochLog(epoch=87, loss=array([-0.00522296,  0.00205562,  0.00178659,
-0.00097393, -0.0020374 ,
       -0.00303922,  0.00089885, -0.00241427,  0.00053895, -0.00530774]))
```

```
EpochLog(epoch=88, loss=array([-0.0010727 ,  0.00750107,  0.00406865,
-0.00110896, -0.00173339,
        0.00219001,  0.00373104,  0.00015675,  0.00141726,  0.00037436]))
EpochLog(epoch=89, loss=array([-0.00048657, -0.00343783, -0.00115151,
-0.00285175,  0.00041153,
        0.00231066, -0.00021789, -0.00278264, -0.00259417, -0.00429579]))
EpochLog(epoch=90, loss=array([-4.40961272e-03, -3.69903378e-03,
4.26844785e-03, -5.64159297e-03,
       -2.44763648e-03,  9.93585062e-05, -2.34575936e-03, -1.59080933e-03,
       -4.89324772e-04,  2.58979445e-03]))
```




```
EpochLog(epoch=91, loss=array([-4.82786334e-03, -7.61448719e-04,
8.35334540e-05, -4.11517655e-03,
       -3.24975994e-03, -1.23082978e-03,  1.75317681e-03, -6.02354796e-04,
       -1.30588050e-03, -2.65538291e-03]))
EpochLog(epoch=92, loss=array([-0.00129872, -0.00229616, -0.00031654,
-0.00039698, -0.00332369,
       -0.00274204,  0.00067537, -0.00272496,  0.00151113, -0.00194181]))
EpochLog(epoch=93, loss=array([ 0.00454525,  0.00299435, -0.00139651,
0.00155223,  0.00486163,
        0.00258245,  0.00060226, -0.00785423,  0.00143304, -0.00126572]))
EpochLog(epoch=94, loss=array([ 4.10252350e-03,  1.34144339e-03,
```

```
-2.47695994e-03, -4.78642386e-03,
       -9.25215573e-04, -9.60766499e-05, -4.38755698e-04, -3.29420897e-03,
        4.22193785e-04,  2.24470982e-03]))
EpochLog(epoch=95, loss=array([ 0.00203672,  0.00169695,  0.00125937,
-0.00018755, -0.00254612,
       -0.00121875,  0.00127276,  0.00283688, -0.00178326, -0.00225908]))
EpochLog(epoch=96, loss=array([ 1.54513136e-03,  1.61999626e-03,
1.80771109e-04, -8.17558340e-04,
       -2.33147575e-03,  3.25297537e-03,  1.88561163e-03,  2.88485093e-03,
       -6.00944729e-03, -2.29280697e-05]))
EpochLog(epoch=97, loss=array([-0.00105547,  0.00351646,  0.00069237,
0.00472725, -0.00102256,
        0.00104664, -0.00052859, -0.00284672,  0.00336292,  0.00077801]))
EpochLog(epoch=98, loss=array([ 0.0001244 ,  0.00052954, -0.00154044,
-0.00284611,  0.00083925,
        0.0028533 ,  0.00321667, -0.0008197 , -0.00260988,  0.00269716]))
EpochLog(epoch=99, loss=array([-3.17055126e-03,  1.94013909e-04,
-3.50042348e-04,  3.04646489e-03,
        6.48096699e-05,  4.25023965e-03,  2.66331735e-03,  2.06588221e-03,
        2.78497580e-03,  2.61045327e-04]))
```



```
TrainingScore(accuracy=0.9533333333333334, precision=0.9537051331971967,
recall=0.9533333333333334, f1_score=0.9531064291817608)
```

1.1.1 Wnioski

Sieć neuronowa radzi sobie bardzo dobrze na zbiorze MNIST. Ukryte warstwy generalizują dane i pozwalają na uzyskanie wysokiej skuteczności. Warto zauważyć, że sieć nie jest zbyt głęboka, a mimo to osiąga bardzo dobre wyniki.