

ECGR 4105 – HW # 6

Nahush D. Tambe - 801060297

<https://github.com/Ntambe25>

Problem 1:

```
loaded_model_part_a = nn.Sequential(nn.Linear(3072, 512), nn.Tanh(),  
                                     nn.Linear(512, 10),  
                                     nn.LogSoftmax(dim = 1))
```

Figure 1: Fully Connected Neural Network with 1 Hidden Layer

```
2022-12-07 22:44:44.994606 Epoch 0, Training Loss 1.8253761529922485  
2022-12-07 22:48:45.416810 Epoch 10, Training Loss 1.2261266708374023  
2022-12-07 22:52:19.834579 Epoch 20, Training Loss 1.1694875955581665  
2022-12-07 22:55:57.519331 Epoch 30, Training Loss 1.190816044807434  
2022-12-07 23:00:09.100239 Epoch 40, Training Loss 1.0114688873291016  
2022-12-07 23:04:06.716836 Epoch 50, Training Loss 0.8442532420158386  
2022-12-07 23:09:11.270088 Epoch 60, Training Loss 0.43822360038757324  
2022-12-07 23:12:59.107906 Epoch 70, Training Loss 0.5698657035827637  
2022-12-07 23:16:35.433539 Epoch 80, Training Loss 0.4397529065608978  
2022-12-07 23:20:13.971594 Epoch 90, Training Loss 0.22964319586753845  
2022-12-07 23:23:47.732960 Epoch 100, Training Loss 0.2840161919593811  
2022-12-07 23:27:30.221147 Epoch 110, Training Loss 0.2021884024143219  
2022-12-07 23:31:17.947431 Epoch 120, Training Loss 0.1450323760509491  
2022-12-07 23:35:00.592780 Epoch 130, Training Loss 0.15934063494205475  
2022-12-07 23:38:34.602799 Epoch 140, Training Loss 0.095645472407341  
2022-12-07 23:41:56.593162 Epoch 150, Training Loss 0.06306865066289902  
2022-12-07 23:45:17.163632 Epoch 160, Training Loss 0.060579814016819  
2022-12-07 23:48:39.868128 Epoch 170, Training Loss 0.06474480777978897  
2022-12-07 23:52:01.818897 Epoch 180, Training Loss 0.04835997894406319  
2022-12-07 23:55:20.518098 Epoch 190, Training Loss 0.036543574184179306  
2022-12-07 23:58:43.071775 Epoch 200, Training Loss 0.038444940000772476  
2022-12-08 00:02:02.581822 Epoch 210, Training Loss 0.024443434551358223  
2022-12-08 00:05:24.486474 Epoch 220, Training Loss 0.03344174847006798  
2022-12-08 00:08:43.438395 Epoch 230, Training Loss 0.027835246175527573  
2022-12-08 00:12:12.482043 Epoch 240, Training Loss 0.03362679108977318  
2022-12-08 00:15:32.321845 Epoch 250, Training Loss 0.02667803131043911  
2022-12-08 00:18:54.766812 Epoch 260, Training Loss 0.022700419649481773  
2022-12-08 00:22:20.870405 Epoch 270, Training Loss 0.020717602223157883  
2022-12-08 00:25:42.755789 Epoch 280, Training Loss 0.019888561218976974  
2022-12-08 00:29:04.075032 Epoch 290, Training Loss 0.024285869672894478
```

Figure 2: Loss for 300 Epochs for Neural Network with 1 Hidden Layer

As specified in Problem 1, part a, the model was defined with only 1 hidden layer. This can be seen in Figure 1, shown above. Only 1 hidden layer has been used. As it can be seen the loss over 300 epochs varied from the maximum value of 1.82 to a minimum value of 0.02. In between epochs, the loss was at times oscillating, going up and down. For problem 1, part a, the accuracy calculated using the validation set was around 0.47.

```
model_part_b = nn.Sequential(nn.Linear(3072, 2048), nn.Tanh(),
                             nn.Linear(2048, 512), nn.Tanh(),
                             nn.Linear(512, 256), nn.Tanh(),
                             nn.Linear(256, 10), nn.Tanh(),
                             nn.LogSoftmax(dim = 1))
```

Figure 3: Fully Connected Neural Network with 3 Hidden Layer

```
2022-12-08 01:41:47.258438 Epoch 0, Training Loss 2.0479979515075684
2022-12-08 01:50:34.266069 Epoch 10, Training Loss 1.6230140924453735
2022-12-08 01:59:16.812208 Epoch 20, Training Loss 1.342703104019165
2022-12-08 02:07:58.768081 Epoch 30, Training Loss 1.2078759670257568
2022-12-08 02:16:43.894495 Epoch 40, Training Loss 1.450156807899475
2022-12-08 02:25:26.807374 Epoch 50, Training Loss 0.9796058535575867
2022-12-08 02:34:10.600114 Epoch 60, Training Loss 0.9214929938316345
2022-12-08 02:42:56.486086 Epoch 70, Training Loss 1.1126482486724854
2022-12-08 02:51:40.032863 Epoch 80, Training Loss 1.0062534809112549
2022-12-08 03:00:21.689096 Epoch 90, Training Loss 0.9504820108413696
2022-12-08 03:09:02.445550 Epoch 100, Training Loss 1.1079751253128052
2022-12-08 03:17:43.685620 Epoch 110, Training Loss 0.8577156662940979
2022-12-08 03:26:23.536683 Epoch 120, Training Loss 1.0073959827423096
2022-12-08 03:35:04.459506 Epoch 130, Training Loss 0.9235573410987854
2022-12-08 03:43:54.980475 Epoch 140, Training Loss 0.8181724548339844
2022-12-08 03:52:43.729013 Epoch 150, Training Loss 0.9429395198822021
2022-12-08 04:01:28.837981 Epoch 160, Training Loss 0.7974256873130798
2022-12-08 04:10:14.921705 Epoch 170, Training Loss 0.8919129371643066
2022-12-08 04:18:58.860586 Epoch 180, Training Loss 0.7974254488945007
2022-12-08 04:27:41.586756 Epoch 190, Training Loss 0.8912424445152283
2022-12-08 04:36:23.237821 Epoch 200, Training Loss 1.0799740552902222
2022-12-08 04:45:11.951338 Epoch 210, Training Loss 0.8911986947059631
2022-12-08 04:53:52.354970 Epoch 220, Training Loss 0.9117913246154785
2022-12-08 05:02:33.986244 Epoch 230, Training Loss 0.9219064116477966
2022-12-08 05:11:30.787215 Epoch 240, Training Loss 0.8911435008049011
2022-12-08 05:20:16.486450 Epoch 250, Training Loss 0.7970902919769287
2022-12-08 05:28:58.188048 Epoch 260, Training Loss 1.005816102027893
2022-12-08 05:37:38.178341 Epoch 270, Training Loss 0.7971267700195312
2022-12-08 05:46:21.670988 Epoch 280, Training Loss 0.8910205364227295
2022-12-08 05:55:05.840664 Epoch 290, Training Loss 0.8910744786262512
```

Figure 4: Loss for 300 Epochs for Neural Network with 3 Hidden Layer

As specified in Problem 1, part b, the model was defined with 2 more additional layers making it 3 total layers. Figure 3 shows the same. As it can be seen the loss

over 300 epochs varied from the maximum value of 2.04 to a minimum value of 0.89. In between epochs, the loss was at times oscillating, going up and down, but when compared to problem 1a, the decrease of the loss was more gradual and smoother and less oscillating. For problem 1, part a, the accuracy calculated using the validation set was around 0.495. The accuracy has increased for the validation set with an addition of 2 more hidden layers.

Problem 2:

```

2022-12-10 12:30:52.997731 Epoch 1, Training Loss 2.0543598640910194
2022-12-10 12:36:13.546336 Epoch 10, Training Loss 1.1958040703288124
2022-12-10 12:42:05.820028 Epoch 20, Training Loss 1.013959146292923
2022-12-10 12:47:52.256805 Epoch 30, Training Loss 0.9064702283390953
2022-12-10 12:53:40.274262 Epoch 40, Training Loss 0.843773039786712
2022-12-10 12:59:23.852780 Epoch 50, Training Loss 0.8058790556152763
2022-12-10 13:06:02.444425 Epoch 60, Training Loss 0.7749857910148933
2022-12-10 13:12:38.107592 Epoch 70, Training Loss 0.747799181991526
2022-12-10 13:18:37.942449 Epoch 80, Training Loss 0.729450122932034
2022-12-10 13:24:24.360593 Epoch 90, Training Loss 0.7102556972933547
2022-12-10 13:30:09.199887 Epoch 100, Training Loss 0.692855961754194
2022-12-10 13:35:59.027673 Epoch 110, Training Loss 0.6802598592799033
2022-12-10 13:41:46.741818 Epoch 120, Training Loss 0.6655139482920737
2022-12-10 13:47:34.024318 Epoch 130, Training Loss 0.6543021775648722
2022-12-10 13:53:21.466781 Epoch 140, Training Loss 0.6439662533419211
2022-12-10 13:59:04.112835 Epoch 150, Training Loss 0.6318329172709104
2022-12-10 14:04:56.799375 Epoch 160, Training Loss 0.6230715788005258
2022-12-10 14:10:47.739658 Epoch 170, Training Loss 0.6139330036576142
2022-12-10 14:16:35.295498 Epoch 180, Training Loss 0.6042161126194707
2022-12-10 14:22:22.087639 Epoch 190, Training Loss 0.5965553151295923
2022-12-10 14:28:04.738427 Epoch 200, Training Loss 0.5889834132417083
2022-12-10 14:34:03.477936 Epoch 210, Training Loss 0.5814849533083494
2022-12-10 14:39:49.490656 Epoch 220, Training Loss 0.5757385792253572
2022-12-10 14:45:43.197263 Epoch 230, Training Loss 0.5696734457522097
2022-12-10 14:51:42.880448 Epoch 240, Training Loss 0.5640115015342108
2022-12-10 14:57:25.324668 Epoch 250, Training Loss 0.5567568042089263
2022-12-10 15:03:09.319732 Epoch 260, Training Loss 0.5516662240180823
2022-12-10 15:08:58.929021 Epoch 270, Training Loss 0.5466603650842481
2022-12-10 15:14:42.541399 Epoch 280, Training Loss 0.542008890577442
2022-12-10 15:20:21.216198 Epoch 290, Training Loss 0.5365391156786238
2022-12-10 15:25:58.220588 Epoch 300, Training Loss 0.5346228527977034

```

Figure 5: Loss over 300 Epochs for a CNN for Part a

```

2022-12-10 17:27:34.303518 Epoch 1, Training Loss 2.0369032587846525
2022-12-10 17:33:11.410521 Epoch 10, Training Loss 1.1831883990856082
2022-12-10 17:38:58.658766 Epoch 20, Training Loss 1.0020822544232049
2022-12-10 17:44:46.279317 Epoch 30, Training Loss 0.9225083262566716
2022-12-10 17:50:37.155050 Epoch 40, Training Loss 0.8689730754669975
2022-12-10 17:56:26.426281 Epoch 50, Training Loss 0.8279266221748899
2022-12-10 18:02:13.856025 Epoch 60, Training Loss 0.7939400663003897
2022-12-10 18:47:52.085517 Epoch 70, Training Loss 0.7667722842653694
2022-12-10 18:57:10.743248 Epoch 80, Training Loss 0.742296373181026
2022-12-10 19:06:35.121050 Epoch 90, Training Loss 0.7218191839011429
2022-12-10 19:15:41.094067 Epoch 100, Training Loss 0.7036517176329328
2022-12-10 19:24:34.005317 Epoch 110, Training Loss 0.6875542137019165
2022-12-10 19:33:32.481298 Epoch 120, Training Loss 0.6743000709187345
2022-12-10 19:42:39.400717 Epoch 130, Training Loss 0.6621979605739988
2022-12-10 19:51:48.267684 Epoch 140, Training Loss 0.6476988485249717
2022-12-10 20:00:59.772916 Epoch 150, Training Loss 0.6391252548340947
2022-12-10 20:16:07.756059 Epoch 160, Training Loss 0.6286876555294028
2022-12-10 20:26:04.678731 Epoch 170, Training Loss 0.6210060711483212
2022-12-10 20:35:14.563382 Epoch 180, Training Loss 0.6108529501406433
2022-12-10 21:21:20.926446 Epoch 190, Training Loss 0.602737217265017
2022-12-10 21:27:21.879817 Epoch 200, Training Loss 0.5940131061064923
2022-12-10 21:33:19.903793 Epoch 210, Training Loss 0.58668473789759
2022-12-10 21:39:22.170207 Epoch 220, Training Loss 0.5804361770753665
2022-12-10 21:45:20.222970 Epoch 230, Training Loss 0.5732532905800568
2022-12-10 21:51:22.065037 Epoch 240, Training Loss 0.5674169273365794
2022-12-10 21:57:20.419090 Epoch 250, Training Loss 0.5601439091860486
2022-12-10 22:03:20.134953 Epoch 260, Training Loss 0.5552792291888191
2022-12-10 22:09:17.313592 Epoch 270, Training Loss 0.5520625307470026
2022-12-10 22:15:15.571856 Epoch 280, Training Loss 0.5469319719030424
2022-12-10 22:21:21.749799 Epoch 290, Training Loss 0.5420706868552796
2022-12-10 22:27:21.906200 Epoch 300, Training Loss 0.5380271983421062

```

Figure 6: Loss over 300 Epochs for a CNN for Part b

For part 1 of the problem, the loss was seen to be decreasing gradually starting from 2.054 and went down to around 0.89, while, on the other hand, for part b, the same decreasing trend was seen, but this time, the loss went down to around 0.53. Figure 5 and Figure 6 show the same. The training accuracy for both the models was around 82 % and the test accuracy was around 65 %.