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Entry Number: 2020CS10413

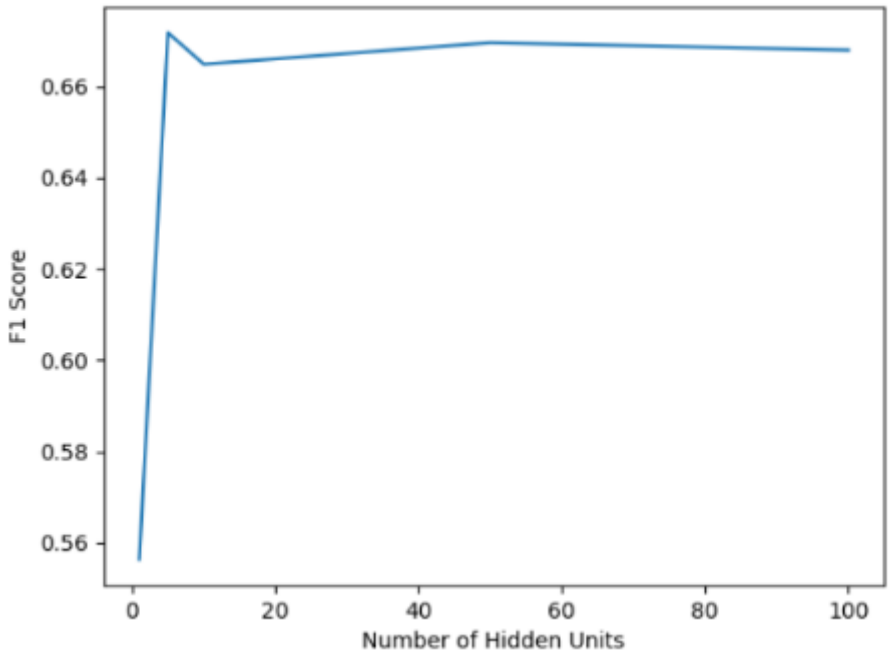
Neural Network

(a)

Threshold = 10−8
Max Epochs = 500

(b)

Test Metrics



1. Hidden Layer Units = 1

CLASS	PRECISION	RECALL	F1-SCORE	SUPPORT
0	0.66	1.00	0.79	229
1	0.60	0.31	0.41	198
2	0.60	0.42	0.49	199
3	0.46	0.28	0.35	187
4	0.57	0.91	0.70	187

CLASS	PRECISION	RECALL	F1-SCORE	SUPPORT
Micro Avg	0.59	0.59	0.59	1000
Macro Avg	0.58	0.58	0.55	1000
Weighted Avg	0.58	0.59	0.56	1000
Samples Avg	0.59	0.59	0.59	1000

Accuracy: 54.79453051765438%

2. Hidden Layer Units = 5

CLASS	PRECISION	RECALL	F1-SCORE	SUPPORT
0	0.91	0.88	0.89	229
1	0.67	0.66	0.66	198
2	0.58	0.51	0.54	199
3	0.49	0.58	0.53	187
4	0.69	0.69	0.69	187
Micro Avg	0.67	0.67	0.67	1000
Macro Avg	0.67	0.66	0.66	1000
Weighted Avg	0.68	0.67	0.67	1000
Samples Avg	0.67	0.67	0.67	1000

Accuracy: 66.43256515621637%

3. Hidden Layer Units = 10

CLASS	PRECISION	RECALL	F1-SCORE	SUPPORT
0	0.91	0.88	0.90	229
1	0.65	0.72	0.68	198
2	0.58	0.49	0.53	199
3	0.48	0.52	0.50	187
4	0.68	0.69	0.69	187
Micro Avg	0.67	0.67	0.67	1000
Macro Avg	0.66	0.66	0.66	1000

CLASS	PRECISION	RECALL	F1-SCORE	SUPPORT
Weighted Avg	0.67	0.67	0.67	1000
Samples Avg	0.67	0.67	0.67	1000

Accuracy: 65.81006101150952%

4. Hidden Layer Units = 50

CLASS	PRECISION	RECALL	F1-SCORE	SUPPORT
0	0.92	0.86	0.89	229
1	0.64	0.67	0.66	198
2	0.52	0.54	0.53	199
3	0.47	0.43	0.45	187
4	0.67	0.74	0.70	187
Micro Avg	0.66	0.66	0.66	1000
Macro Avg	0.65	0.65	0.65	1000
Weighted Avg	0.66	0.66	0.66	1000
Samples Avg	0.66	0.66	0.66	1000

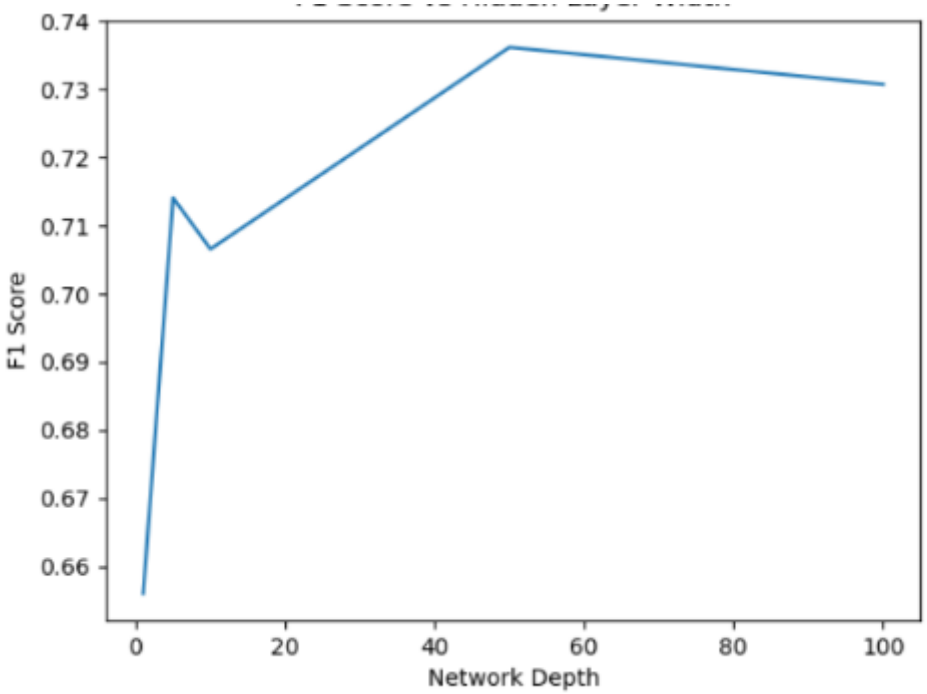
Accuracy: 64.61828941831156%

5. Hidden Layer Units = 100

CLASS	PRECISION	RECALL	F1-SCORE	SUPPORT
0	0.90	0.88	0.89	229
1	0.64	0.70	0.67	198
2	0.52	0.53	0.52	199
3	0.45	0.42	0.43	187
4	0.68	0.66	0.67	187
Micro Avg	0.65	0.65	0.65	1000
Macro Avg	0.64	0.64	0.64	1000
Weighted Avg	0.65	0.65	0.65	1000
Samples Avg	0.65	0.65	0.65	1000

Accuracy: 63.75828188326473

Train Metrics



1. Hidden Layer Units = 1

CLASS	PRECISION	RECALL	F1-SCORE
Class 0	0.69	0.99	0.81
Class 1	0.65	0.45	0.53
Class 2	0.61	0.49	0.48
Class 3	0.43	0.19	0.26
Class 4	0.54	0.95	0.69

2. Hidden Layer Units = 5

CLASS	PRECISION	RECALL	F1-SCORE
Class 0	0.87	0.90	0.89
Class 1	0.69	0.71	0.70
Class 2	0.58	0.57	0.57
Class 3	0.54	0.46	0.50
Class 4	0.72	0.78	0.75

3. Hidden Layer Units = 10

CLASS	PRECISION	RECALL	F1-SCORE
Class 0	0.87	0.90	0.89
Class 1	0.71	0.68	0.70
Class 2	0.58	0.61	0.59
Class 3	0.55	0.47	0.51
Class 4	0.71	0.78	0.75

4. Hidden Layer Units = 50

CLASS	PRECISION	RECALL	F1-SCORE
Class 0	0.87	0.90	0.89
Class 1	0.71	0.68	0.70
Class 2	0.58	0.61	0.59
Class 3	0.55	0.47	0.51
Class 4	0.71	0.78	0.75

5. Hidden Layer Units = 100

CLASS	PRECISION	RECALL	F1-SCORE
Class 0	0.87	0.91	0.89
Class 1	0.71	0.68	0.69
Class 2	0.58	0.57	0.57
Class 3	0.53	0.50	0.52
Class 4	0.72	0.77	0.75

The graph illustrates that as the number of hidden units is increased, the accuracy on the training data improves. However, the accuracy on the test data initially increases, but then levels off. This behavior can be attributed to the fact that a wider neural network can capture more information than a narrower one when evaluated on the same training dataset. A similar pattern is observed with the test data, where initially the neural network performs well, but it eventually starts overfitting to the

training data, resulting in a decline in test accuracy. This suggests that the model may have overfit the training data.

Furthermore, it is noticeable that the network performs effectively when there is only one object in the image. However, when there are multiple objects, especially between three and four, the network becomes considerably confused, which is a predictable outcome. Distinguishing boundaries becomes more challenging when numerous objects are present

(c)

Train Metrics

1. 512

CLASS	PRECISION	RECALL	F1-SCORE
Class 0	0.90	0.93	0.90
Class 1	0.76	0.72	0.74
Class 2	0.61	0.69	0.64
Class 3	0.61	0.48	0.54
Class 4	0.74	0.82	0.78

2. 512, 256

CLASS	PRECISION	RECALL	F1-SCORE
Class 0	0.96	0.94	0.95
Class 1	0.82	0.81	0.82
Class 2	0.69	0.66	0.68
Class 3	0.57	0.67	0.62
Class 4	0.80	0.73	0.76

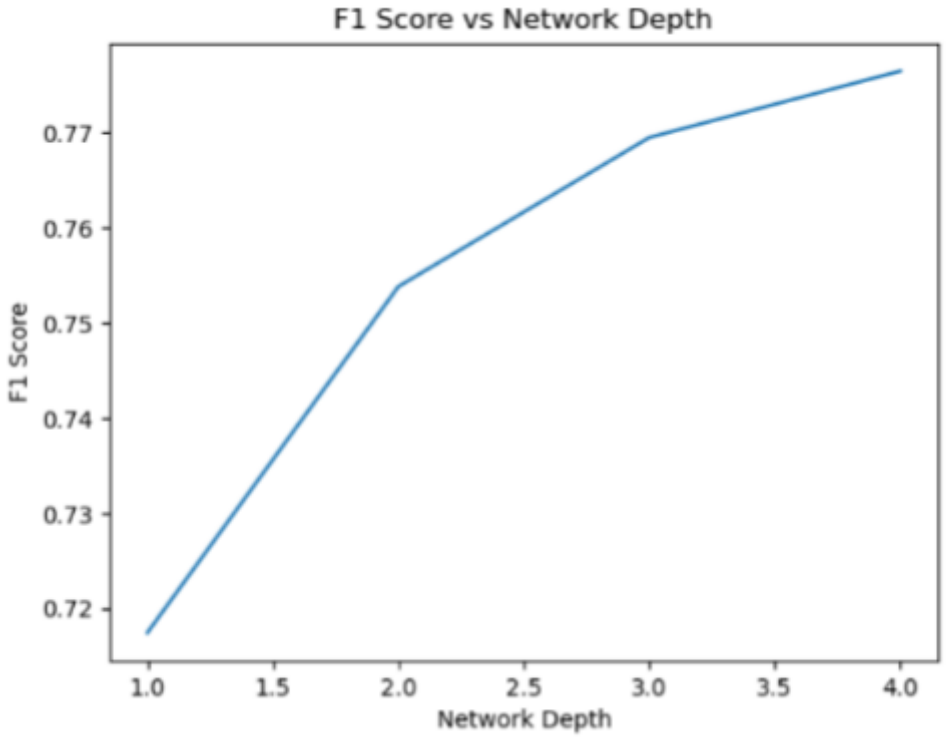
3. 512, 256, 128

CLASS	PRECISION	RECALL	F1-SCORE
Class 0	0.94	0.99	0.97

CLASS	PRECISION	RECALL	F1-SCORE
Class 1	0.86	0.84	0.85
Class 2	0.72	0.66	0.69
Class 3	0.61	0.55	0.58
Class 4	0.74	0.85	0.79

4. 512, 256, 128, 64

CLASS	PRECISION	RECALL	F1-SCORE
Class 0	0.96	0.98	0.97
Class 1	0.87	0.85	0.86
Class 2	0.71	0.71	0.71
Class 3	0.61	0.57	0.59
Class 4	0.76	0.81	0.78



Test Metrics

1. 512

CLASS	PRECISION	RECALL	F1-SCORE
Class 0	0.90	0.90	0.90
Class 1	0.66	0.72	0.69
Class 2	0.58	0.46	0.51
Class 3	0.48	0.58	0.53
Class 4	0.71	0.64	0.68

2. 512, 256

CLASS	PRECISION	RECALL	F1-SCORE
Class 0	0.90	0.93	0.91
Class 1	0.72	0.69	0.70
Class 2	0.58	0.62	0.60
Class 3	0.53	0.50	0.51
Class 4	0.71	0.72	0.71

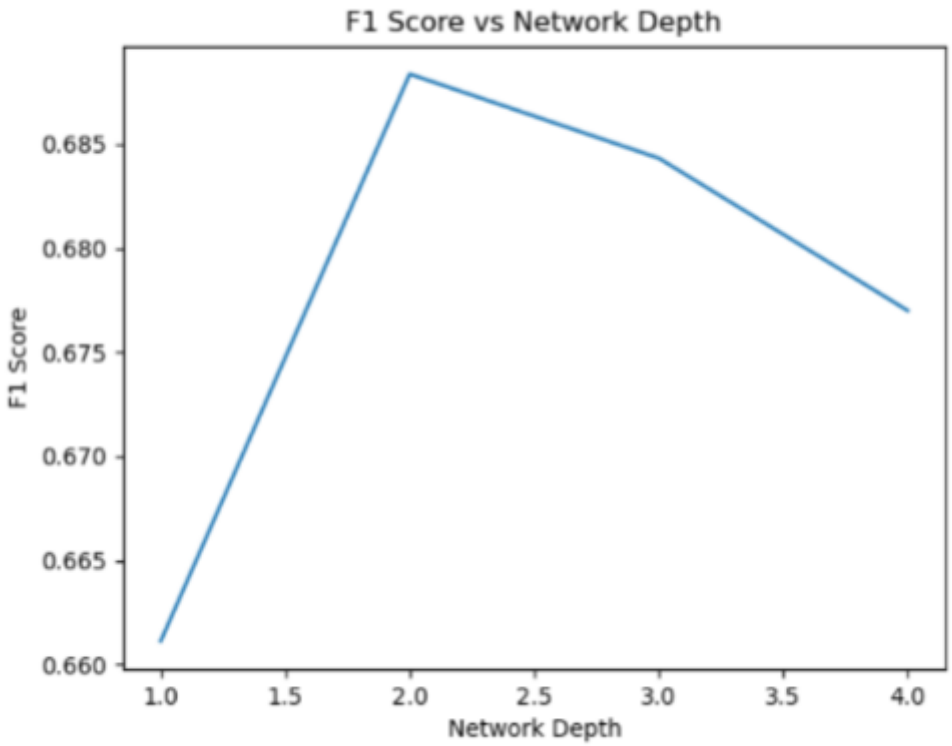
3. 512, 256, 128

CLASS	PRECISION	RECALL	F1-SCORE
Class 0	0.93	0.87	0.90
Class 1	0.70	0.66	0.68
Class 2	0.60	0.57	0.58
Class 3	0.52	0.54	0.53
Class 4	0.68	0.78	0.73

4. 512, 256, 128, 64

CLASS	PRECISION	RECALL	F1-SCORE
Class 0	0.90	0.92	0.91
Class 1	0.70	0.70	0.70
Class 2	0.59	0.54	0.57
Class 3	0.50	0.50	0.50

CLASS	PRECISION	RECALL	F1-SCORE
Class 4	0.69	0.73	0.71



(d)

Train Metrics

1. 512

CLASS	PRECISION	RECALL	F1-SCORE
Class 0	0.90	0.93	0.90
Class 1	0.76	0.72	0.74
Class 2	0.61	0.69	0.64
Class 3	0.61	0.48	0.54
Class 4	0.74	0.82	0.78

2. 512, 256

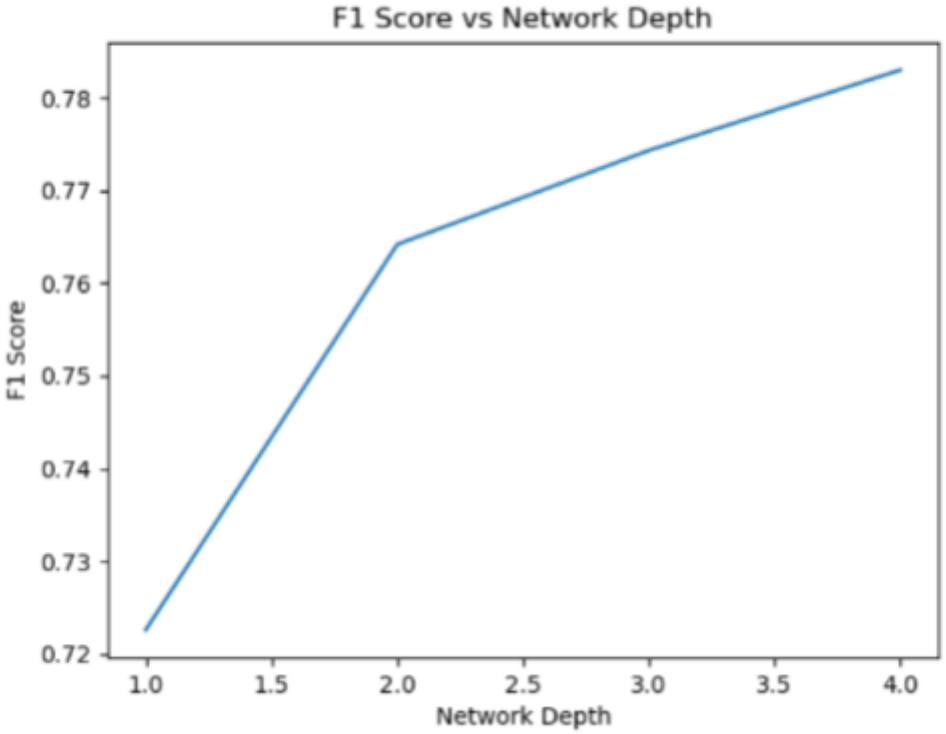
CLASS	PRECISION	RECALL	F1-SCORE
Class 0	0.96	0.94	0.95
Class 1	0.82	0.81	0.82
Class 2	0.69	0.66	0.68
Class 3	0.57	0.67	0.62
Class 4	0.80	0.73	0.76

3. 512, 256, 128

CLASS	PRECISION	RECALL	F1-SCORE
Class 0	0.94	0.99	0.97
Class 1	0.86	0.84	0.85
Class 2	0.72	0.66	0.69
Class 3	0.61	0.55	0.58
Class 4	0.74	0.85	0.79

4. 512, 256, 128, 64

CLASS	PRECISION	RECALL	F1-SCORE
Class 0	0.96	0.98	0.97
Class 1	0.87	0.85	0.86
Class 2	0.71	0.71	0.71
Class 3	0.61	0.57	0.59
Class 4	0.76	0.81	0.78



Test Metrics

1. 512

CLASS	PRECISION	RECALL	F1-SCORE
Class 0	0.89	0.94	0.92
Class 1	0.73	0.68	0.71
Class 2	0.61	0.59	0.60
Class 3	0.52	0.58	0.55
Class 4	0.73	0.68	0.71

2. 512, 256

CLASS	PRECISION	RECALL	F1-SCORE
Class 0	0.94	0.95	0.94
Class 1	0.77	0.75	0.76
Class 2	0.64	0.67	0.66
Class 3	0.54	0.58	0.56

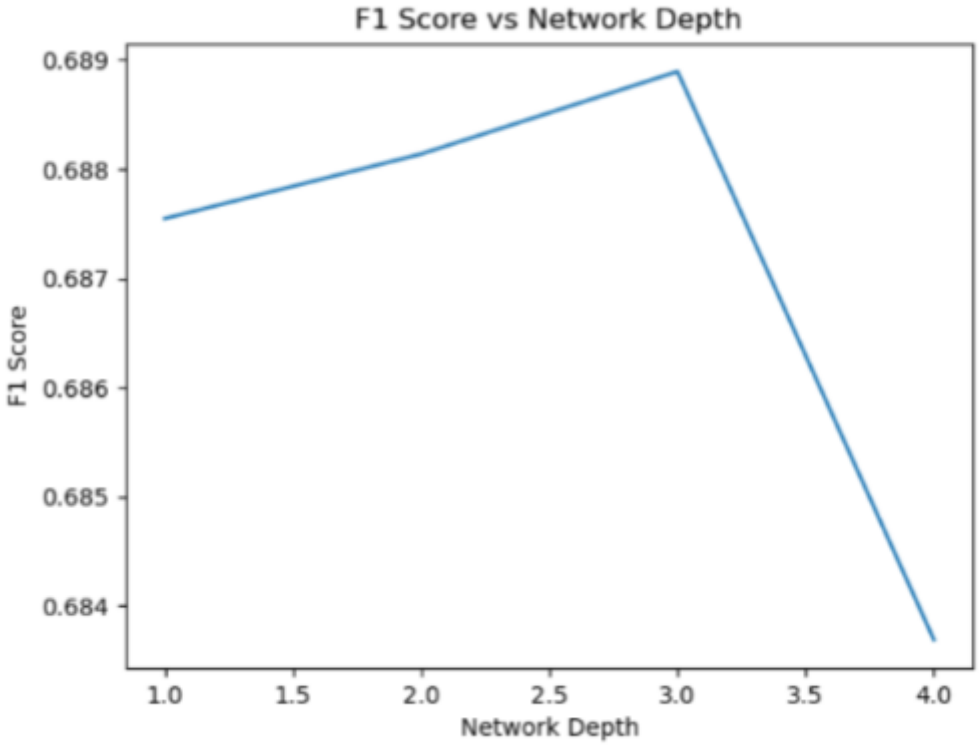
CLASS	PRECISION	RECALL	F1-SCORE
Class 4	0.74	0.65	0.69

3. 512, 256, 128

CLASS	PRECISION	RECALL	F1-SCORE
Class 0	0.98	0.95	0.97
Class 1	0.83	0.77	0.80
Class 2	0.67	0.64	0.66
Class 3	0.59	0.54	0.57
Class 4	0.69	0.86	0.77

4. 512, 256, 128, 64

CLASS	PRECISION	RECALL	F1-SCORE
Class 0	0.98	0.99	0.98
Class 1	0.85	0.85	0.85
Class 2	0.72	0.67	0.70
Class 3	0.61	0.58	0.60
Class 4	0.72	0.80	0.76



The use of adaptive learning rates results in slightly higher accuracies compared to a constant learning rate. This is because, by dynamically adjusting the learning rate during optimization, the model is less prone to overshooting the optimal solution, thus enhancing its ability to generalize better on unseen data. Notably, the training time for the model remains comparable to that of the previous approach

(e)

Train Metrics

1. 512

CLASS	PRECISION	RECALL	F1-SCORE
Class 0	0.98	0.97	0.98
Class 1	0.93	0.86	0.89
Class 2	0.82	0.80	0.81
Class 3	0.74	0.88	0.81
Class 4	0.94	0.85	0.89

2. 512, 256

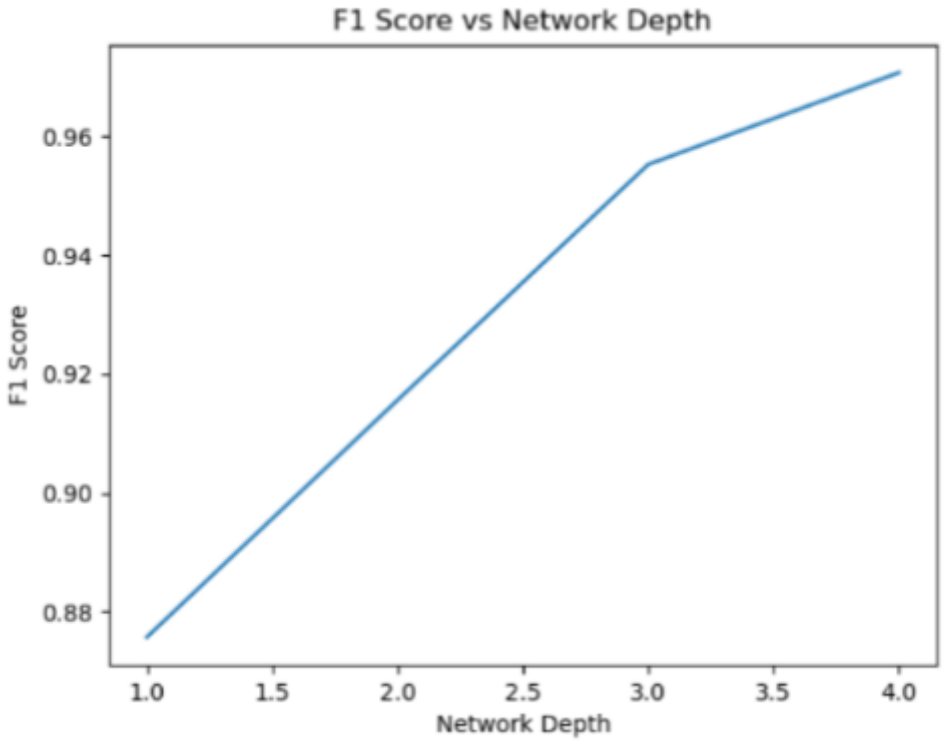
CLASS	PRECISION	RECALL	F1-SCORE
Class 0	1.00	0.99	0.99
Class 1	0.95	0.97	0.96
Class 2	0.94	0.86	0.90
Class 3	0.85	0.80	0.82
Class 4	0.85	0.96	0.90

3. 512, 256, 128

CLASS	PRECISION	RECALL	F1-SCORE
Class 0	1.00	1.00	1.00
Class 1	0.98	0.98	0.98
Class 2	0.94	0.95	0.95
Class 3	0.93	0.89	0.91
Class 4	0.93	0.96	0.95

4. 512, 256, 128, 64

CLASS	PRECISION	RECALL	F1-SCORE
Class 0	1.00	1.00	1.00
Class 1	0.99	0.98	0.99
Class 2	0.96	0.98	0.97
Class 3	0.94	0.95	0.94
Class 4	0.97	0.95	0.96



Test Metrics

1. 512

CLASS	PRECISION	RECALL	F1-SCORE
Class 0	0.97	0.98	0.98
Class 1	0.84	0.82	0.83
Class 2	0.73	0.65	0.69
Class 3	0.57	0.78	0.66
Class 4	0.83	0.65	0.73

2. 512, 256

CLASS	PRECISION	RECALL	F1-SCORE
Class 0	0.99	0.99	0.99
Class 1	0.88	0.92	0.90
Class 2	0.82	0.70	0.76
Class 3	0.63	0.74	0.68

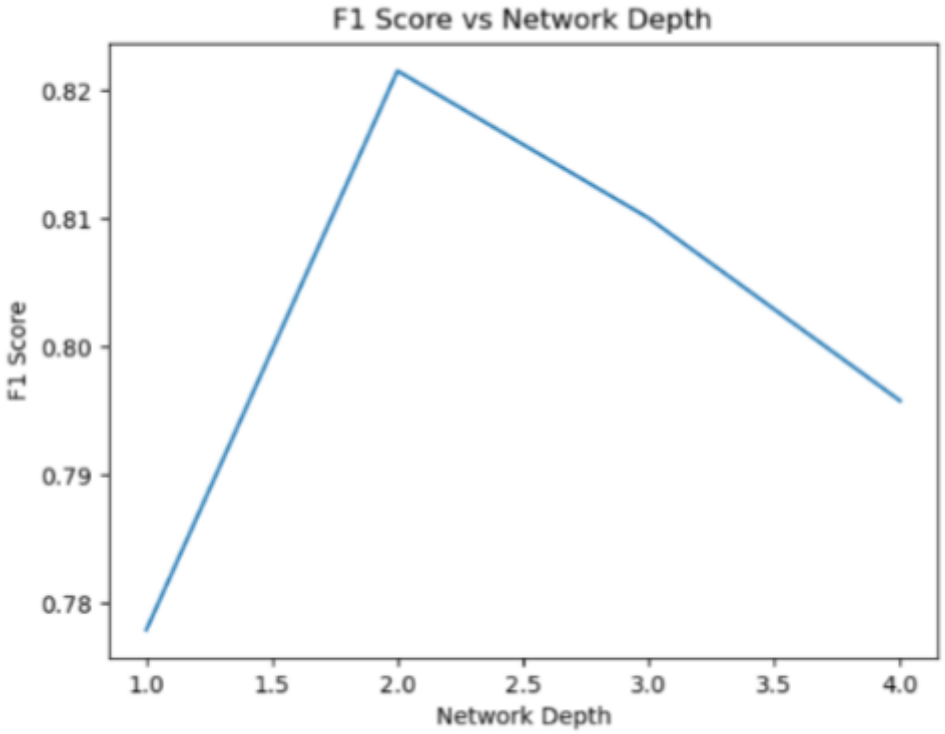
CLASS	PRECISION	RECALL	F1-SCORE
Class 4	0.81	0.76	0.78

3. 512, 256, 128

CLASS	PRECISION	RECALL	F1-SCORE
Class 0	0.98	1.00	0.99
Class 1	0.87	0.90	0.89
Class 2	0.74	0.76	0.75
Class 3	0.64	0.66	0.65
Class 4	0.83	0.73	0.78

4. 512, 256, 128, 64

CLASS	PRECISION	RECALL	F1-SCORE
Class 0	0.98	1.00	0.99
Class 1	0.88	0.92	0.90
Class 2	0.82	0.70	0.76
Class 3	0.63	0.74	0.68
Class 4	0.81	0.76	0.78



Utilizing the relu function in the interior layers, rather than the sigmoid, leads to significantly higher accuracy levels. The provided link in the assignment statement may offer insights into the reasons behind this phenomenon. The sigmoid function tends to saturate and become less sensitive around the 0.5 threshold, while the relu function, owing to its linear nature, remains unaffected by these issues. Although there are situations where tanh or sigmoid activations may outperform relu, the specific dataset we were given consistently delivers superior results with relu. While the resulting graph bears a resemblance to the previous one, it has been shifted upwards on the y-axis by more than 15 percent, resulting in improved accuracies across nearly all the network architectures we tested

(f)

Train Metrics

1. 512

CLASS	PRECISION	RECALL	F1-SCORE
Class 0	0.87	0.88	0.87
Class 1	0.72	0.35	0.47

CLASS	PRECISION	RECALL	F1-SCORE
Class 2	0.61	0.04	0.07
Class 3	0.00	0.00	0.00
Class 4	0.73	0.66	0.70

2. 512, 256

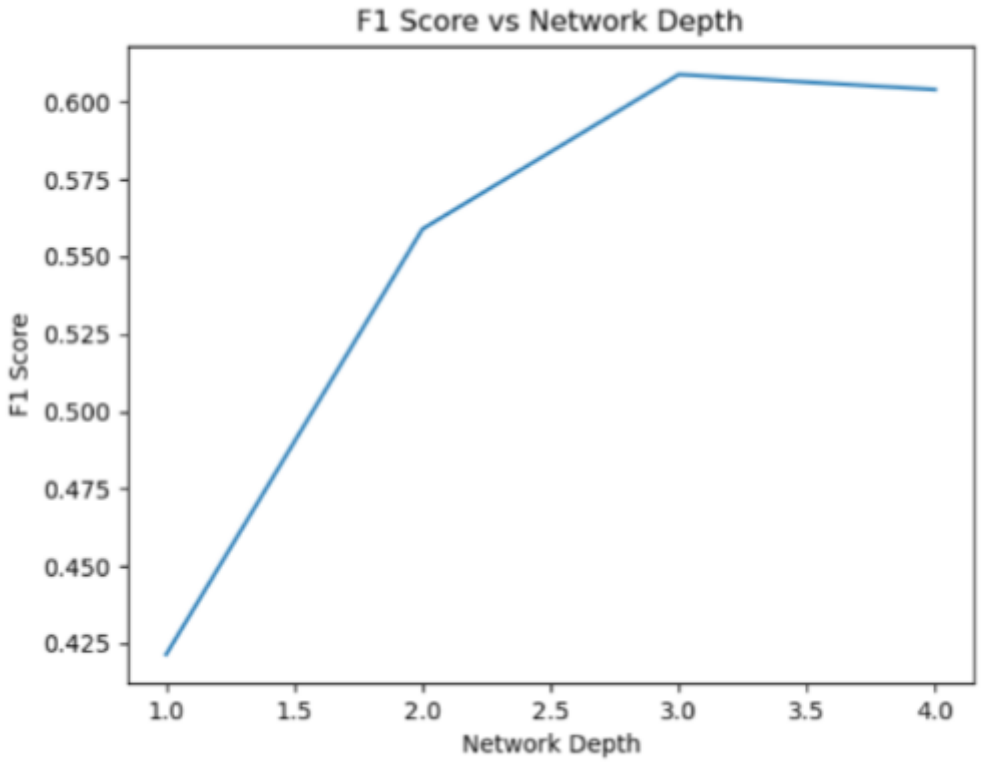
CLASS	PRECISION	RECALL	F1-SCORE
Class 0	0.88	0.89	0.88
Class 1	0.70	0.65	0.67
Class 2	0.60	0.37	0.45
Class 3	0.50	0.05	0.08
Class 4	0.72	0.69	0.70

3. 512, 256, 128

CLASS	PRECISION	RECALL	F1-SCORE
Class 0	0.88	0.89	0.89
Class 1	0.71	0.66	0.68
Class 2	0.59	0.44	0.50
Class 3	0.54	0.17	0.26
Class 4	0.72	0.70	0.71

4. 512, 256, 128, 64

CLASS	PRECISION	RECALL	F1-SCORE
Class 0	0.88	0.89	0.88
Class 1	0.70	0.67	0.69
Class 2	0.59	0.44	0.50
Class 3	0.55	0.15	0.24
Class 4	0.71	0.71	0.71



Test Metrics

1. 512

CLASS	PRECISION	RECALL	F1-SCORE
Class 0	0.90	0.88	0.89
Class 1	0.68	0.31	0.42
Class 2	0.50	0.03	0.05
Class 3	0.00	0.00	0.00
Class 4	0.69	0.58	0.63

2. 512, 256

CLASS	PRECISION	RECALL	F1-SCORE
Class 0	0.90	0.90	0.90
Class 1	0.68	0.65	0.66
Class 2	0.59	0.35	0.44
Class 3	0.38	0.04	0.08

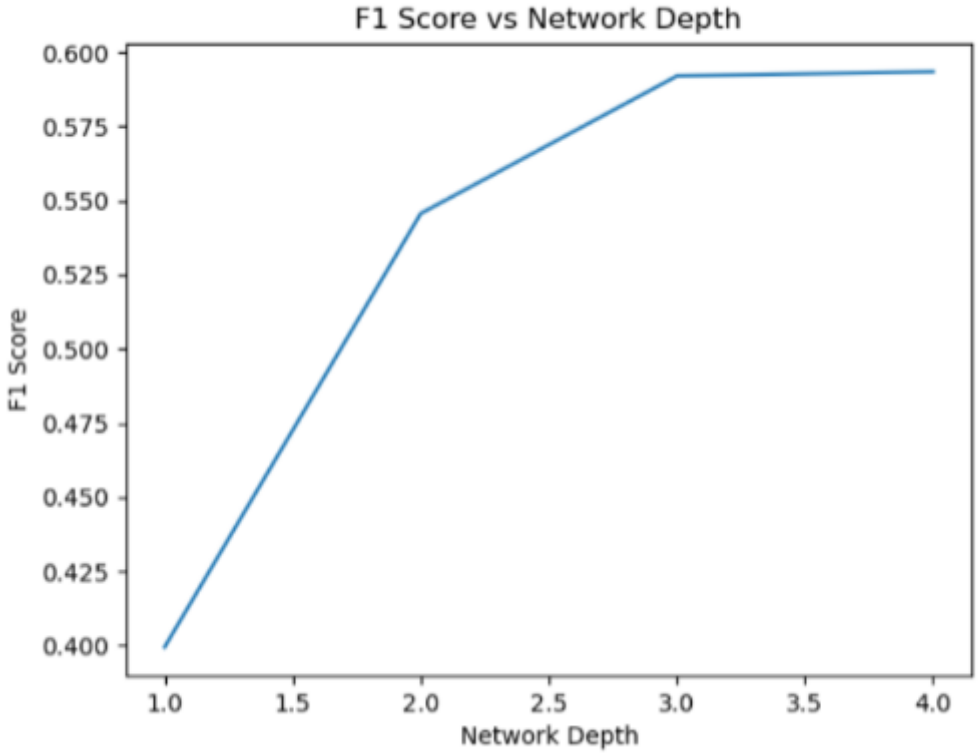
CLASS	PRECISION	RECALL	F1-SCORE
Class 4	0.69	0.61	0.65

3. 512, 256, 128

CLASS	PRECISION	RECALL	F1-SCORE
Class 0	0.90	0.90	0.90
Class 1	0.68	0.63	0.65
Class 2	0.59	0.42	0.49
Class 3	0.47	0.18	0.26
Class 4	0.69	0.63	0.66

4. 512, 256, 128, 64

CLASS	PRECISION	RECALL	F1-SCORE
Class 0	0.90	0.90	0.90
Class 1	0.68	0.65	0.66
Class 2	0.59	0.43	0.50
Class 3	0.51	0.17	0.25
Class 4	0.68	0.63	0.66



The F1 scores achieved with our model are higher than those obtained using the scikit-learn library. This difference may be attributed to the scikit-learn model possibly requiring more training epochs compared to our model. Additionally, I have observed that for certain test examples, our model couldn't predict any class, indicating that it may not have been fully trained