



CS 671

Deep Learning and its Applications

Assignment Report – 1

Group Members:

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Task1: Classification

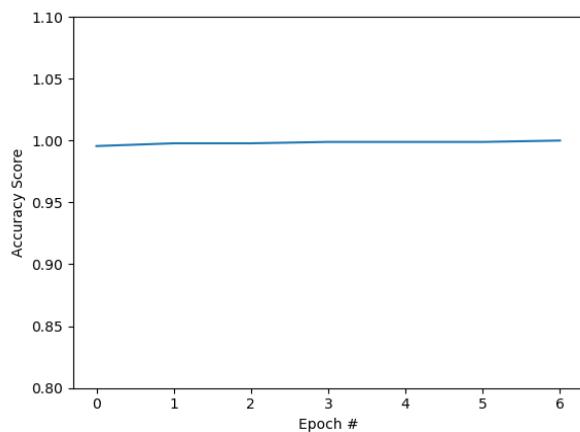
1 . Dataset (1a)

Given dataset was linearly separable.

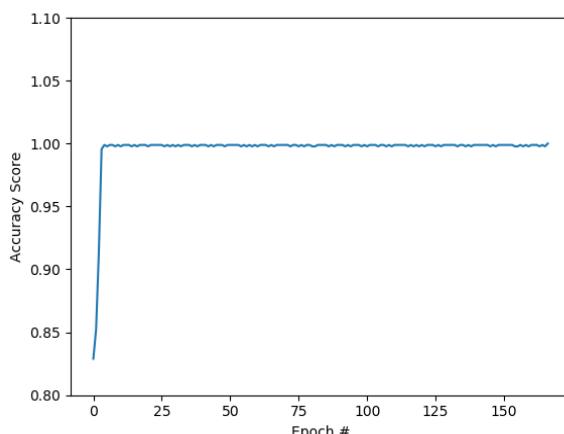
Model 1

This model is built upon perceptron. We adopted one-against-the-rest approach. While taking each class , threshold was set to be : accuracy score = 100%.

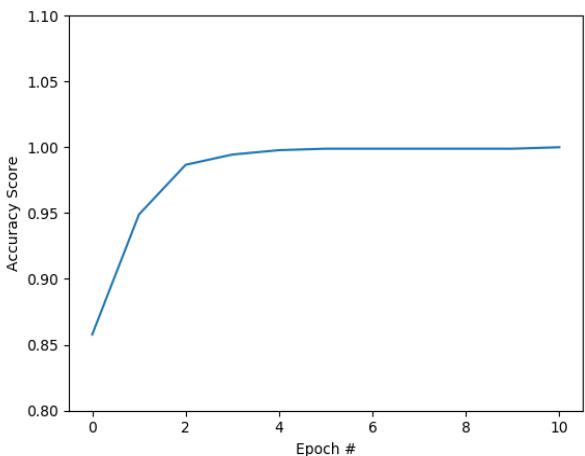
- a) Plot of accuracy score vs number of epochs for class 1 and rest.



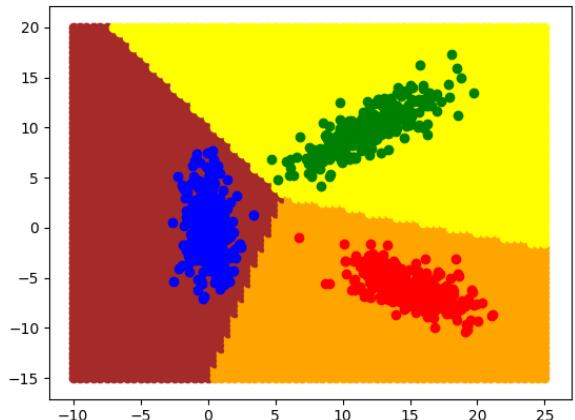
- b) Plot of accuracy score vs number of epochs for class 2 and rest.



- c) Plots of accuracy score vs number of epochs for class 3 and rest.



- d) Decision region plot



- e) Quantitative Results

Accuracy on train data : 100.0

Train data confusion matrix :

$\begin{bmatrix} 300 & 0 & 0 \end{bmatrix}$

$\begin{bmatrix} 0 & 300 & 0 \end{bmatrix}$

$\begin{bmatrix} 0 & 0 & 300 \end{bmatrix}$

Accuracy on validation data :

100.0

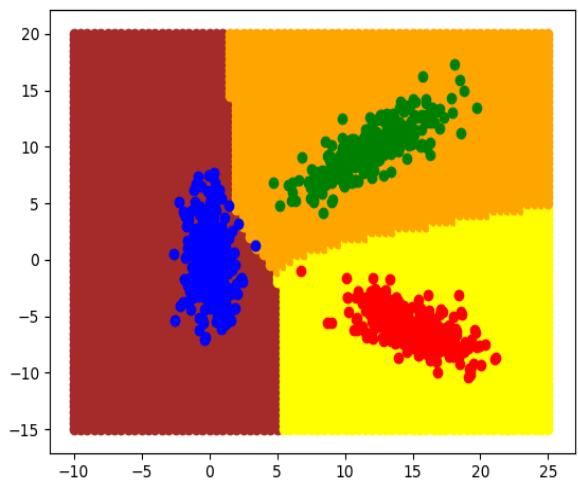
Confusion Matrix validation data :

```
[[100  0  0]
 [ 0 100  0]
 [ 0  0 100]]
```

Accuracy on test data : 100.0

Confusion Matrix on test data :

```
[[100  0  0]
 [ 0 100  0]
 [ 0  0 100]]
```



Model2

This model is multi layer feed-forward neural network.

Architecture :

2 neurons in Input Layer

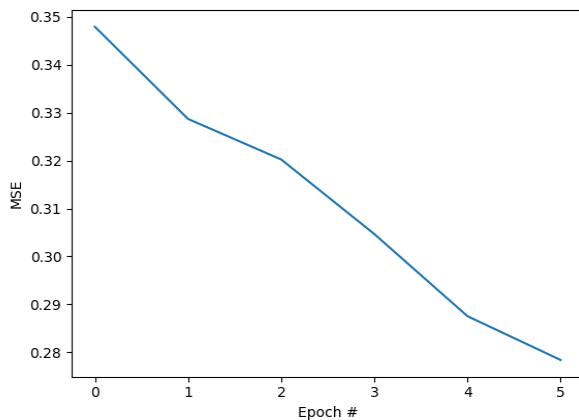
4 neurons in Hidden layer

3 neurons in Output Layer

Threshold:

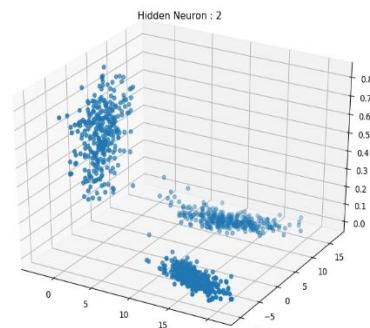
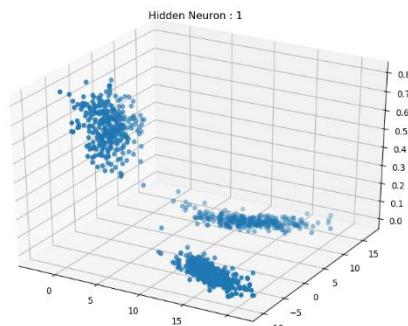
Cross Validation or subsequent difference between MSE falls below 0.0001

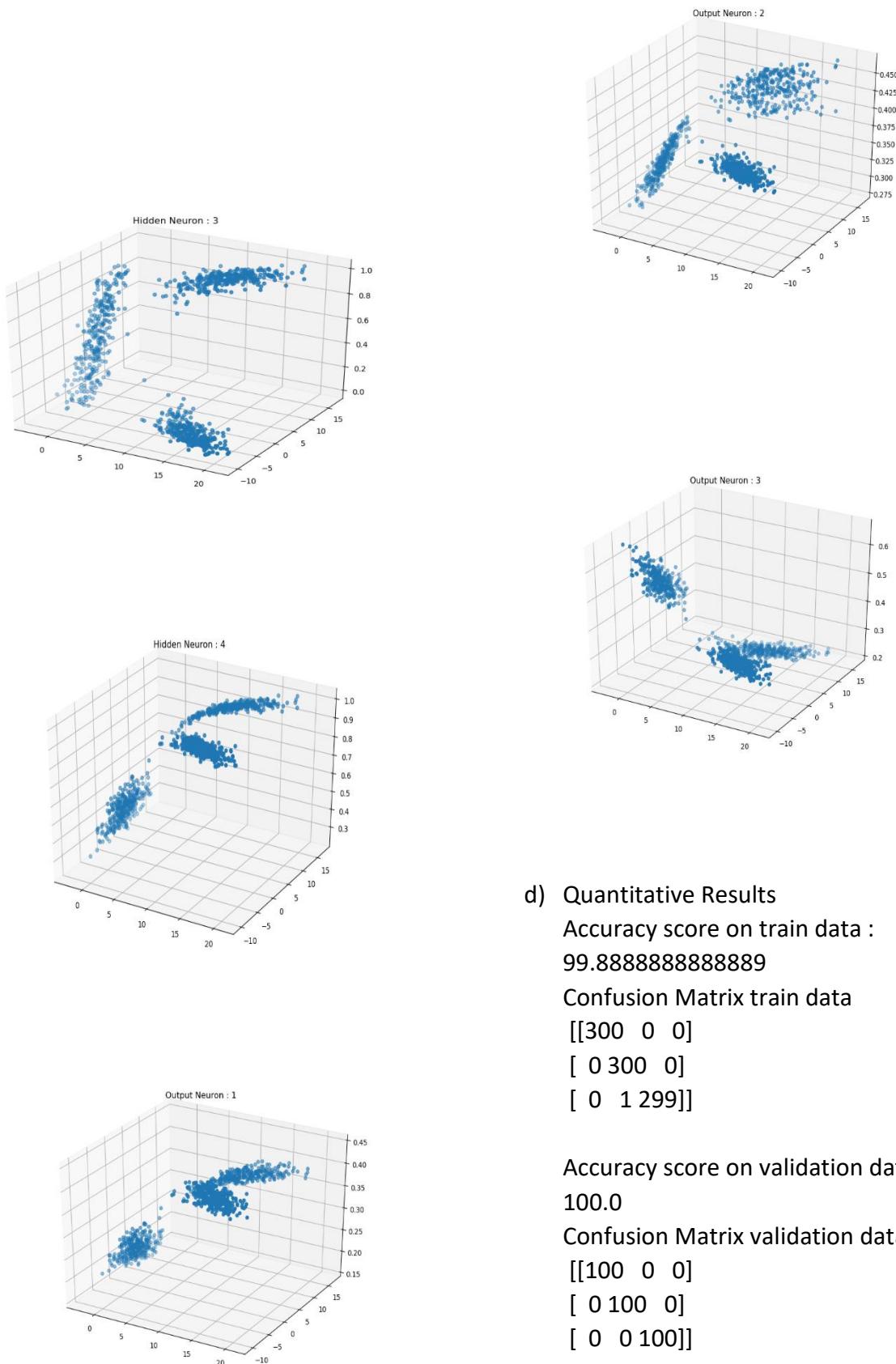
a) Plot of MSE vs epochs



b) Decision Region Plot

c) Plots of outputs of hidden nodes and output nodes





d) Quantitative Results

Accuracy score on train data :

99.8888888888889

Confusion Matrix train data

[[300 0 0]

[0 300 0]

[0 1 299]]

Accuracy score on validation data :

100.0

Confusion Matrix validation data

[[100 0 0]

[0 100 0]

[0 0 100]]

Accuracy score on test data :

100.0

Confusion Matrix test data

$\begin{bmatrix} 100 & 0 & 0 \end{bmatrix}$

$\begin{bmatrix} 0 & 100 & 0 \end{bmatrix}$

$\begin{bmatrix} 0 & 0 & 100 \end{bmatrix}$

Model3

This model is multi layer feed-forward neural network.

Architecture :

2 neurons in Input Layer

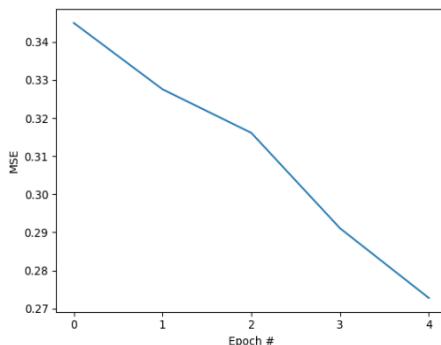
6 neurons in Hidden layer

3 neurons in Output Layer

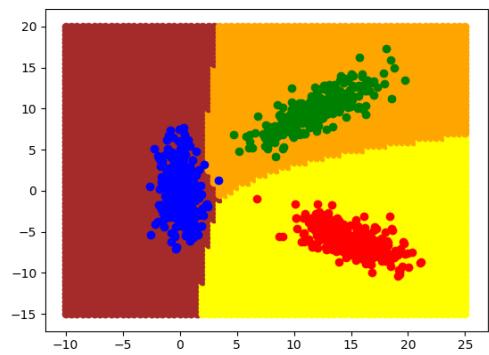
Threshold:

Cross Validation or subsequent difference between MSE falls below 0.0001

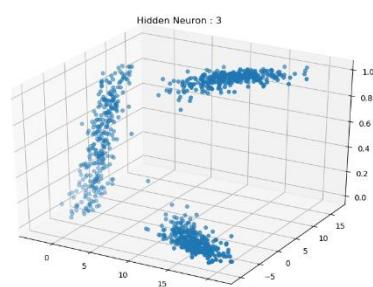
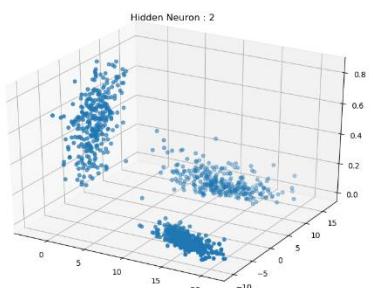
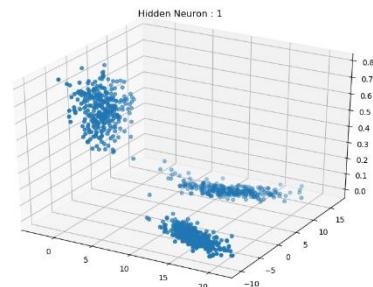
a) Plot between MSE and epochs

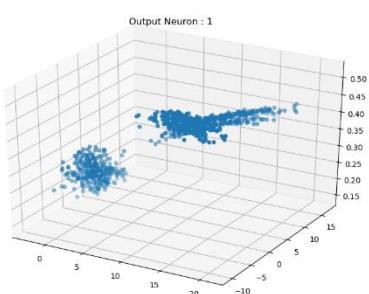
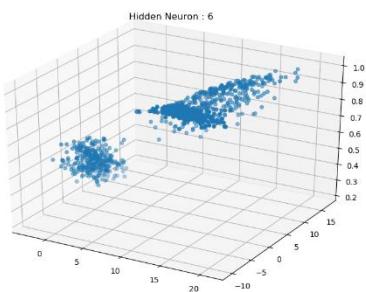
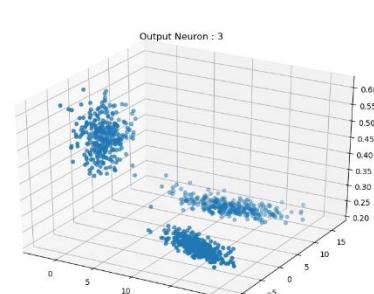
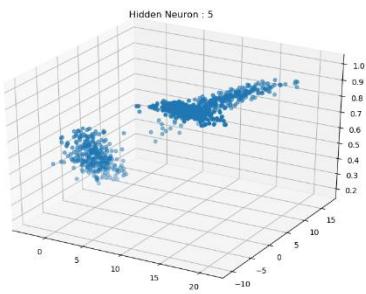
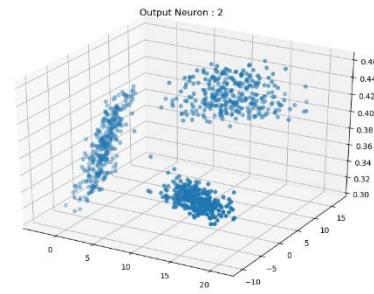
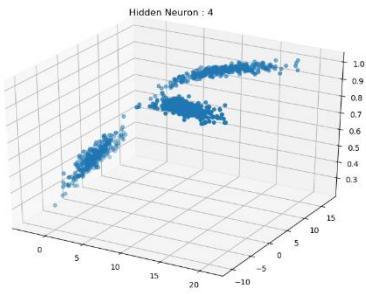


b) Decision Region Plot



c) Plots of outputs of hidden and output nodes





d) Quantitative Results

Accuracy score on train data :

99.88888888888889

Confusion Matrix train data

[[300 0 0]

[0 300 0]

[0 1 299]]

Accuracy score on val data : 100.0

Confusion Matrix val data

[[100 0 0]

[0 100 0]

[0 0 100]]

Accuracy score on test data :

100.0

Confusion Matrix test data

[[100 0 0]

[0 100 0]

[0 0 100]]

Model4

This model is multi layer feed-forward neural network.

Architecture :

2 neurons in Input Layer

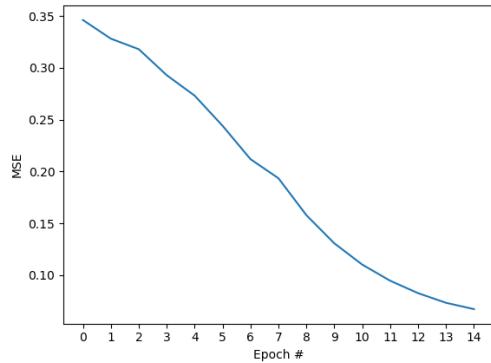
6 neurons in Hidden layer

3 neurons in Output Layer

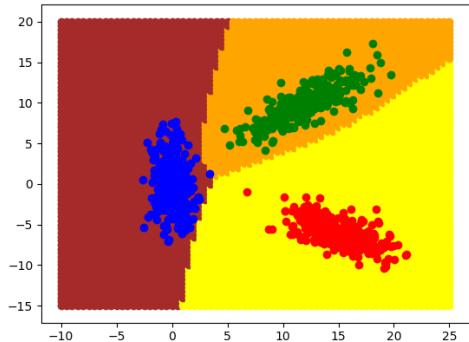
Threshold:

Subsequent difference between MSE falls below 0.0001

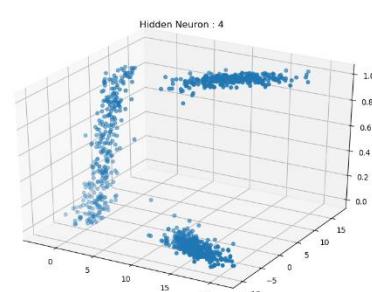
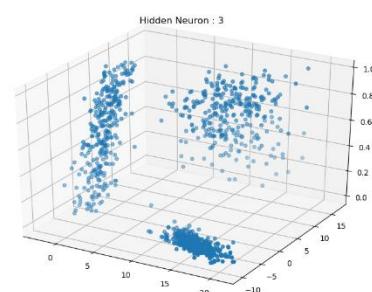
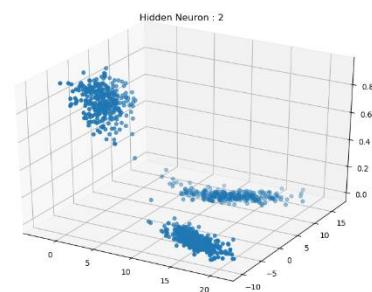
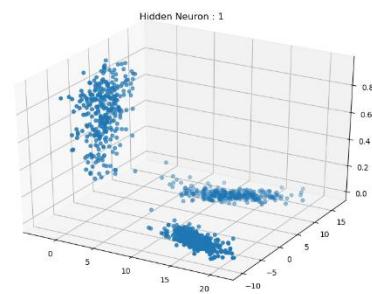
a) Plot between MSE and epochs

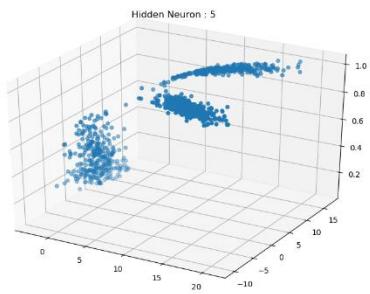


b) Decision Region Plot



c) Plots of outputs of hidden and output nodes





Accuracy score on train data :

100.0

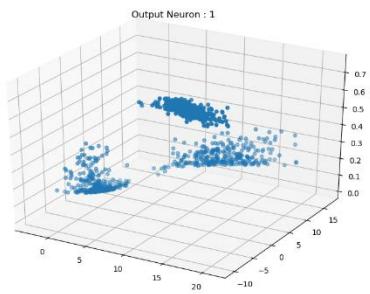
Confusion Matrix train data

```
[[300 0 0]
 [ 0 300 0]
 [ 0 0 300]]
```

Accuracy score on val data : 100.0

Confusion Matrix val data

```
[[100 0 0]
 [ 0 100 0]
 [ 0 0 100]]
```



Accuracy score on test data :

99.66666666666667

Confusion Matrix test data

```
[[100 0 0]
 [ 0 100 0]
 [ 1 0 99]]
```

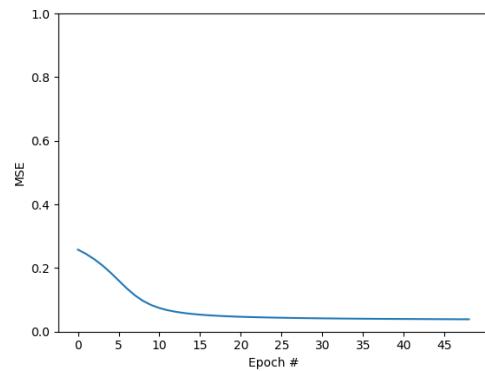
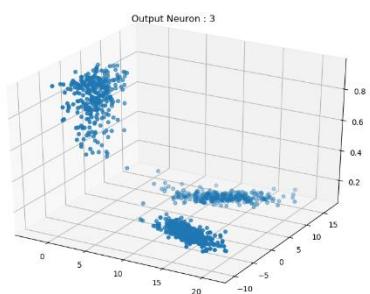
Dataset (1b)

Given dataset was non-linearly separable.

Model1

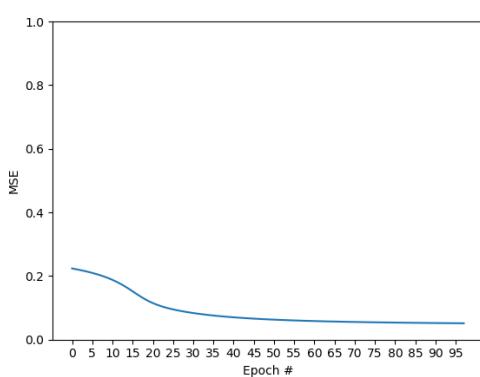
This model is built upon perceptron. We adopted one-against-the-rest approach. While taking each class , threshold was set to be : accuracy score = 100%.

- a) Plot of MSE vs epochs for class 1 and rest.



- d) Quantitative Results

- b) Plot of MSE vs epochs for class 2 and rest.



c) Plot of MSE vs epochs for class 3 and rest.

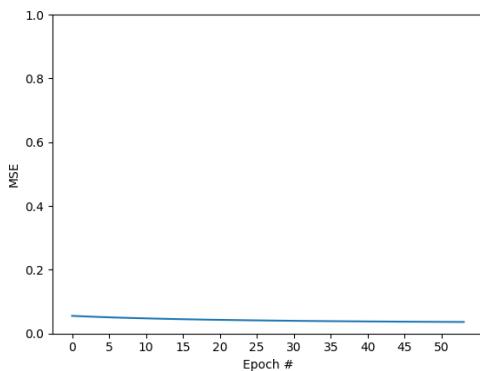
$[[98 \ 2 \ 0]$
 $[17 \ 65 \ 18]$
 $[\ 0 \ 9 \ 91]]$

Accuracy on test data :
85.3333333333334
Confusion Matrix on test data :
 $[[91 \ 9 \ 0]$
 $[15 \ 67 \ 18]$
 $[\ 0 \ 2 \ 98]]$

Model2

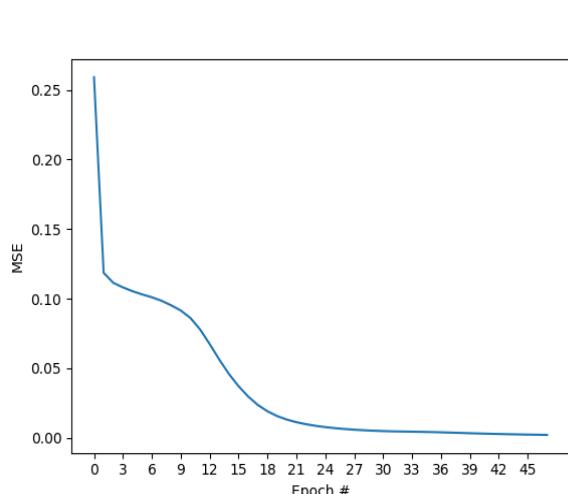
This model is multi layer feed-forward neural network.

Architecture :
2 neurons in Input Layer
20 neurons in Hidden layer
3 neurons in Output Layer
Threshold:
Cross Validation or subsequent difference between MSE falls below 0.0001



d) Decision Region Plot

a) Plot of MSE vs Epochs



e) Quantitative Results

Accuracy on train data :

84.55555555555556

Confusion Matrix train data:

$[[282 \ 18 \ 0]$

$[\ 51 \ 194 \ 55]$

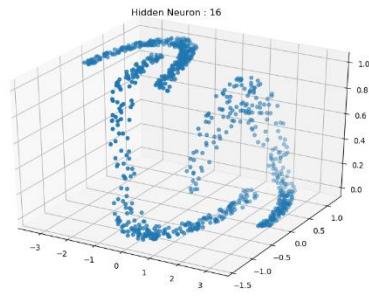
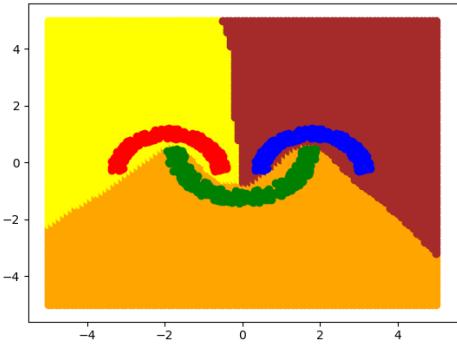
$[\ 0 \ 15 \ 285]]$

Accuracy on validation data :

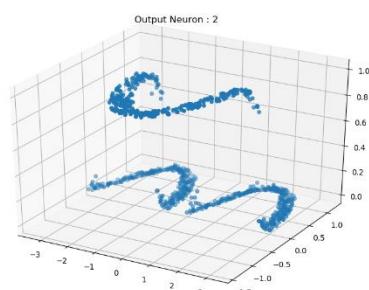
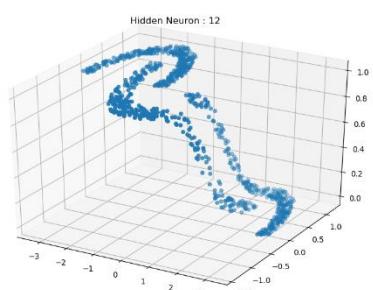
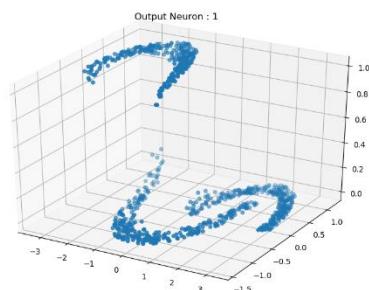
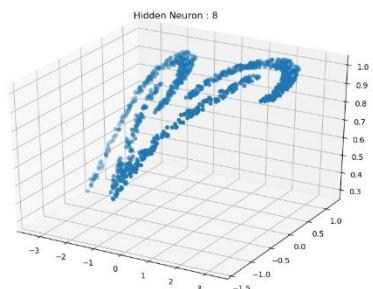
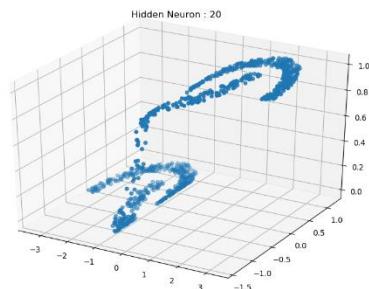
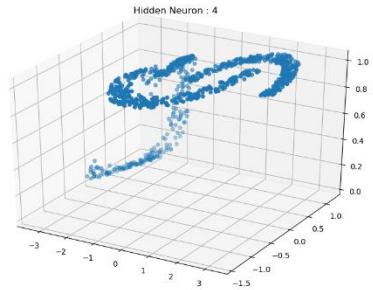
84.66666666666667

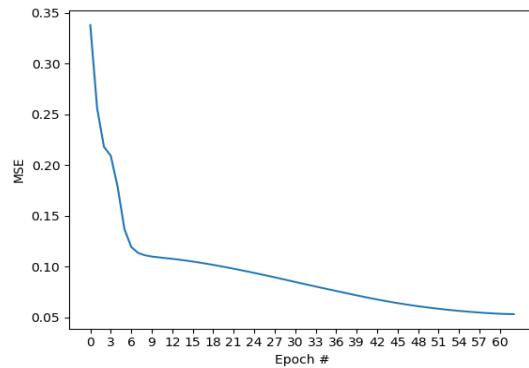
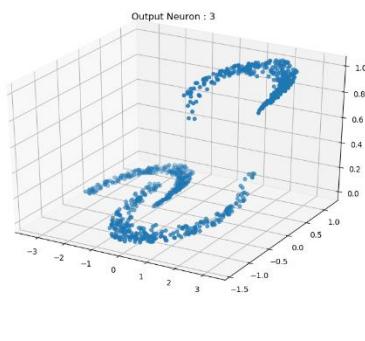
Confusion Matrix on val data :

b) Decision Region Plot



c) Plots of outputs of hidden nodes and output nodes.





d) Quantitative Results

Accuracy score on train data : 100.0

Confusion Matrix on train data :

```
[[300 0 0]
 [ 0 300 0]
 [ 0 0 300]]
```

Accuracy score on validation data : 100.0

Confusion Matrix on validation data :

```
[[100 0 0]
 [ 0 100 0]
 [ 0 0 100]]
```

Accuracy score on test data :

99.66666666666667

Confusion Matrix on test data :

```
[[100 0 0]
 [ 1 99 0]
 [ 0 0 100]]
```

Model3

This model is multi layer feed-forward neural network.

Architecture :

2 neurons in Input Layer

10 neurons in Hidden layer

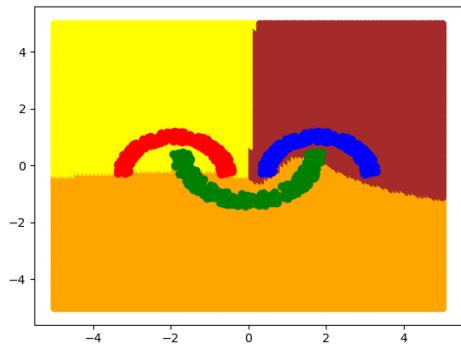
3 neurons in Output Layer

Threshold:

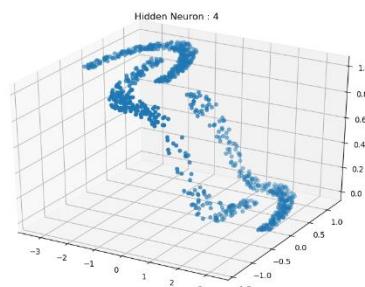
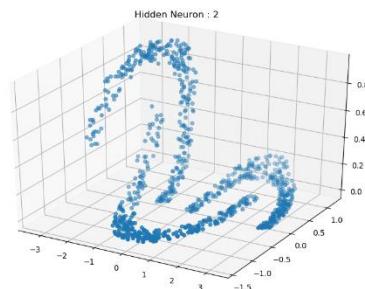
Cross Validation or subsequent difference between MSE falls below 0.0001

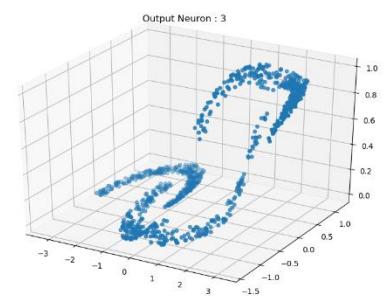
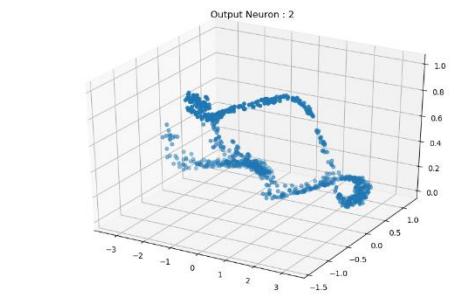
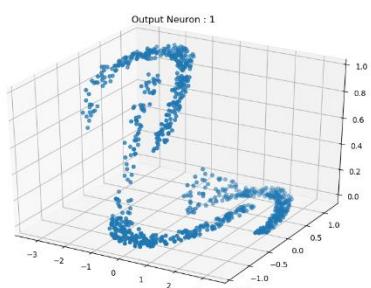
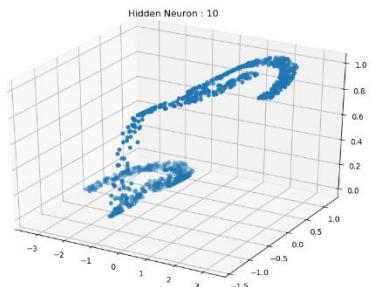
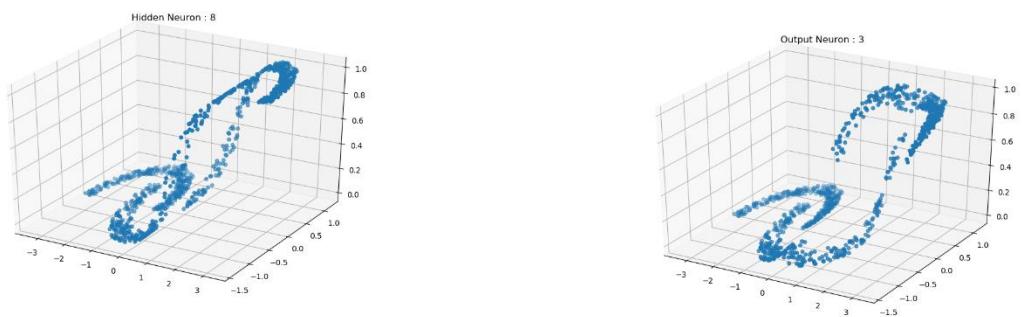
a) Plot between MSE and epochs

b) Decision Region Plot



c) Plots of outputs of hidden and output nodes.





d) Quantitative Results

Accuracy score on train data :
93.11111111111111

Confusion Matrix on train data :
[[285 15 0]
[32 253 15]
[0 0 300]]

Accuracy score on validation data :
93.33333333333333

Confusion Matrix on validation data :
[[96 4 0]
[15 84 1]
[0 0 100]]

Accuracy score on test data :
92.66666666666666

Confusion Matrix on test data :
[[94 6 0]
[13 84 3]
[0 0 100]]

Model 4

This model is multi layer feed-forward neural network.

Architecture :

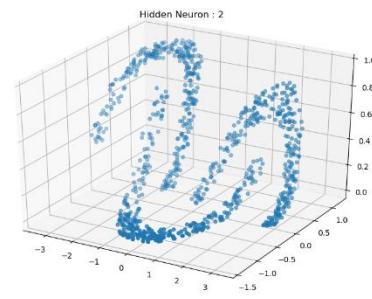
2 neurons in Input Layer

8 neurons in Hidden layer

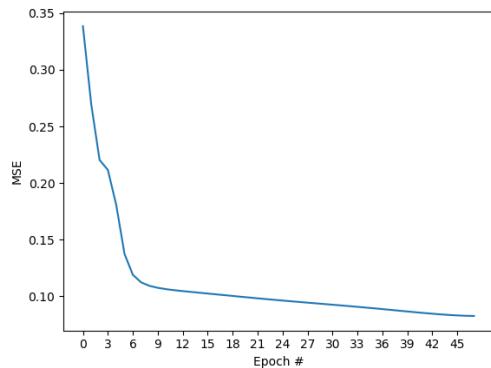
3 neurons in Output Layer

Threshold:

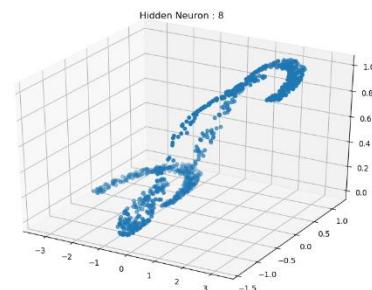
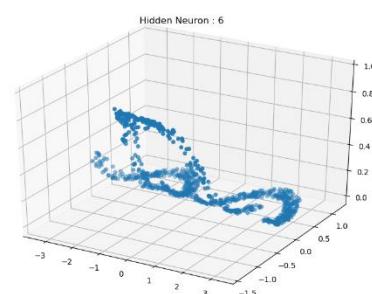
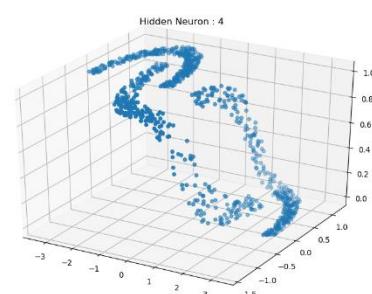
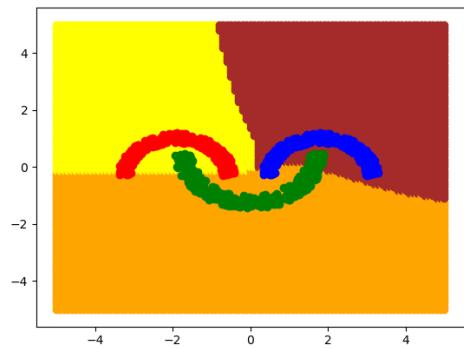
Cross Validation or subsequent difference between MSE falls below 0.0001



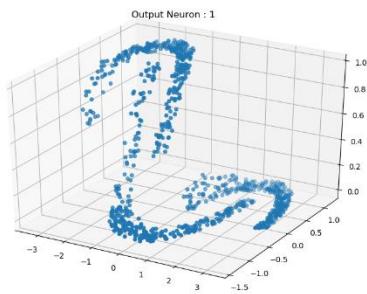
a) Plot between MSE and epochs



b) Decision Region Plot



c) Plots of hidden and output nodes



Accuracy score on test data :

87.33333333333333

Confusion Matrix on test data :

$\begin{bmatrix} 91 & 9 & 0 \end{bmatrix}$

$\begin{bmatrix} 14 & 74 & 12 \end{bmatrix}$

$\begin{bmatrix} 0 & 3 & 97 \end{bmatrix}$

Dataset 2

Model1

This model is multi layer feed-forward neural network.

Architecture :

32 neurons in Input Layer

32 neurons in Hidden layer 1

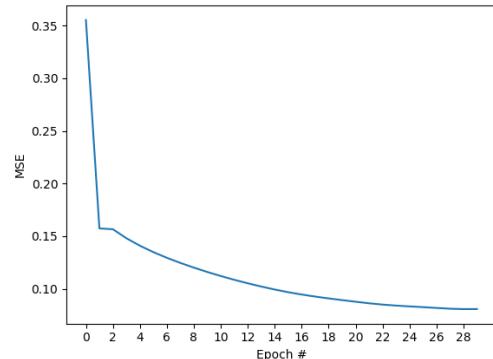
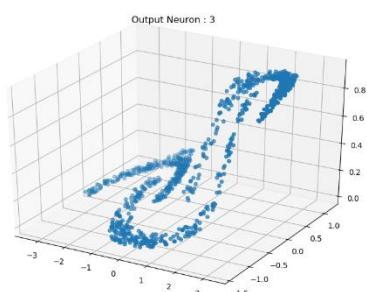
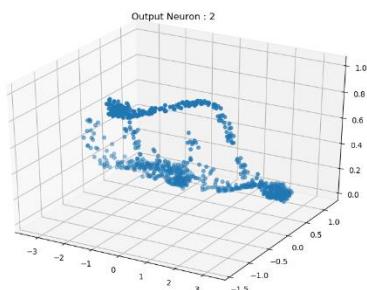
64 neurons in Hidden layer 2

3 neurons in Output Layer

Threshold:

Cross Validation or subsequent difference between MSE falls below 0.0001

a) Plot between MSE and epochs



d) Quantitative Results

Accuracy score on train data :

88.33333333333333

Confusion Matrix on train data :

$\begin{bmatrix} 273 & 27 & 0 \end{bmatrix}$

$\begin{bmatrix} 34 & 241 & 25 \end{bmatrix}$

$\begin{bmatrix} 0 & 19 & 281 \end{bmatrix}$

Accuracy score on validation data :

87.0

Confusion Matrix on validation data :

$\begin{bmatrix} 91 & 9 & 0 \end{bmatrix}$

$\begin{bmatrix} 15 & 79 & 6 \end{bmatrix}$

$\begin{bmatrix} 0 & 9 & 91 \end{bmatrix}$

b) Quantitative Results

accuracy score on train data :

49.5925959992

accuracy score on val data :

58.4502983144

accuracy score on test data :

49.1540003148

Model 2

This model is multi layer feed-forward neural network.

Architecture :

32 neurons in Input Layer

40 neurons in Hidden layer 1

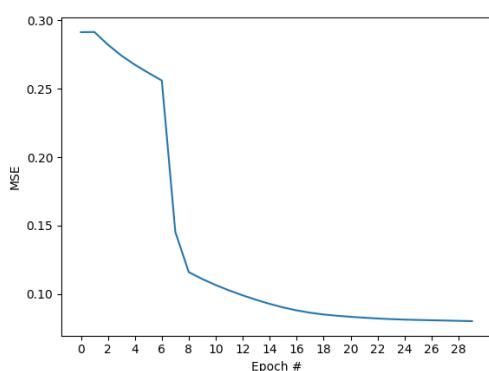
50 neurons in Hidden layer 2

3 neurons in Output Layer

Threshold:

Cross Validation or subsequent difference between MSE falls below 0.0001

a) Plot between MSE and epochs



b) Quantitative Results

accuracy score on train data :

51.1540003148

accuracy score on val data :

55.3274896832

accuracy score on test data :

51.1130641044

INFERENCES AND OBSERVATIONS OF CLASSIFICATION TASK:

1. Perceptron method of classification can be preferred over MLFNN if given dataset is linearly separable as it converges fast and involves less number of calculations.

2. Perceptron method fails on non-linearly separable data as can be seen when perceptron applied on dataset 1b. Accuracy was below 85%.
3. MLFNN takes longer time to train and moreover, it takes more number of epochs than perceptron.
4. MLFNN clearly separates non-linearly separable data. Accuracy was found to be close to 99%.
5. More number of neurons in hidden layers, in general, do not signify more accuracy. It can be clearly seen when we increased number of neurons. Accuracy didn't increase in general.
6. Learning rate doesn't have any significant effect on accuracy. We changed learning rates from 0.01 to 0.8, but accuracy almost remained same. Only, convergence reached faster while taking large learning rates.
7. Cross validation technique helped in faster convergence.
8. To have more insight, we plotted 3-d plots of output nodes. It was seen that each output node was trying to separate one class from the other.
9. Dataset 2 (consisting of images), took a very long to form bag of visual words as it involved many calculations.
10. Accuracy on dataset 2 was found to be close to only 50% as the dataset was not large given that it is 32 dimensional !
11. Dataset 2 was trained using two hidden layers. We used two different models and found almost same performance.

Task2: Regression

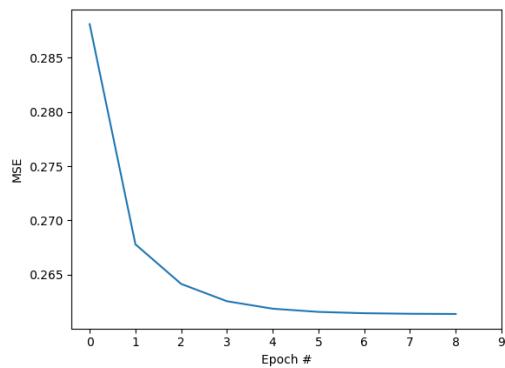
Dataset 1

Univariate Data

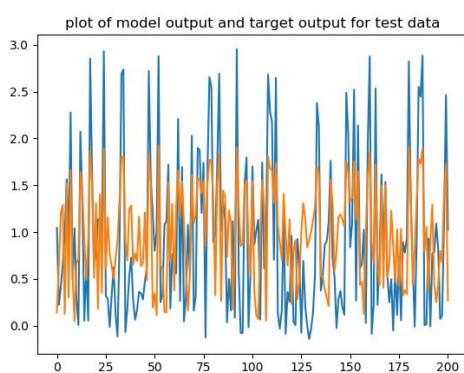
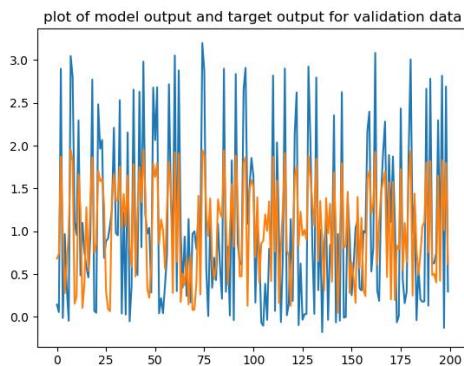
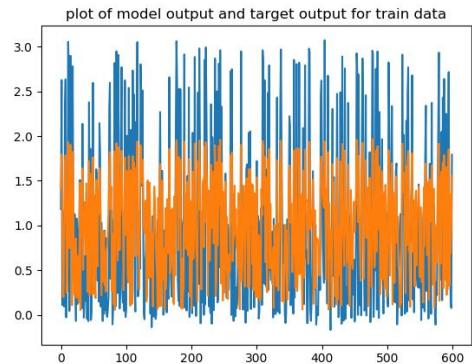
Model 1

This model is built upon perceptron.
Threshold was set to be : subsequent
difference between MSE falls below
0.0001 .

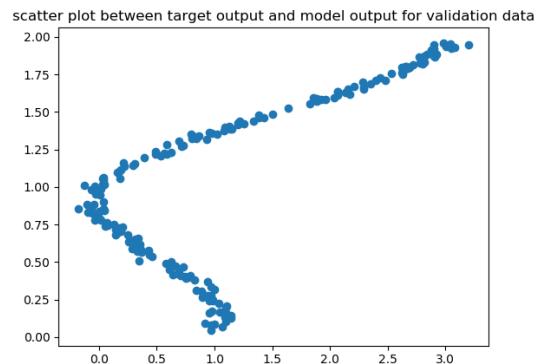
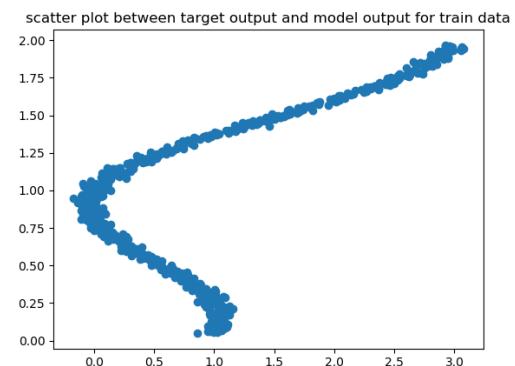
- a) Plot between MSE and epochs

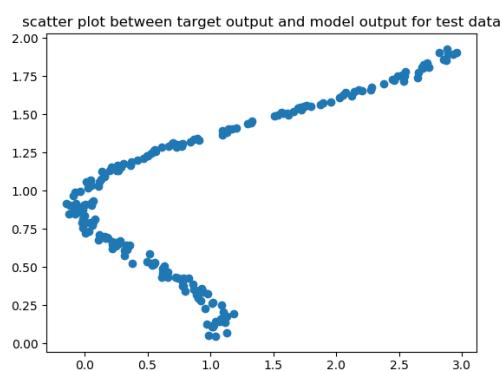


- b) Plots between model output and target output.

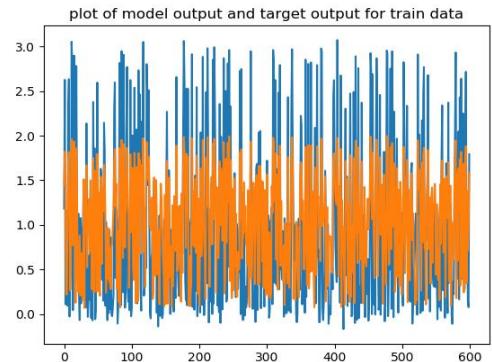


- c) Scatter plots between model output and target output.





b) Plot between model output and target output



Quantitative Results:

MSE on train data is :

0.2584356223243803

MSE on validation data is :

0.2524242445909212

MSE on test data is :

0.2303667239850461

Model2

This model is multi layer feed-forward neural network.

Architecture :

1 neuron in Input Layer

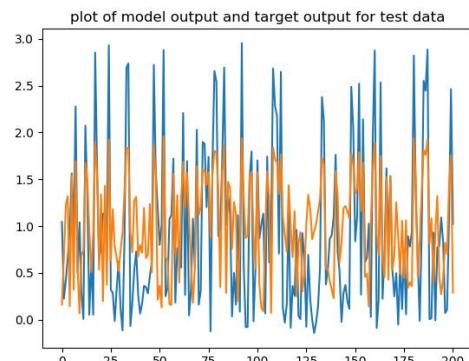
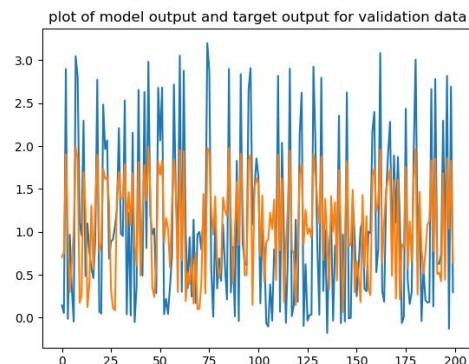
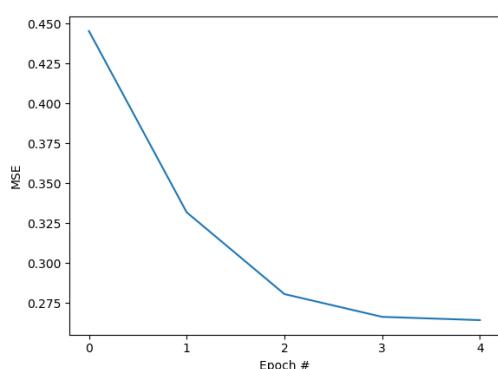
2 neurons in Hidden layer

1 neuron in Output Layer

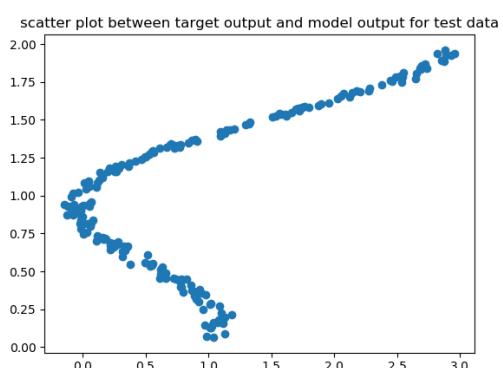
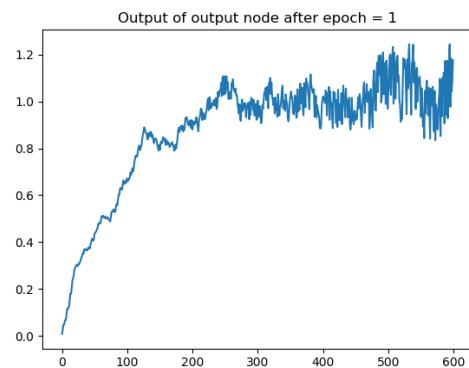
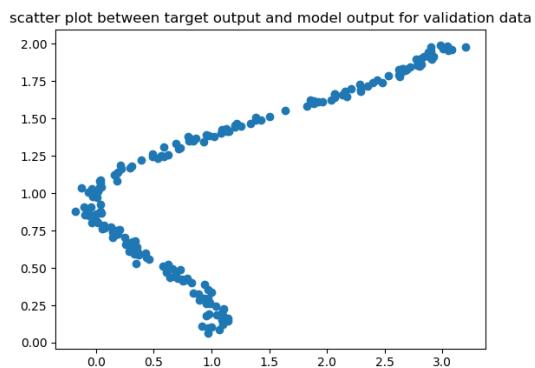
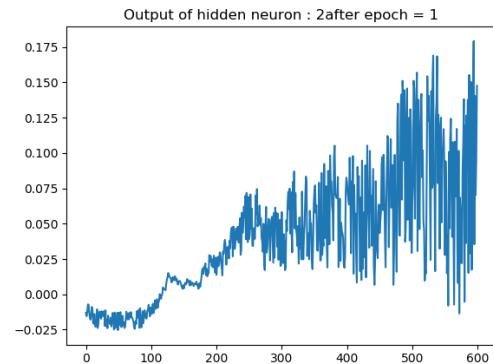
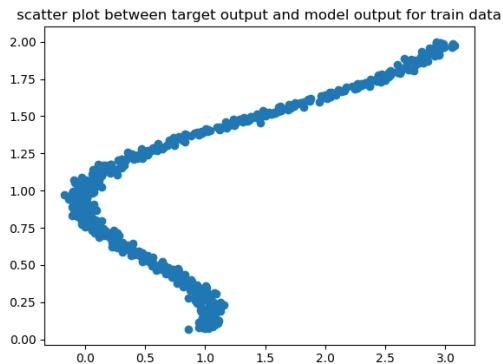
Threshold:

Cross Validation or subsequent difference between MSE falls below 0.0001

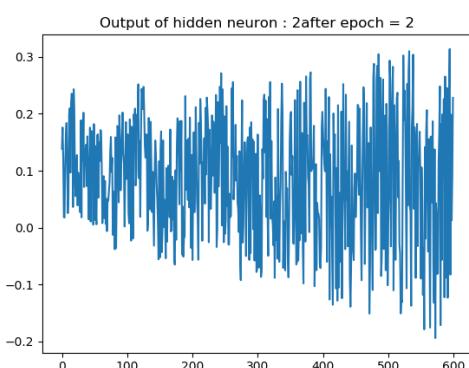
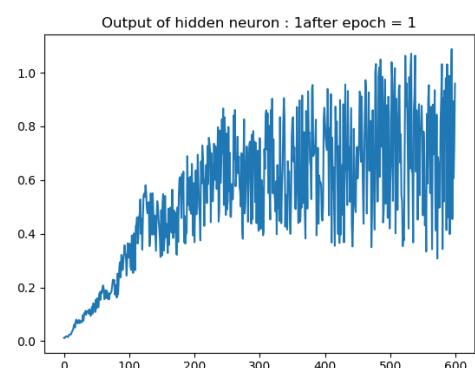
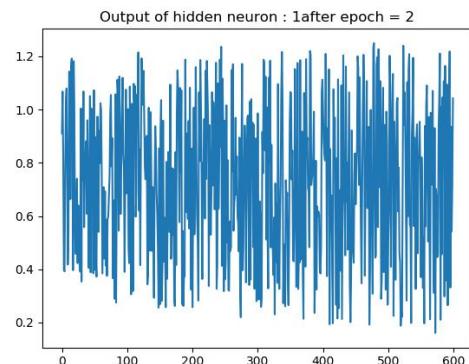
a) Plot between MSE and epochs

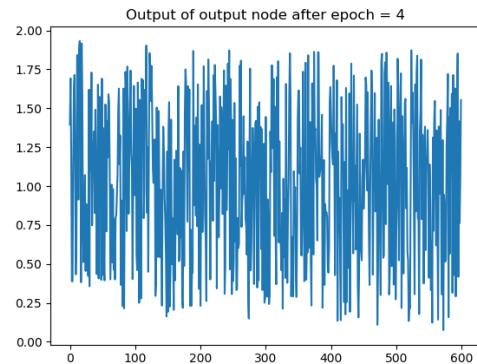
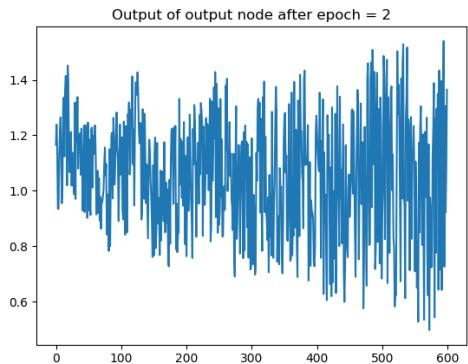


c) Scatter plot between model output and target output



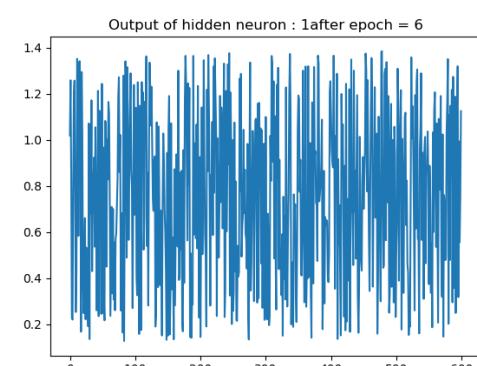
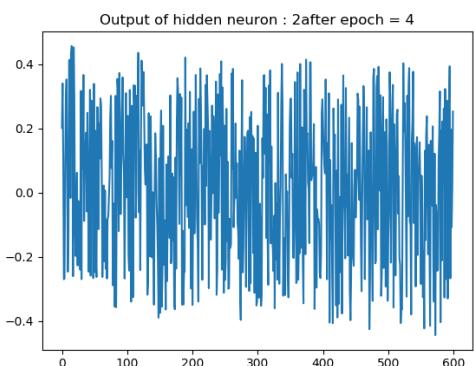
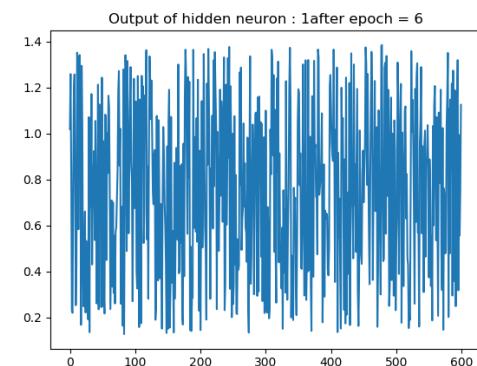
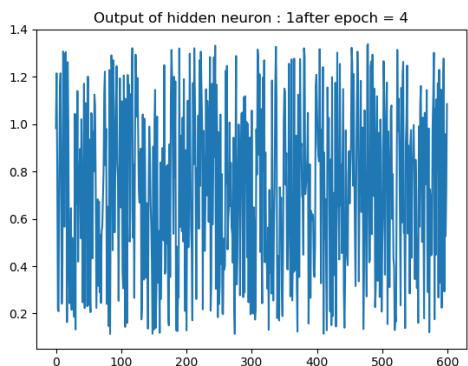
Epoch = 1

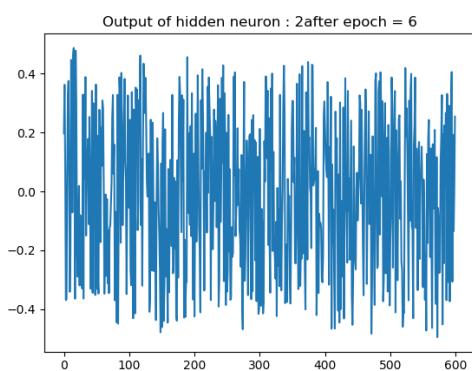




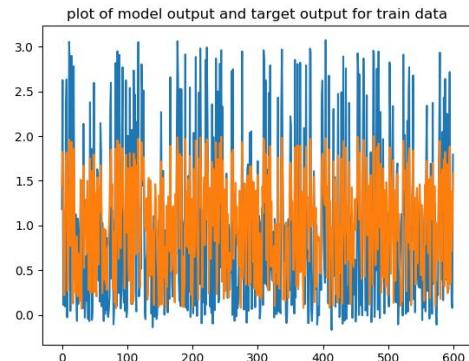
Epoch = 4

Epoch = 6





b) Plots of model output and target outputs



Quantitative Results:

MSE on train data is :

0.2586206111471582

MSE on validation data is :

0.25148946076397855

MSE on test data is :

0.23234479846861816

Model 3

This model is multi layer feed-forward neural network.

Architecture :

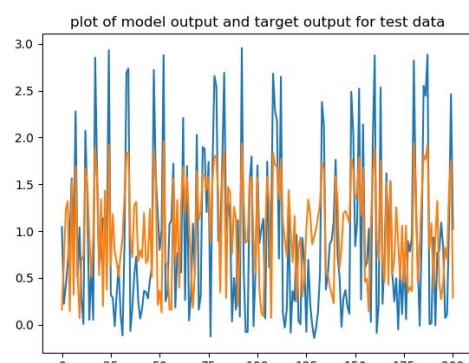
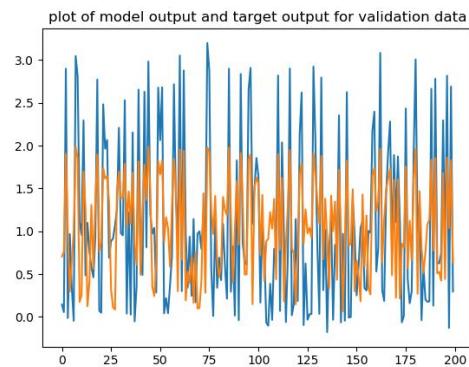
1 neuron in Input Layer

4 neurons in Hidden layer

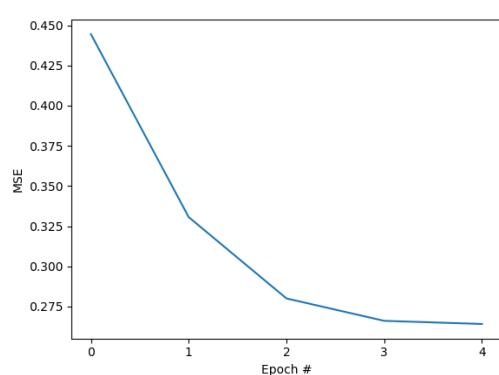
1 neuron in Output Layer

Threshold:

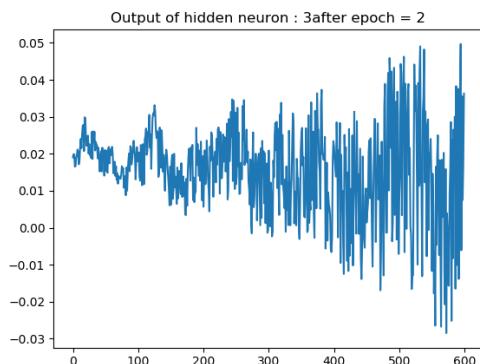
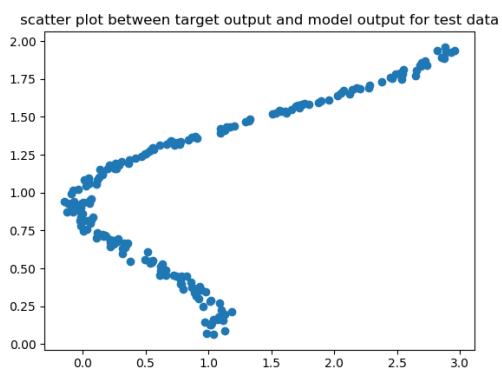
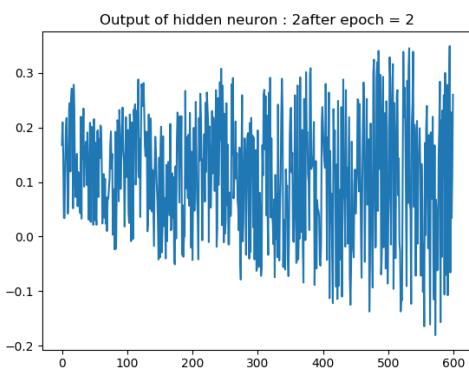
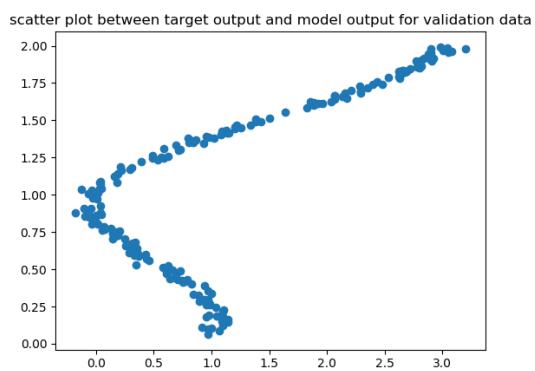
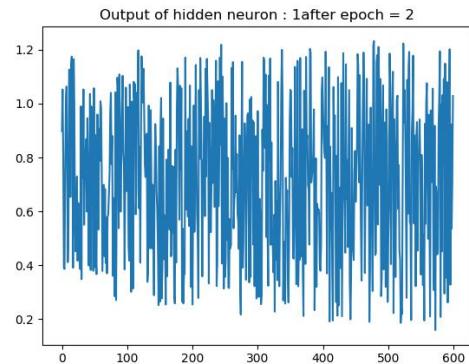
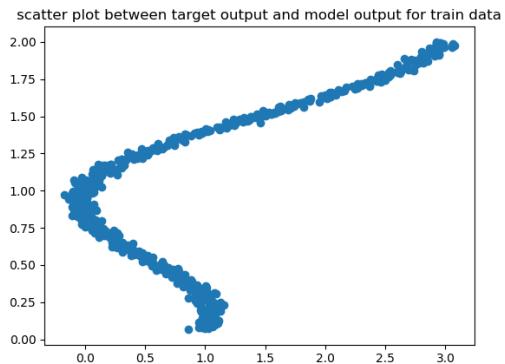
Cross Validation or subsequent difference between MSE falls below 0.0001



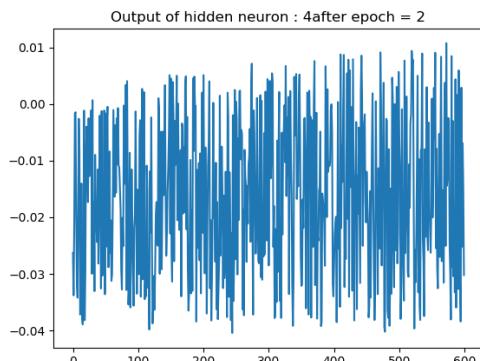
a) Plot between MSE and epochs

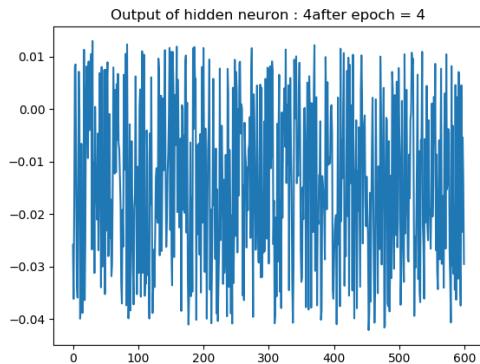
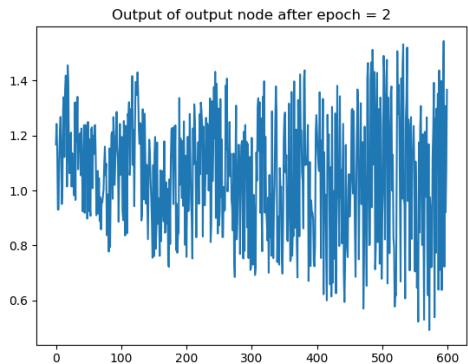


c) Scatter plots between target and model outputs

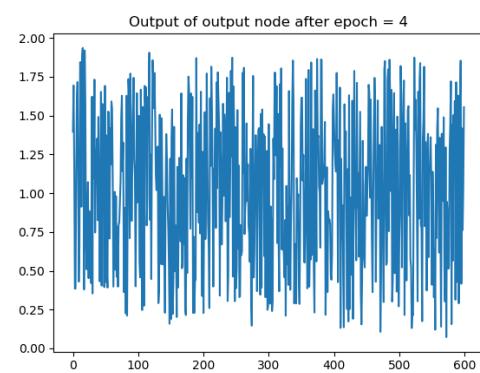
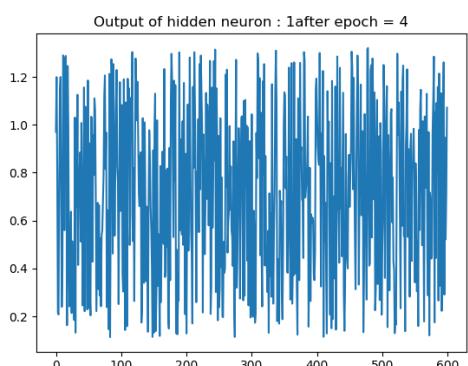


Epoch = 2

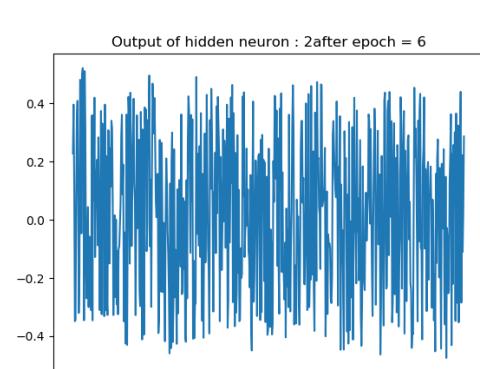
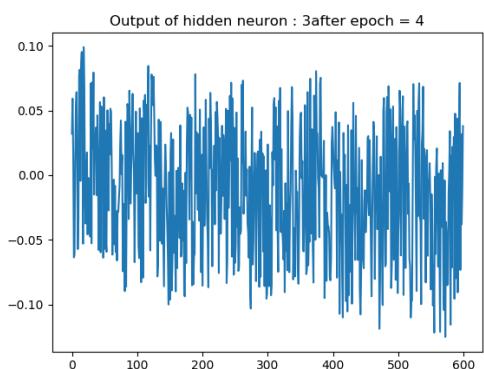
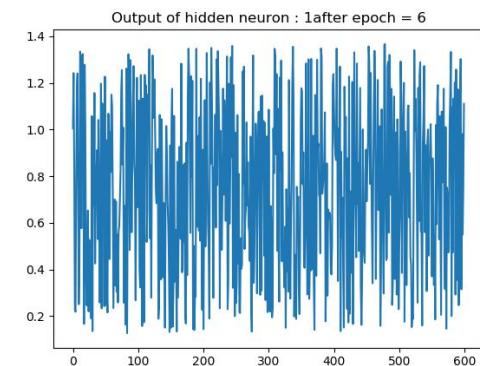
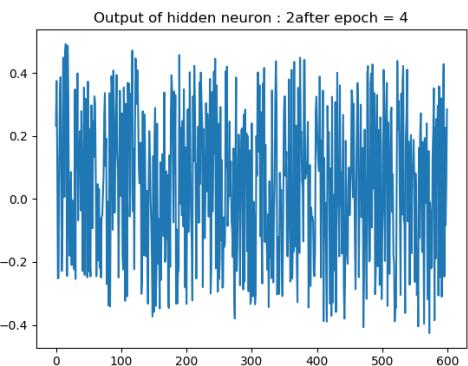




Epoch = 4



Epoch = 6



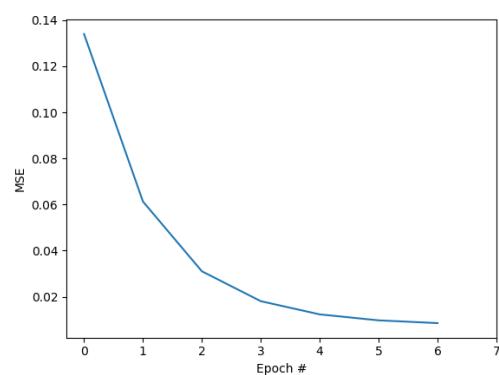
Dataset 2

Bivariate Data

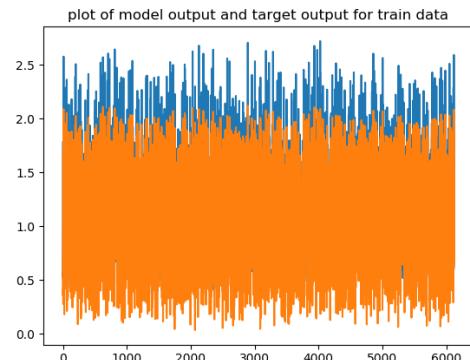
Model1

It is perceptron model. Threshold :
subsequent difference between MSE falls
below 0.0001

a) Plot between MSE and epochs



b) Plots of model and target outputs



Quantitative Results:

MSE on train data is :

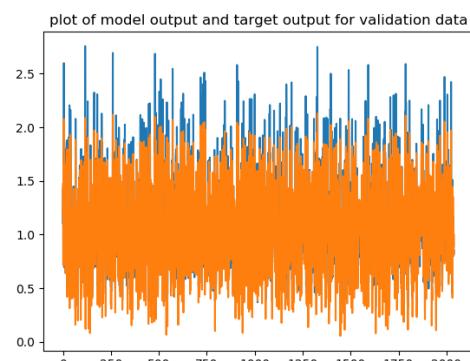
0.25862736985962426

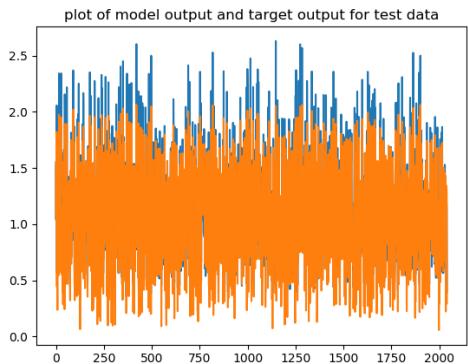
MSE on validation data is :

0.25147477071455776

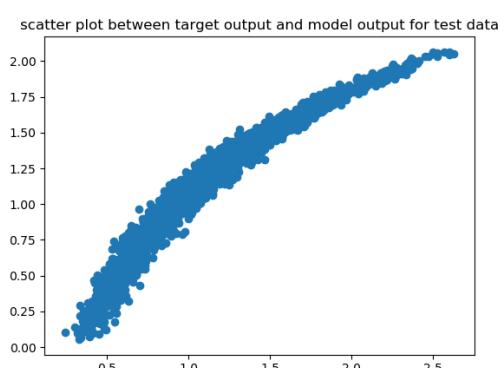
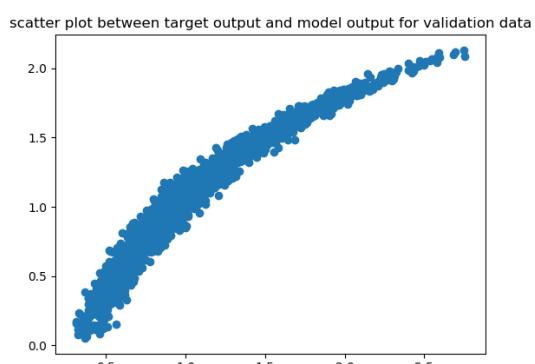
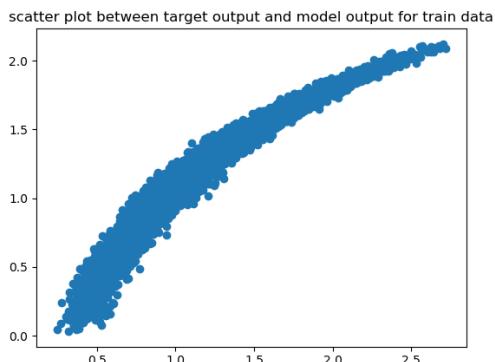
MSE on test data is :

0.23237530263458336





c) Scatter plots between model and target outputs.



Quantitative Results:

MSE on train data is :

0.008205788166659901

MSE on validation data is :

0.008165194000296533

MSE on test data is :

0.007904943207014308

Model2

This model is multi layer feed-forward neural network.

Architecture :

2 neuron in Input Layer

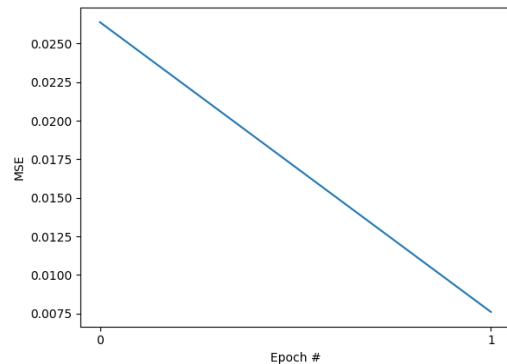
4 neurons in Hidden layer

1 neuron in Output Layer

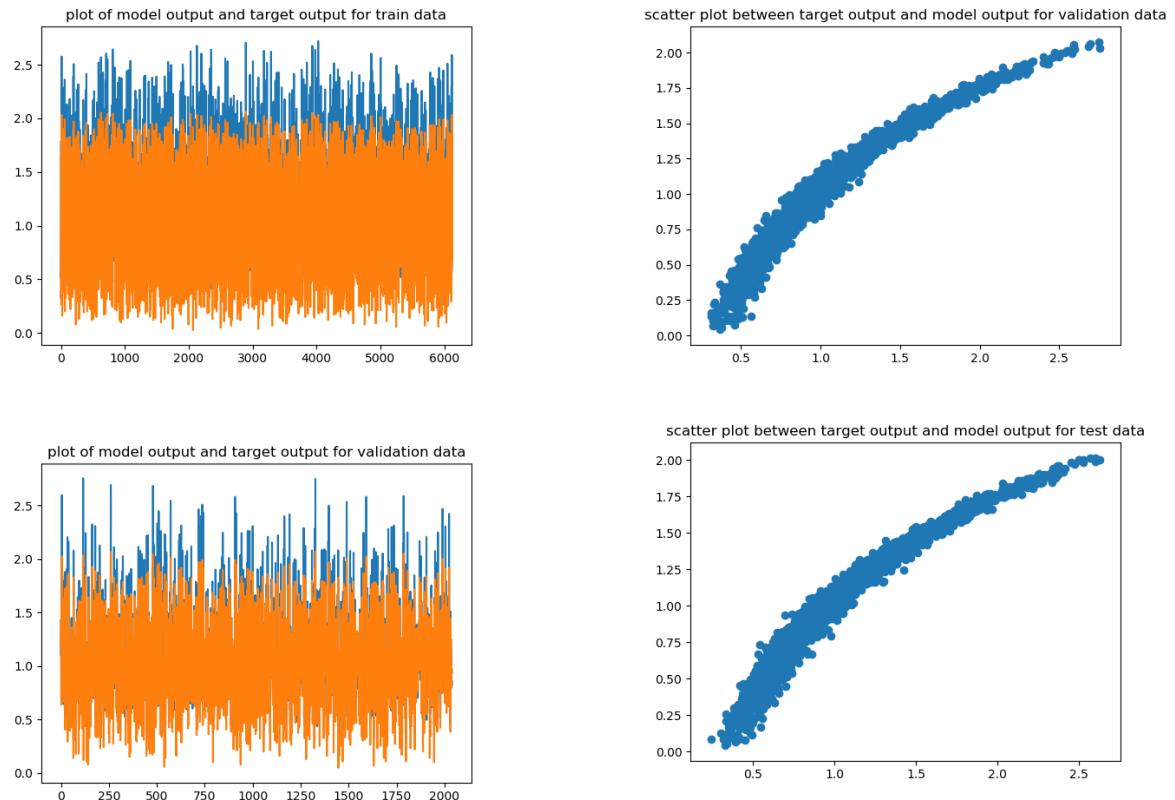
Threshold:

Cross Validation or subsequent difference between MSE falls below 0.0001

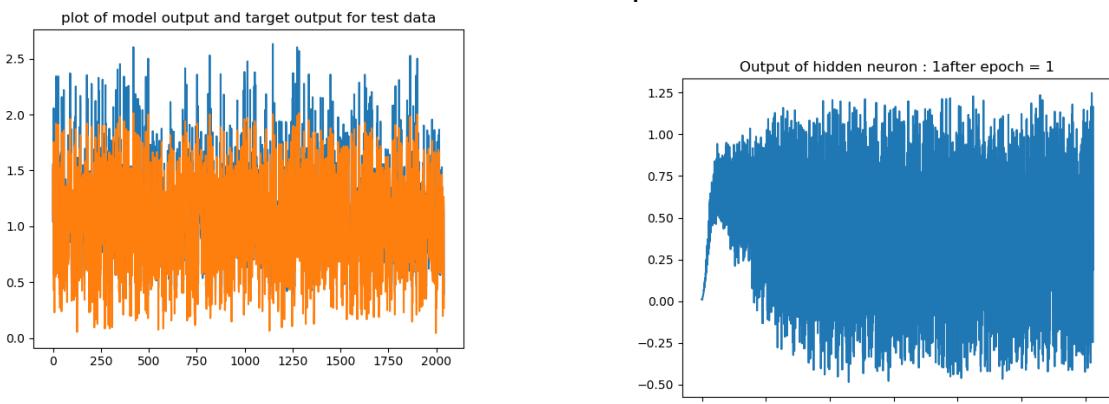
a) Plot between MSE and epochs



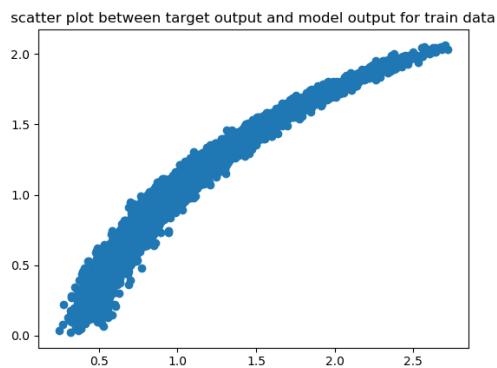
b) Plots of model and target outputs

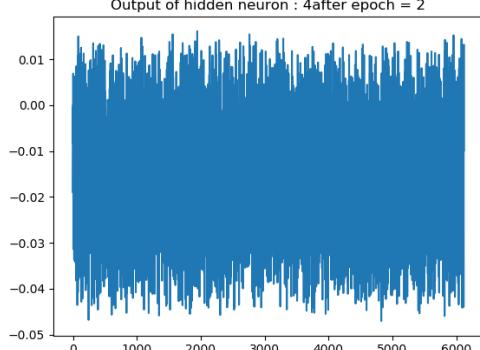
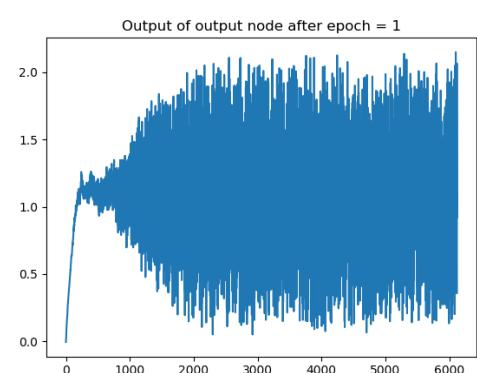
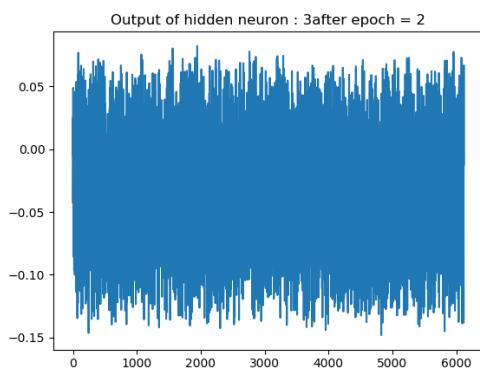
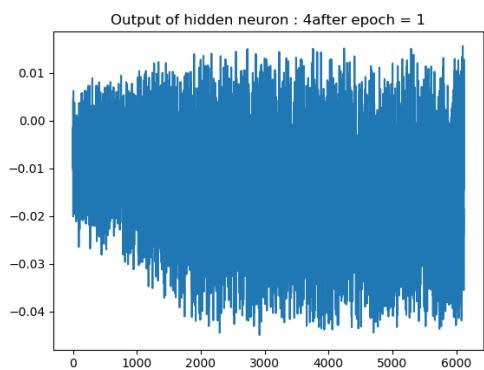
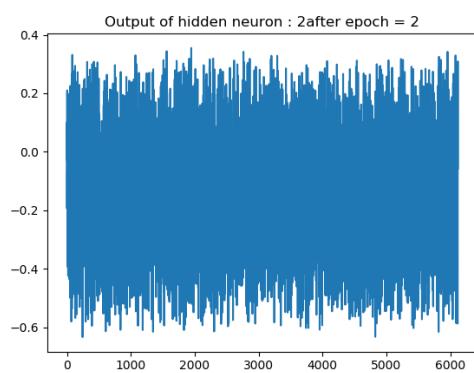
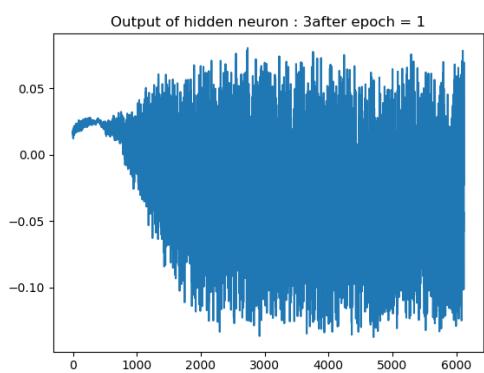
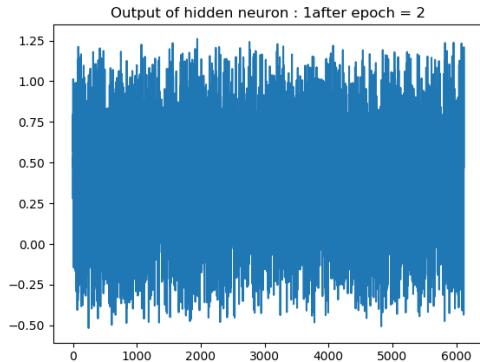
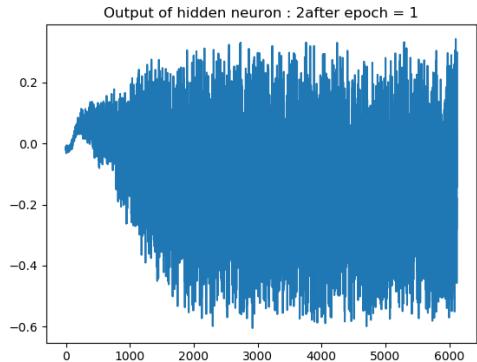


Epoch = 1

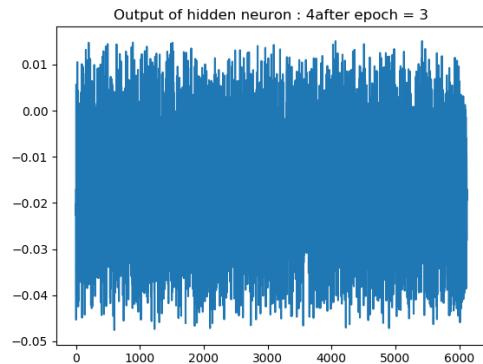
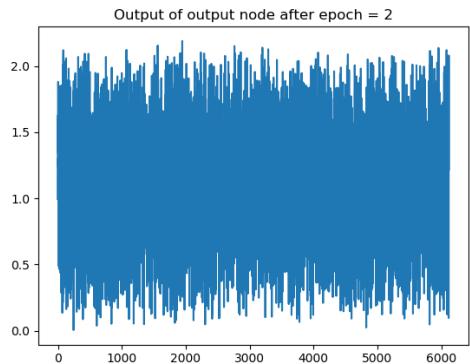


c) Scatter plots between target and model outputs

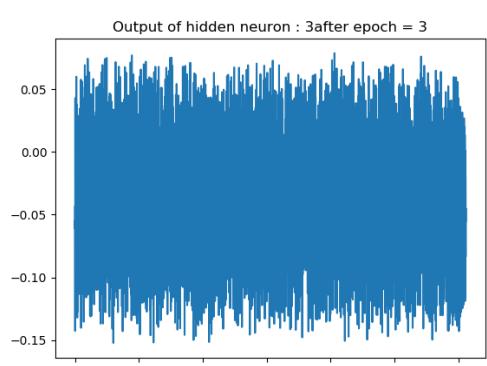
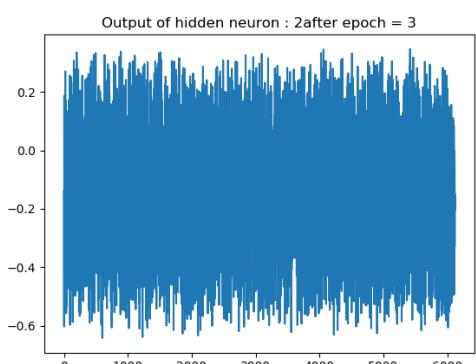
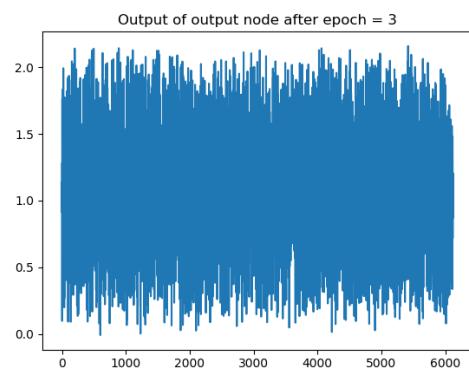
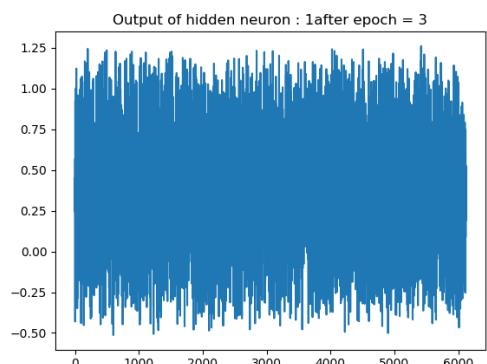




Epoch =2



Epoch =3



Quantitative Results

MSE on train data is :

0.008420051629117095

MSE on validation data is :

0.008247569025013194

MSE on test data is :

0.008125254530826477

Model3

This model is multi layer feed-forward neural network.

Architecture :

2 neuron in Input Layer

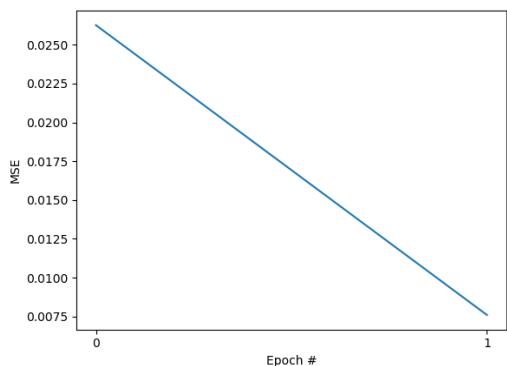
2 neurons in Hidden layer

1 neuron in Output Layer

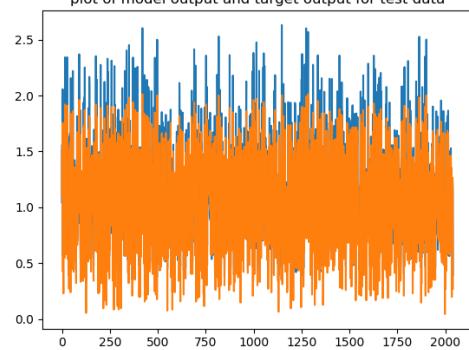
Threshold:

Cross Validation or subsequent difference between MSE falls below 0.0001

a) Plot between MSE and epochs

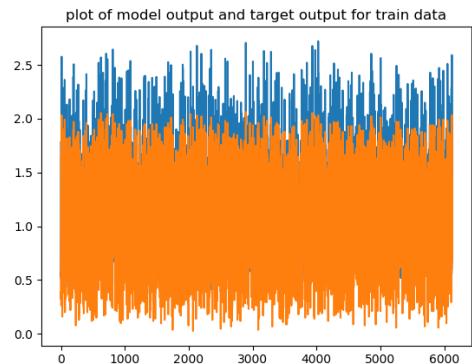


plot of model output and target output for test data

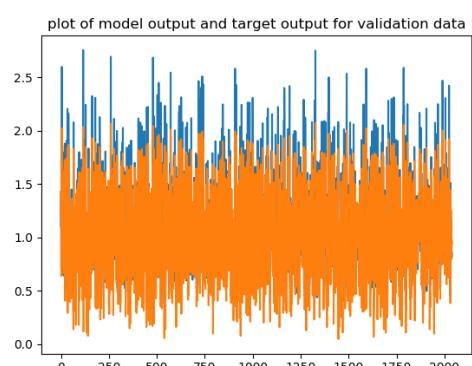
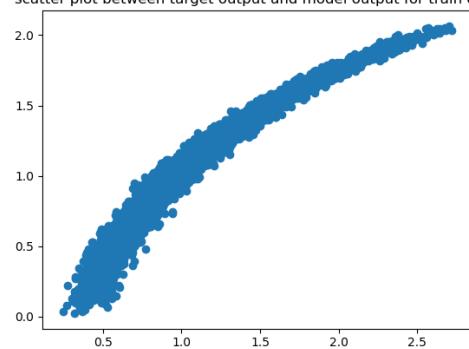


b) Scatter plots between target and model outputs

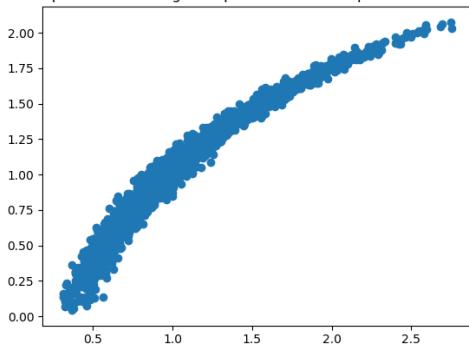
b) plots of target and model outputs



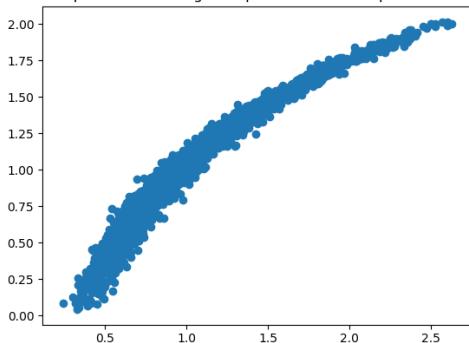
scatter plot between target output and model output for train data



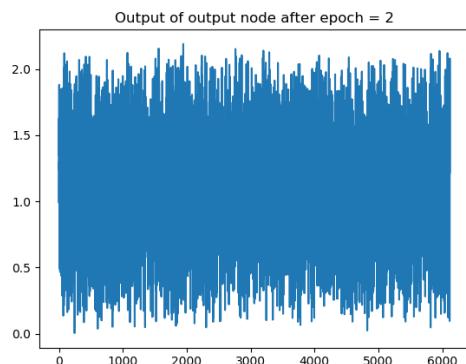
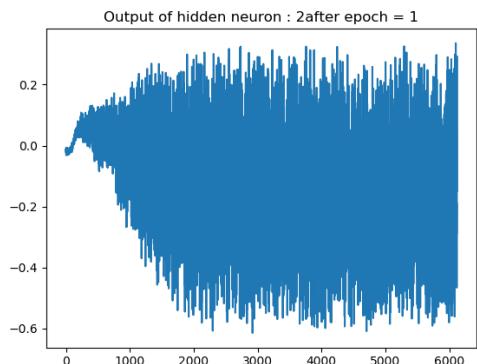
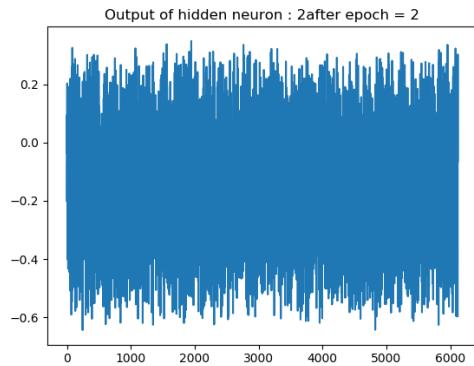
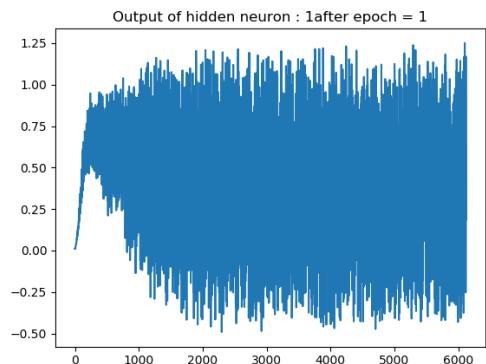
scatter plot between target output and model output for validation data



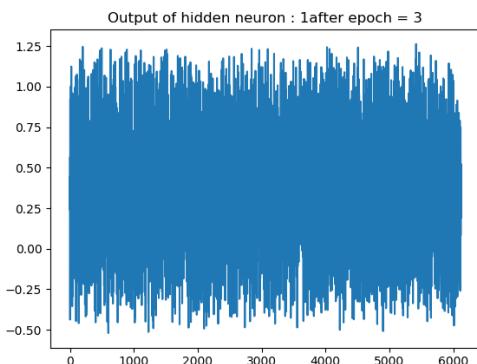
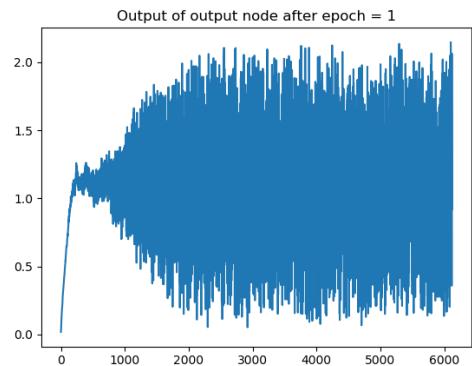
scatter plot between target output and model output for test data



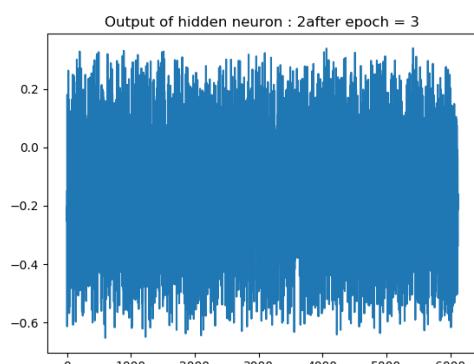
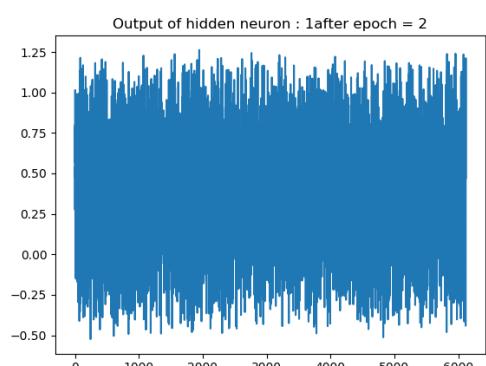
Epoch = 1

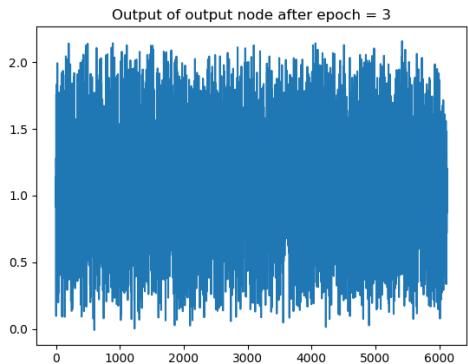


Epoch =3



Epoch =2





Quantitative Results

MSE on train data is :

0.008407005917613525

MSE on validation data is :

0.00823518505572979

MSE on test data is :

0.008112507990485426

INFERENCES AND OBSERVATIONS OF REGRESSION TASK:

1. In univariate dataset, perceptron and MLFNN model were found to be have almost same mean square errors.
2. We used two different models of MLFNN , and MSEs were almost same in both cases.
3. Change in learning rates didn't have significant effects on MSEs. Only, convergence reached faster for relatively larger learning rates.
4. Models were found to be more effective on bivariate dataset. MSEs reached down to mere 0.008
5. When analysing plots after different epochs, we found out that target output was more and more resembling model output. In

a way, it was trying to decrease MSE.

6. Analysis of scatter plots showed that the points are very close to the line $y = x$ in bivariate dataset. Univariate dataset scatter plots showed some deviations from $y = x$ initially.
7. In general, increasing hidden nodes does not guarantee less MSEs.

-----end of report-----

