Introduction:

This Report shows the procedure followed and varying effects of sigma on the Mean square error and accuracy.

Sigma values chosen:

```
sigma=[0.5,1.0,1.5,2.0,2.5,3.0,5.0,8.0,10.0]
```

- I have selected low values of sigma i.e. 0.5 and 1.0 which may not provide good interpolation between the samples.
- Some optimal range of values 2-5 are taken.
- Higher values 8.0 and 10.0 are taken to see the information loss.

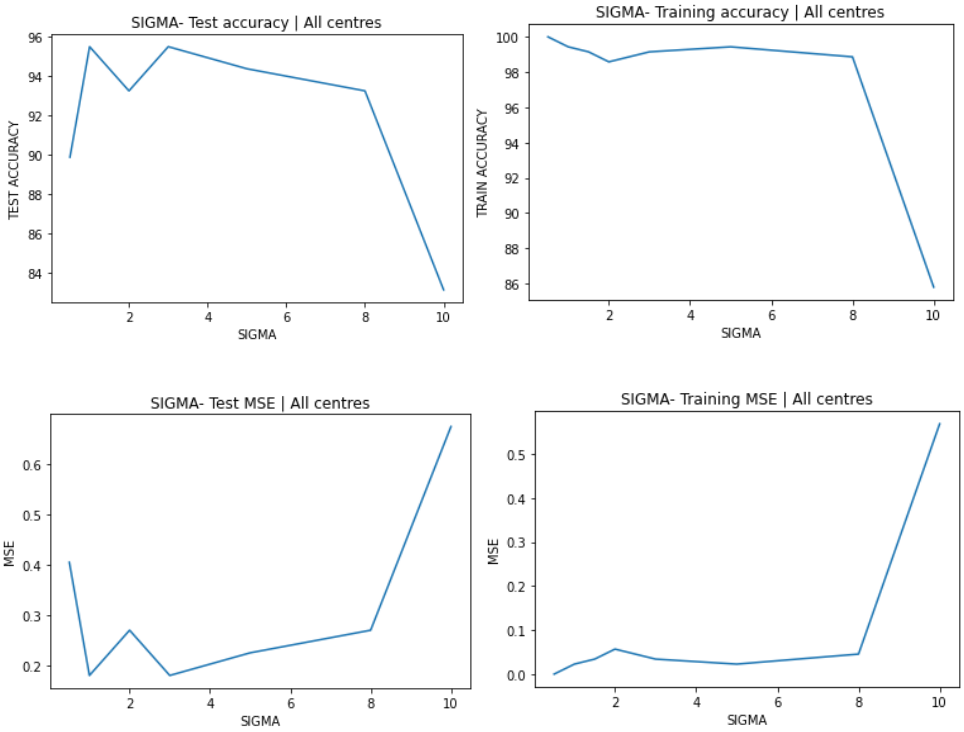
ANALYSIS

Part 1: | All Inputs as centers |

- Testing Accuracy:
    - A **minimum MSE of 0.17** is achieved at sigma= 3.0 which gives a decent accuracy of 95%. It is the value of spread where the approximation by RBF is close to the real curve and no overfitting is seen given the training accuracy as well.
    - At **higher values of sigma (sigma=10)**, The spread is wide and as a result some information is getting lost when the range of RBF is away from the original range.
    - At **lower width 0.5,** good interpolation isn't seen given the MSE is 0.40.

-----Testing Results taking all centers-----

	Sigma	Accuracy	MSE
0	0.5	89.887640	0.404494
1	1.0	95.505618	0.179775
2	1.5	94.382022	0.224719
3	2.0	93.258427	0.269663
4	2.5	94.382022	0.224719
5	3.0	95.505618	0.179775
6	5.0	94.382022	0.224719
7	8.0	93.258427	0.269663
8	10.0	83.146067	0.674157



- Training Accuracy:

  - When all the input data taken as centers for the kernel functions, accuracy of the train set along with different spread parameters remains between 98.86% to 100% at sigma=[0.5,8] both included[overfitting]. A gradual drop can be seen at sigma=10.0.

-----Training Results taking all centers-----

	Sigma	Accuracy	MSE
0	0.5	100.000000	0.000000
1	1.0	99.431818	0.022727
2	1.5	99.147727	0.034091
3	2.0	98.579545	0.056818
4	2.5	98.863636	0.045455
5	3.0	99.147727	0.034091
6	5.0	99.431818	0.022727
7	8.0	98.863636	0.045455
8	10.0	85.795455	0.568182

Result: Best sigma is 3.0 in our case which approximates to the real curve.

Part 2(a): | 150 Randomly selected centers |

- Less overlapping can be seen as a result of 150 kernel functions.

- **Testing Accuracy:**
  - **At sigma=1.0**, MSE is 0.17 which is minimum, and it provides decent results for the following sigma values.

    Sigma=[1.0,1.5,2.0,2.5,**3.0,5,8**]

    with an accuracy of around 95% and interpolates with the real curve for our data.

  - **A low width of 0.5**, Accuracy of 91% with MSE 0.35 can be seen providing not so good interpolation of the function between the sample data.
  - **Again, at high width of 10.0**, the range of radial functions is far away from the original range of function which was the case in Part 1.

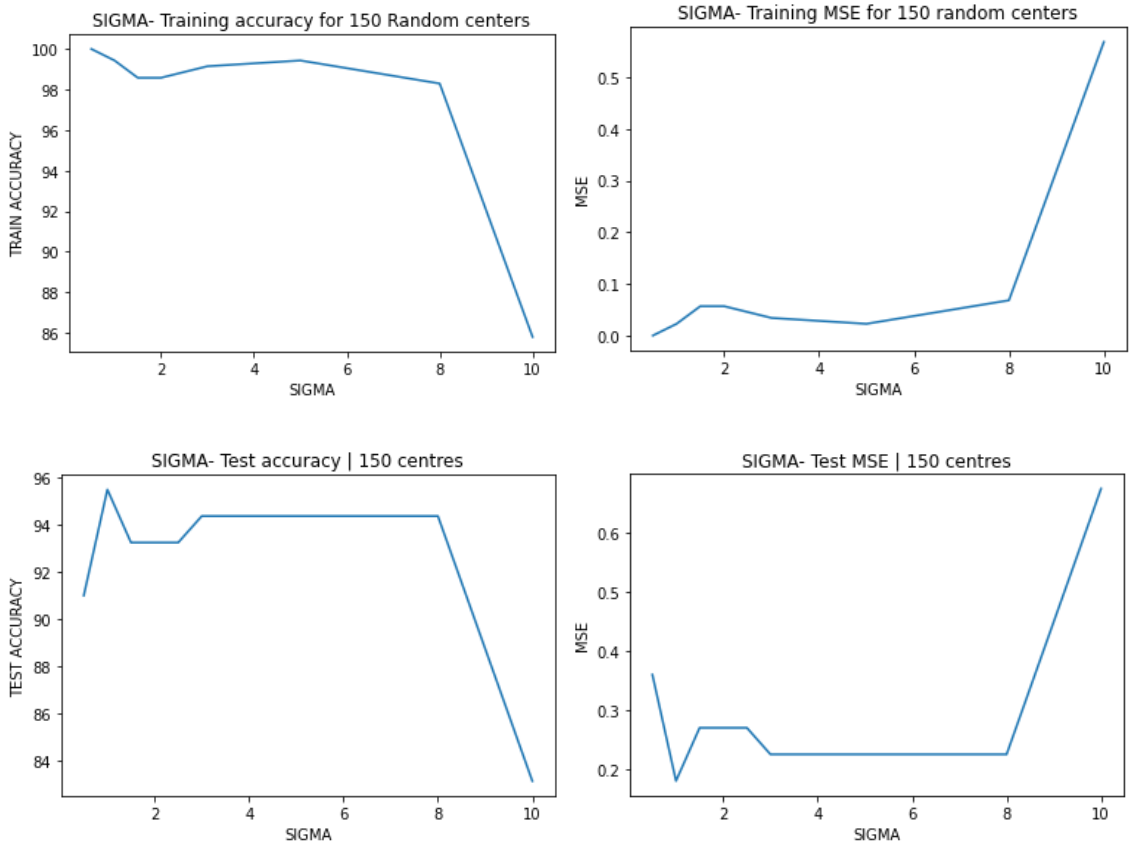
-----Testing Results taking 150 centers-----

	Sigma	Accuracy	MSE
0	0.5	91.011236	0.359551
1	1.0	95.505618	0.179775
2	1.5	93.258427	0.269663
3	2.0	93.258427	0.269663
4	2.5	93.258427	0.269663
5	3.0	94.382022	0.224719
6	5.0	94.382022	0.224719
7	8.0	94.382022	0.224719
8	10.0	83.146067	0.674157

- **Training Accuracy:**
  - Training accuracy decreases as the sigma/width increases for the training set. A gradual drop can be seen at sigma=10.0 and initially there can be seen overfitting where the mean square error is 0 which can also be seen in testing accuracy.

-----Training Results taking 150 centers-----

	Sigma	Accuracy	MSE
0	0.5	100.000000	0.000000
1	1.0	99.431818	0.022727
2	1.5	98.579545	0.056818
3	2.0	98.579545	0.056818
4	2.5	98.863636	0.045455
5	3.0	99.147727	0.034091
6	5.0	99.431818	0.022727
7	8.0	98.295455	0.068182
8	10.0	85.795455	0.568182



Result: Best sigma=[3,5,8] , best interpolation can be seen.

Part 2(b): | 150 selected centers using k means |

- **Testing Accuracy:**
    - At sigma=3.0, least mean square error of 0.17 is achieved which increases gradually at sigma=10.
    - Thus, selecting less clusters using k means provides decent results at optimal value of sigma which was also seen in the case of all centers. Less number of centers results in less overlapping which is also one of the important factors.

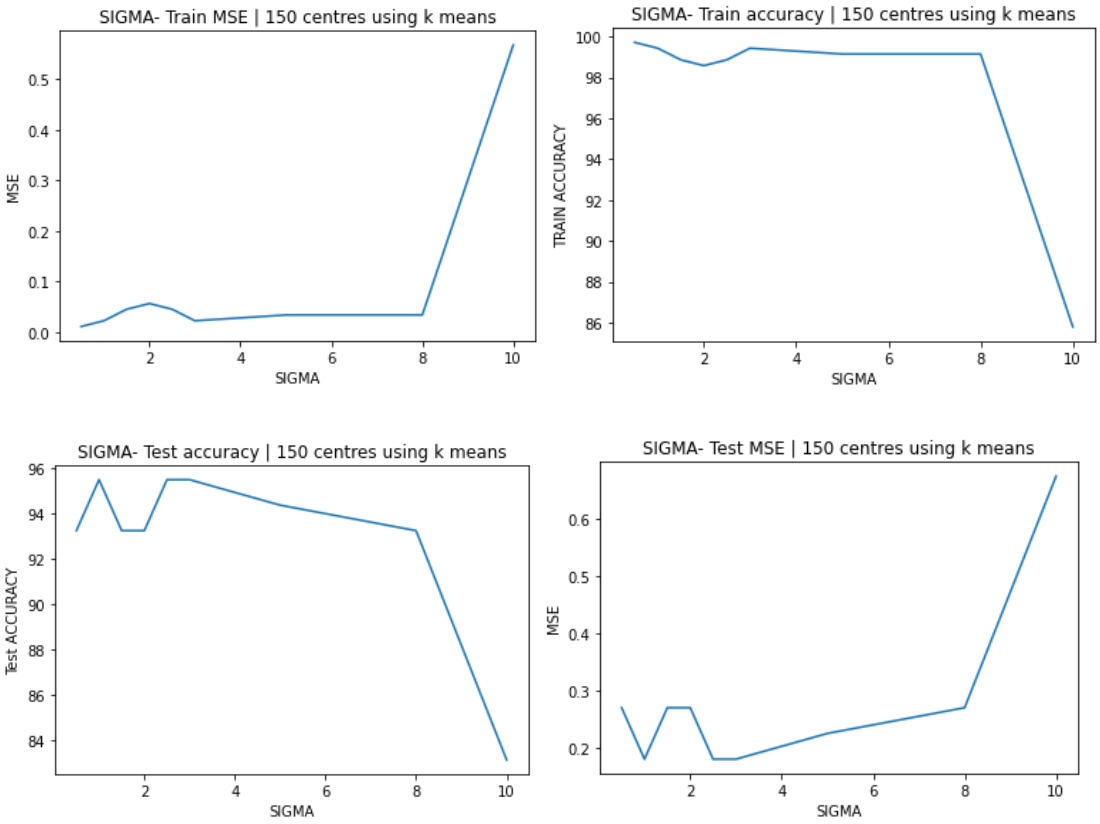
-----Testing Results taking 150 centers using k means-----

	Sigma	Accuracy	MSE
0	0.5	93.258427	0.269663
1	1.0	95.505618	0.179775
2	1.5	93.258427	0.269663
3	2.0	93.258427	0.269663
4	2.5	95.505618	0.179775
5	3.0	95.505618	0.179775
6	5.0	94.382022	0.224719
7	8.0	93.258427	0.269663
8	10.0	83.146067	0.674157

- **Training Accuracy:**
    - Overfitting can be seen at lower values of sigma i.e. 0.5 which gives the accuracy of 99% for the train set and the accuracy for same sigma for test set is 93%.

-----Training Results taking 150 centers using k means-----

	Sigma	Accuracy	MSE
0	0.5	99.715909	0.011364
1	1.0	99.431818	0.022727
2	1.5	98.863636	0.045455
3	2.0	98.579545	0.056818
4	2.5	98.863636	0.045455
5	3.0	99.431818	0.022727
6	5.0	99.147727	0.034091
7	8.0	99.147727	0.034091
8	10.0	85.795455	0.568182



Some More comparisons:

- **Width**
  - Sigma=3 can be seen providing good interpolation of the function between the sample data.
  - Other widths of [5,8] can also be seen providing promising results approximating to the real curve whereas smaller values of sigma lead to the problem of overfitting.
- **Network comparison**
  - When the smaller number of random centroids(150) are taken, it results in better performance at large number of sigma values which can be see in the MSE graph given the fact that less overlapping is there.

- When the centroids are taken by k-means, better results can be seen at multiple sigma values : [1.0-8.0] as the centroids were not taken randomly and well-defined clusters were formed.
- These two seems performing better over large number of sigma values than the first one.