Report on

Deep Learning and Applications (CS671)

Assignment 4

Indian Institute of Technology Mandi

Submitted by:

GROUP - 9

Shashank Kapoor (S22022)

Shubham Patwar (T22108)

Syed Rizwan Ali Quadri (T22113)

Assignment Problem Statement

In this assignment, the key objective is to deepen understanding of the autoencoders. The major task here is to build an autoencoder to obtain the hidden representation and use it for classification.

Overall Result:

Task1 :

PCA Components	Neural Architecture	No. of Epochs	Training Accuracy	Validation Accuracy
32	(128,64,32)	9	0.9908	0.9781
	(256,128,64)	**18**	**0.9962**	**0.9855**
	(512,256,128)	8	0.9841	0.9762
64	(128,64,32)	14	0.9967	0.9805
	(256,128,64)	10	0.9948	0.9810
	(512,256,128)	**13**	**0.9950**	**0.9810**
128	(128,64,32)	11	0.9979	0.9807
	(256,128,64)	**10**	**0.9959**	**0.9810**
	(512,256,128)	8	0.9913	0.9739
256	(128,64,32)	9	0.9972	0.9760
	(256,128,64)	**9**	**0.9966**	**0.9760**
	(512,256,128)	9	0.9949	0.9757

* Mark in bold is Best architecture according to the validation accuracy

Confusion Matrix of the Best Architecture:

1. **PCA components=32:**
   - **Neural Architecture: 256, 128,64**

predicted label	Actual Label				
	2	**4**	**6**	**7**	**8**
2	737	2	5	7	8
4	1	750	3	3	2
6	5	5	744	0	5
7	9	5	0	741	4
8	7	2	7	3	740

Testing Accuracy: 0.9781

Fig.1. Confusion matrix of the best 32 components representation by FCNN (256,128,64)

2. **PCA components=64:**
   - **Neural Architecture: 512,256,128**

predicted label	Actual Label				
	2	**4**	**6**	**7**	**8**
2	734	5	6	5	9
4	1	749	6	2	1
6	4	3	744	0	8
7	11	10	0	734	4
8	11	2	1	4	741

Testing Accuracy: 0.9754

Fig.2. Confusion matrix of the best 64 components representation by FCNN (512,256,128)

3. **PCA components=128:**
   - **Neural Architecture: 256,128,64**

predicted label	Actual Label				
	2	**4**	**6**	**7**	**8**
2	737	7	7	7	1
4	3	747	3	5	1
6	3	0	750	0	6
7	7	10	1	739	2
8	12	6	6	3	732

Testing Accuracy: 0.9762

Fig.3. Confusion matrix of the best 64 components representation by FCNN (512,256,128)

4. **PCA components=256:**
   - **Neural Architecture: 256,128,64**

predicted label	Actual Label				
	2	**4**	**6**	**7**	**8**
2	731	8	4	6	10
4	0	743	4	7	5
6	2	10	739	0	8
7	8	5	1	739	6
8	9	6	2	2	740

Testing Accuracy: 0.9728

Fig.4. Confusion matrix of the best 64 components representation by FCNN (512,256,128)

Task 2:

Autoencoder	Bottleneck Size	Average reconstruction training Error	Average reconstruction validation Error	Average reconstruction testingError
1 Layer Autoencoder	**32**	0.0198	0.0200	0.0201
	64	0.0131	0.0134	0.0134
	128	0.0093	0.0095	0.0096
	256	**0.0084**	**0.0086**	**0.0087**
3 Layer Autoencoder	**32**	0.0251	0.0255	0.0256
	64	**0.0196**	**0.0200**	**0.0201**
	128	0.0207	0.0213	0.0213
	256	0.0254	0.0260	0.0259

1. **1-layer Autoencoder Image Reconstruction:**
   - **32 Bottleneck Size Autoencoder**
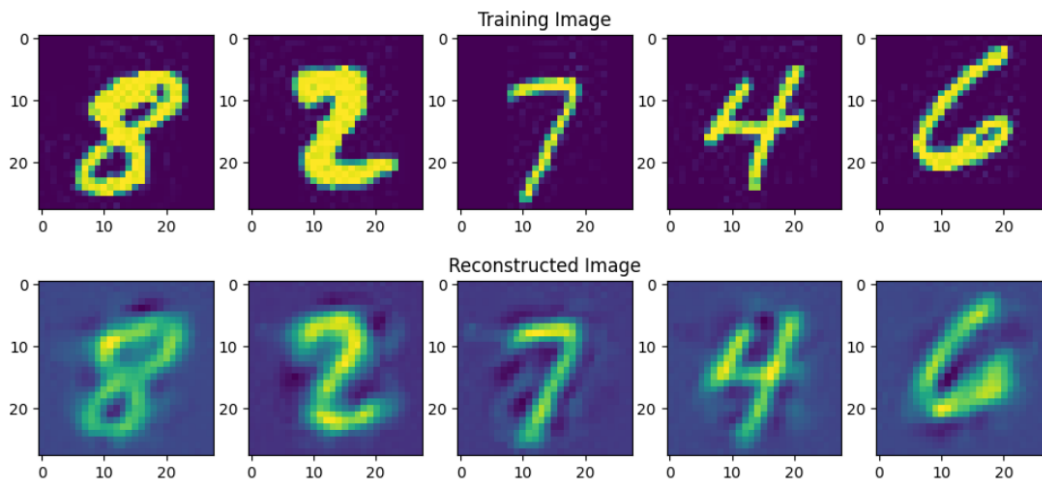
Fig. original vs reconstructed image from 1 layer Autoencoder with 32 Bottleneck size

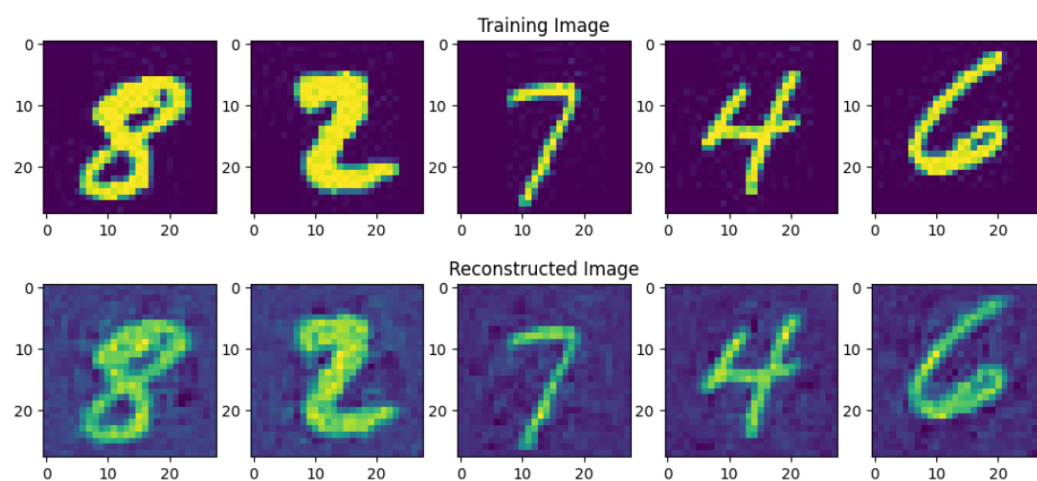- **64 Bottleneck Size Autoencoder**
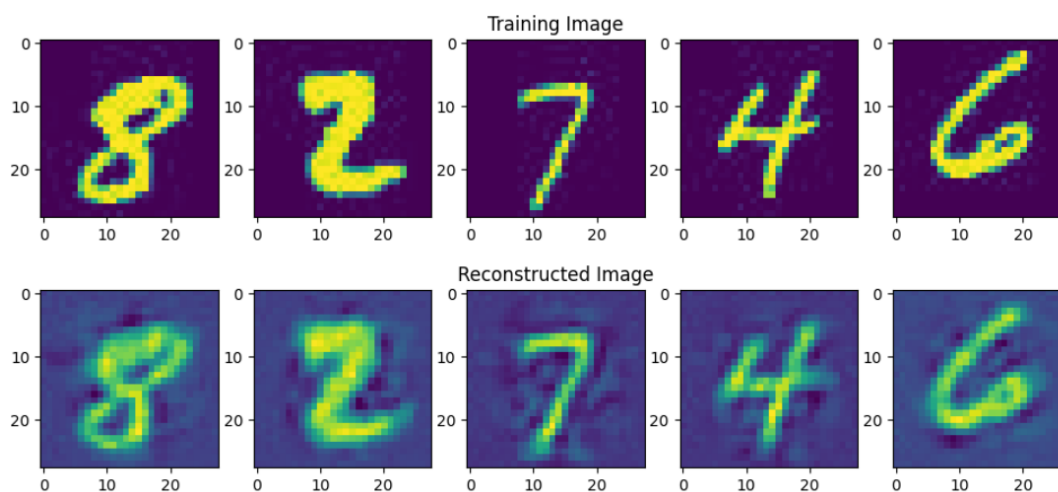
Fig. original vs reconstructed image from 1 layer Autoencoder with 64 Bottleneck size

- **128 Bottleneck Size Autoencoder**
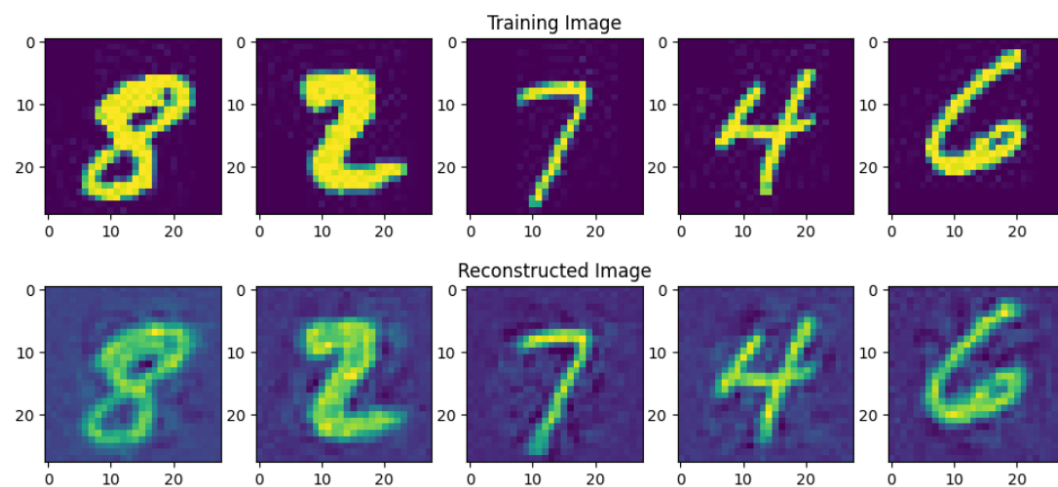
Fig. original vs reconstructed image from 1 layer Autoencoder with 128 Bottleneck size

- **256 Bottleneck Size Autoencoder**

Fig. original vs reconstructed image from 1 layer Autoencoder with 256 Bottleneck size

2. 3-layer Autoencoder Image Reconstruction:
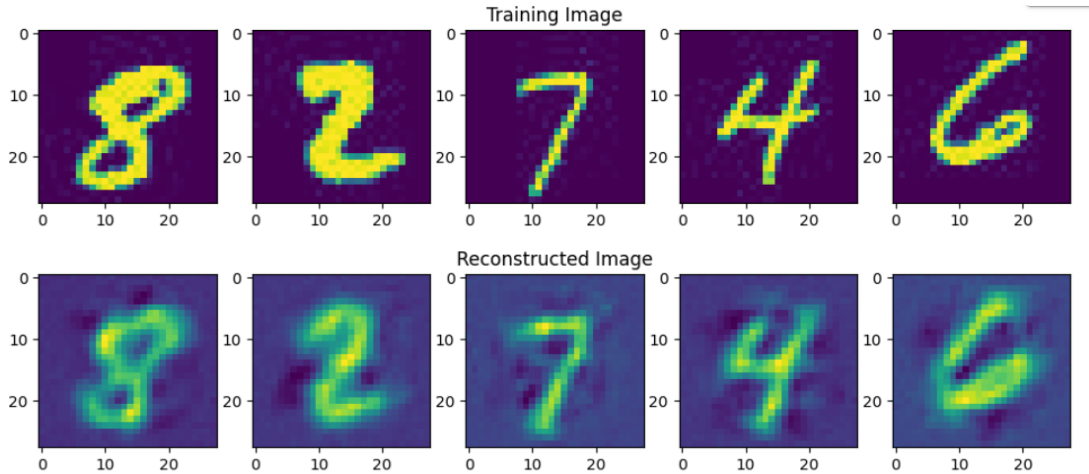
- **32 Bottleneck Size Autoencoder**

Fig. original vs reconstructed image from 3 layer Autoencoder with 32 Bottleneck size

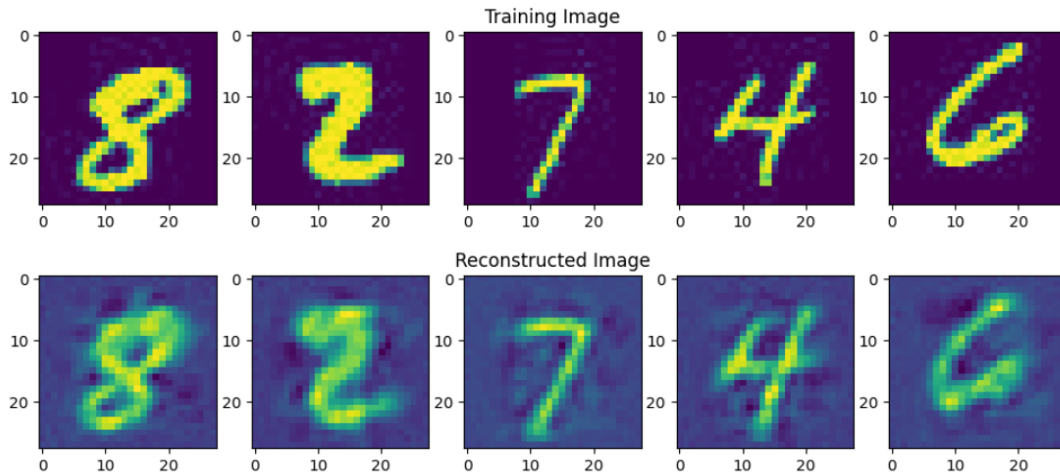- **64 Bottleneck Size Autoencoder**

Fig. original vs reconstructed image from 3 layer Autoencoder with 64 Bottleneck size

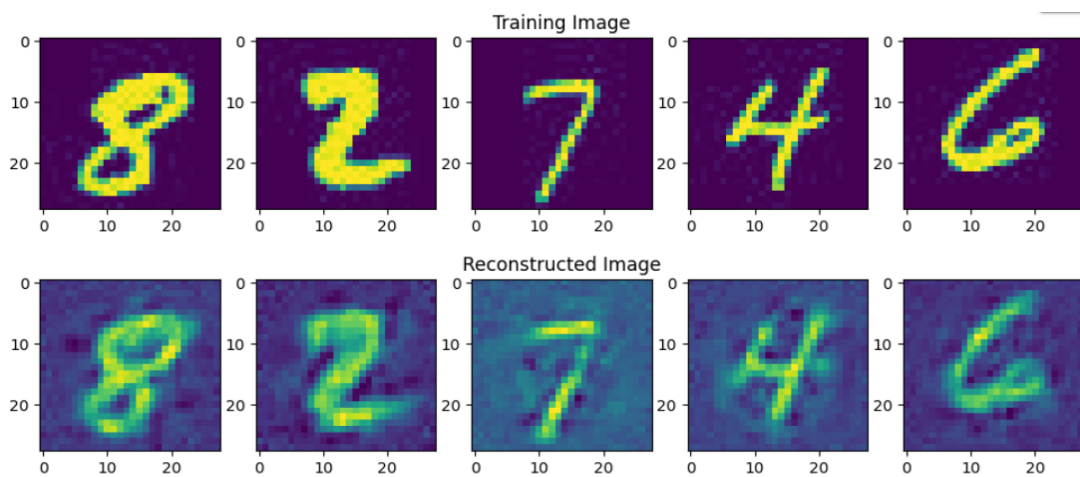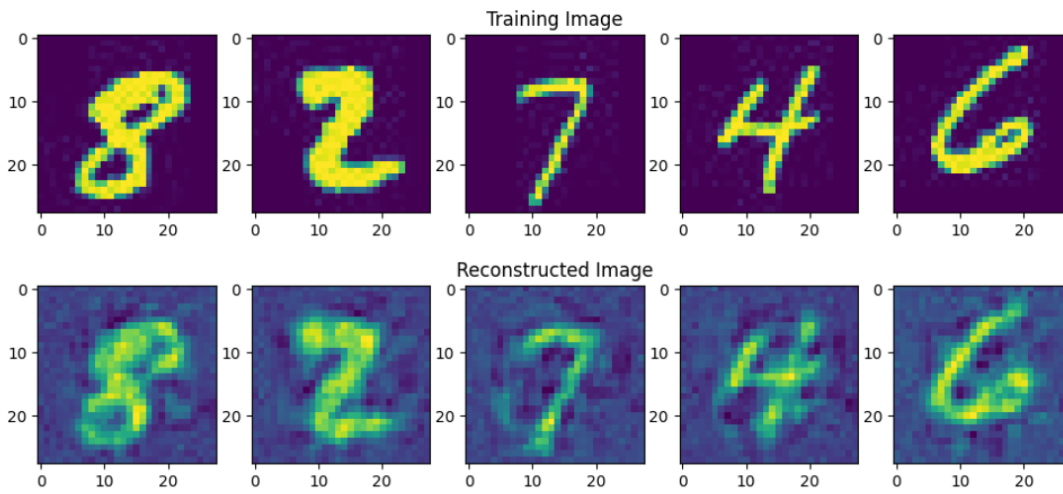- **128 Bottleneck Size Autoencoder**

Fig. original vs reconstructed image from 3 layer Autoencoder with 128 Bottleneck size

- **256 Bottleneck Size Autoencoder**

Fig. original vs reconstructed image from 3 layer Autoencoder with 256 Bottleneck size

Task3 :

Encoder outputs	Neural Architecture	No. of Epochs	Training Accuracy	Validation Accuracy
32	**(128,64,32)**	**19**	**0.9956**	**0.9797**
	(256,128,64)	17	0.9921	0.9789
	(512,256,128)	16	0.9871	0.9736
64	**(128,64,32)**	**13**	**0.9949**	**0.9818**
	(256,128,64)	12	0.9928	0.9768
	(512,256,128)	13	0.9906	0.9812
128	(128,64,32)	13	0.9978	0.9739
	(256,128,64)	**13**	**0.9965**	**0.9778**
	(512,256,128)	10	0.9913	0.9770
256	**(128,64,32)**	**9**	**0.9954**	**0.9768**
	(256,128,64)	10	0.9949	0.9741
	(512,256,128)	13	0.9955	0.9752

* Mark in bold is Best architecture according to the validation accuracy

Confusion Matrix of the Best Architecture:
    1-hidden layer autoencoder components=32:
       ● **Neural Architecture: 128,64,32**

predicted label / Actual Label	2	4	6	7	8
2	736	3	3	13	4
4	2	745	6	3	3
6	4	2	743	1	9
7	6	4	1	747	1
8	8	4	13	9	725

Testing Accuracy: 0.9739

Fig.1. Confusion matrix of the best 32 components representation by FCNN (128,64,32)

1-hidden layer autoencoder components=64:
- **Neural Architecture: 128,64,32**

predicted label	Actual Label				
	2	**4**	**6**	**7**	**8**
2	737	2	6	9	5
4	1	744	6	6	2
6	4	3	747	0	5
7	8	7	1	740	3
8	18	5	5	1	730

Testing Accuracy: 0.97444

Fig.2. Confusion matrix of the best 64 components representation by FCNN (128,64,32)

1-hidden layer autoencoder components=128:
- **Neural Architecture: 256,128,64**

predicted label	Actual Label				
	2	**4**	**6**	**7**	**8**
2	732	5	4	15	3
4	6	741	3	7	2
6	7	2	744	2	4
7	5	8	0	744	2
8	13	6	7	7	726

Testing Accuracy: 0.97154

Fig.3. Confusion matrix of the best 64 components representation by FCNN (256,128,64)

1-hidden layer autoencoder components=256:
- **Neural Architecture: 128,64,32**

predicted label	Actual Label				
	2	**4**	**6**	**7**	**8**
2	720	9	10	6	14
4	2	748	4	5	0
6	3	6	744	0	6
7	8	8	0	740	3
8	8	10	7	6	728

Testing Accuracy: 0.969697

Fig.4. Confusion matrix of the best 64 components representation by FCNN (128,64,32)

10

Task4 :

Bottleneck size	Neural Architecture	No. of Epochs	Training Accuracy	Validation Accuracy
32	(128,64,32)	13	0.9902	0.9697
	(256,128,64)	**13**	**0.9856**	**0.9697**
	(512,256,128)	22	0.9882	0.9726
64	(128,64,32)	8	0.9893	0.9702
	(256,128,64)	**10**	**0.9890**	**0.9779**
	(512,256,128)	15	0.9923	0.9779
128	**(128,64,32)**	**8**	**0.9923**	**0.9757**
	(256,128,64)	11	0.9948	0.9744
	(512,256,128)	11	0.9924	0.9755
256	(128,64,32)	10	0.9937	0.9639
	(256,128,64)	**10**	**0.9938**	**0.9778**
	(512,256,128)	12	0.9945	0.9710

* Mark in bold is Best architecture according to the validation accuracy

Confusion Matrix of the Best Architecture:
  1. **3-hidden layer autoencoder components=32:**
     ● **Neural Architecture: 256,128,64**

Fig.1. Confusion matrix of the best 32 components representation by FCNN (256,128,64)

2. 3-hidden layer autoencoder components=64:
  ● **Neural Architecture: 256,128,64**

predicted label		Actual Label				
		2	4	6	7	8
	2	723	4	6	15	11
	4	2	738	7	8	4
	6	3	5	746	1	4
	7	7	7	0	740	5
	8	4	7	16	6	726

Testing Accuracy: 0.96785

Fig.2. Confusion matrix of the best 64 components representation by FCNN (256,128,64)

3. 3-hidden layer autoencoder components=128:
  ● **Neural Architecture: 128,64,32**

predicted label		Actual Label				
		2	4	6	7	8
	2	733	6	2	10	8
	4	1	746	6	5	1
	6	2	6	741	1	9
	7	6	6	1	743	3
	8	10	10	12	4	723

Testing Accuracy: 0.971278

Fig.3. Confusion matrix of the best 64 components representation by FCNN (128,64,32)

4. 3-hidden layer autoencoder components=256:
  ● **Neural Architecture: 256,128,64**

predicted label		Actual Label				
		2	4	6	7	8
	2	719	15	5	13	7
	4	2	752	3	1	1
	6	8	8	737	0	6
	7	8	14	1	734	2
	8	18	5	8	7	721

Testing Accuracy: 0.9652174

Fig.4. Confusion matrix of the best 64 components representation by FCNN (256,128,64)

Task 5:

Noisy in training Data (in %)	1 layer Autoencoder Architecture	Average reconstruction training Error	Average reconstruction validation Error	Average reconstruction testingError
20	**(784,64,784)**	0.0150	0.0153	0.0153
40	**(784,64,784)**	0.0214	0.0217	0.0217

3. **1-layer Autoencoder:**
    - **Autoencoder Architecture (784,64,784)**
        - **20% noisy**
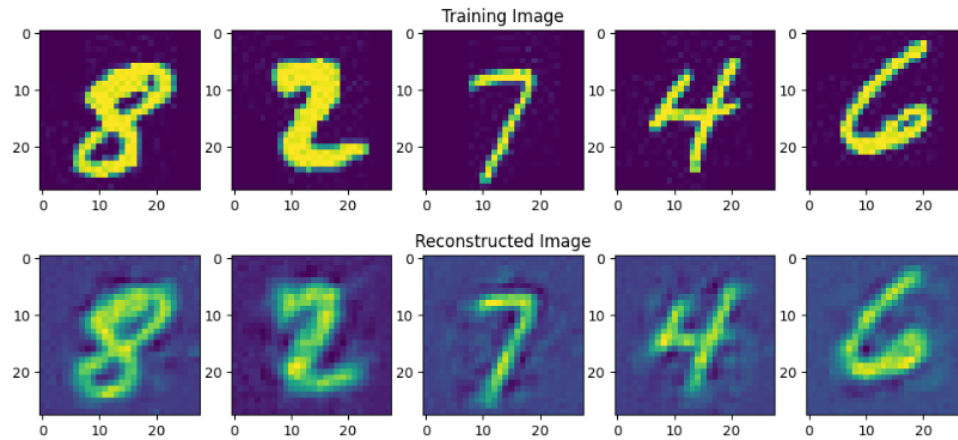
Fig. original vs reconstructed image from 1 layer Autoencoder with 64 Bottleneck size
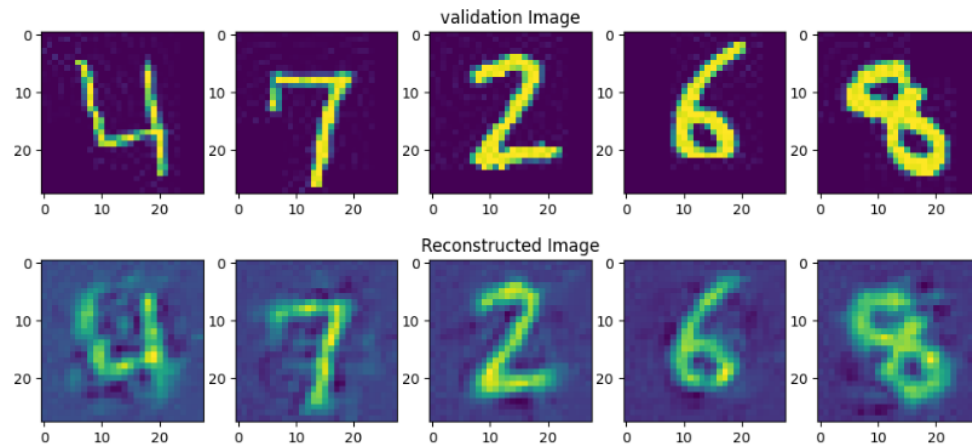
Fig. original vs reconstructed image from 1 layer Autoencoder with 64 Bottleneck size
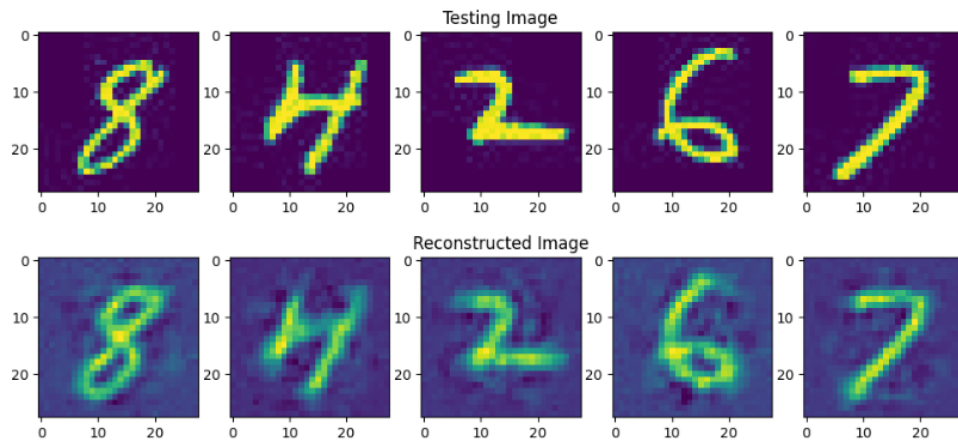
Fig. original vs reconstructed image from 1 layer Autoencoder with 64 Bottleneck size

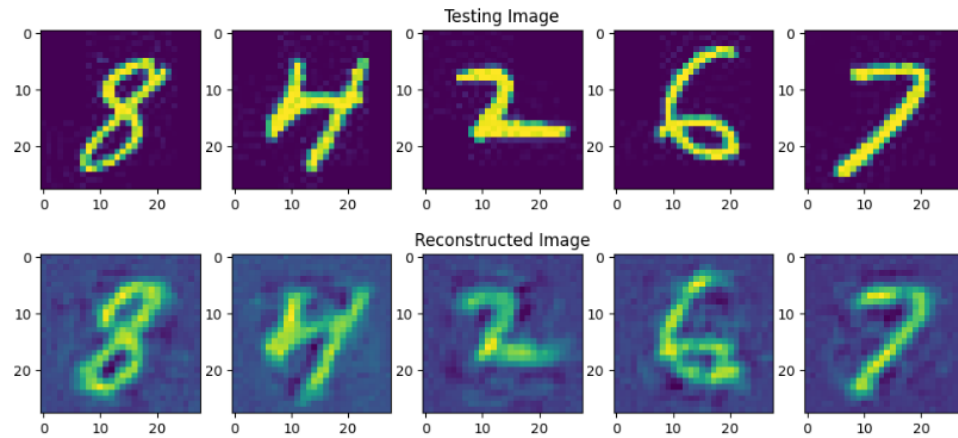- **Autoencoder Architecture (784,64,784)**
  - **40% noisy**
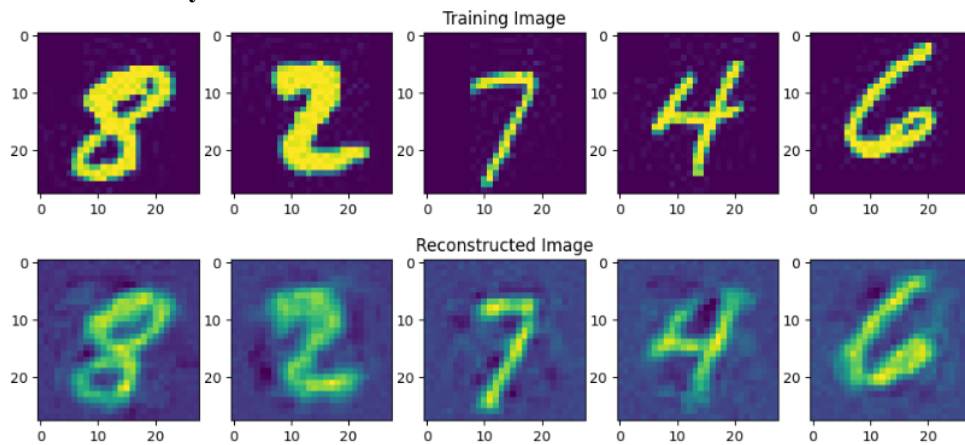
Fig. original vs reconstructed image from 1 layer Autoencoder with 64 Bottleneck size
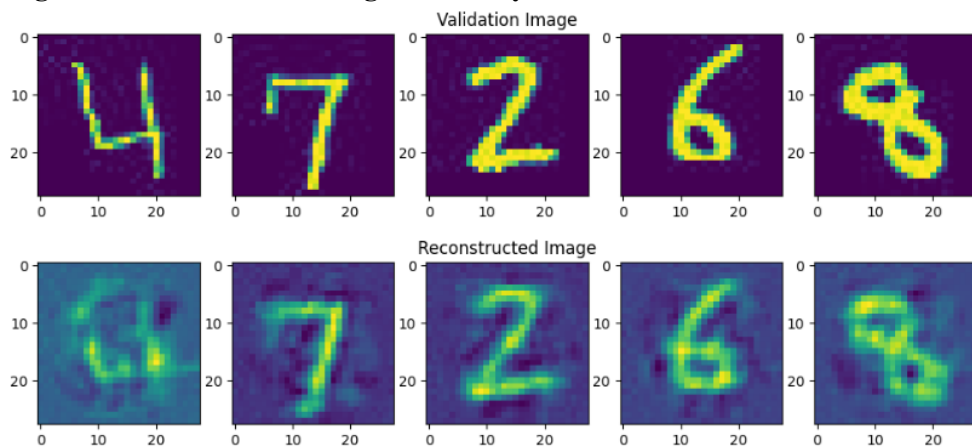
Fig. original vs reconstructed image from 1 layer Autoencoder with 64 Bottleneck size

Fig. original vs reconstructed image from 1 layer Autoencoder with 64 Bottleneck size

Noisy in training Data (in %)	1 layer Autoencoder Architecture	No. of Epochs	Training Accuracy	Validation Accuracy	Testing Accuracy
20	**(128,64,32)**	**12**	**0.9935**	**0.9802**	**0.9760**
	(256,128,64)	10	0.9914	0.9789	0.9723
	(512,256,128)	10	0.9870	0.9752	0.9734
40	(128,64,32)	10	0.98998	0.97154	0.9618
	(256,128,64)	**12**	**0.9923**	**0.9736**	**0.9647**
	(512,256,128)	13	0.9893	0.9720	0.9634

Fig.: classification accuracy on the training, validation and test set for the different architectures of FCNN classification model.
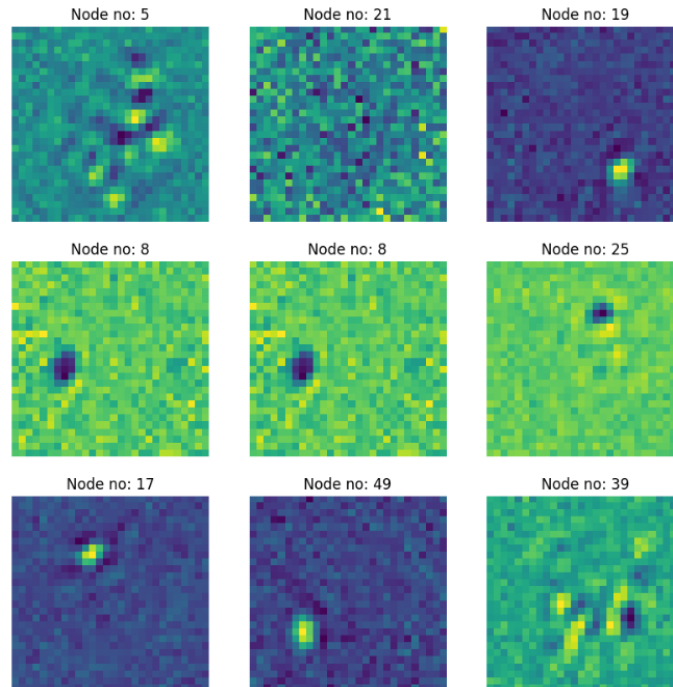
Task 6:

● Weights Visualization of the one hidden layer Autoencoder with the best representation **64** in our case.
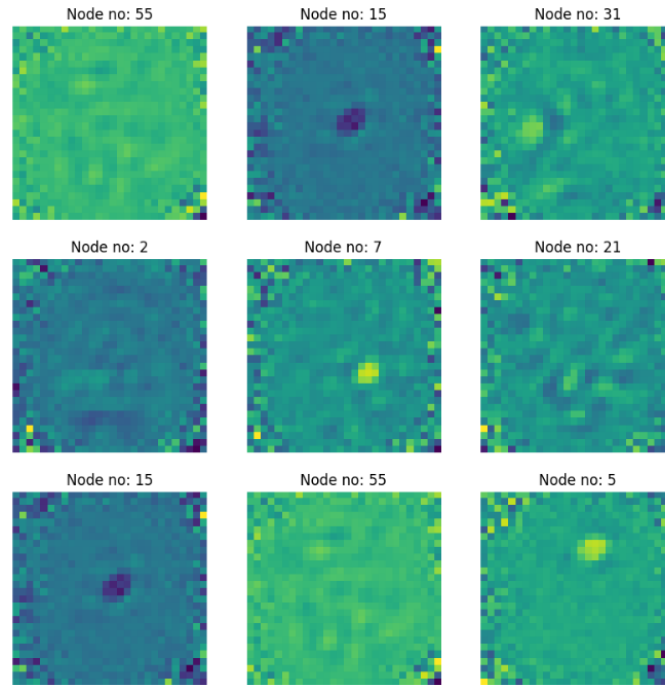
Fig. Weights Visualization of the one hidden layer for 64 size in bottleneck
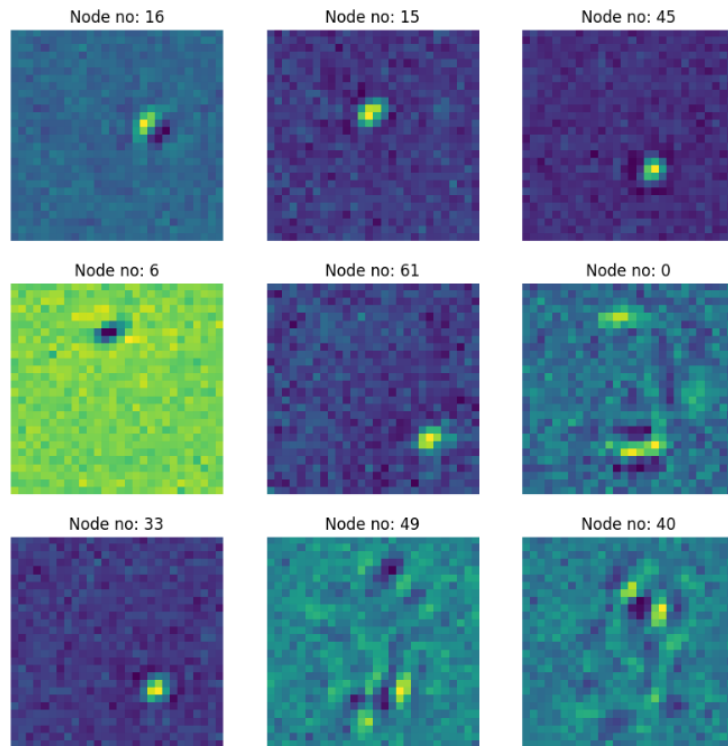
● Weights Visualization of the one hidden layer autoencoder with the best representation **64** in our case , with 20% denoising Data.

Fig. Weights Visualization of the one hidden layer for 64 size in bottleneck and 20% denoising

- Weights Visualization of the one hidden layer autoencoder with the best representation **64** in our case , with 40% denoising Data.

Fig. Weights Visualization of the one hidden layer for 64 size in bottleneck and 40% denoising