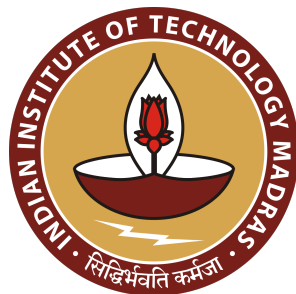# Computational Neuroscience Assignment 3

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1 Question 1

1.1 Visualization

The images were read and converted into `numpy arrays` using the `numpy.loadtxt` function. In order to ensure that black pixels were represented as +1 and white pixels were represented as -1, the sign of the array was taken. Further, the positions where the pixel value was 0 was assigned to 1. The final assignment ensured monotonic error decrease.
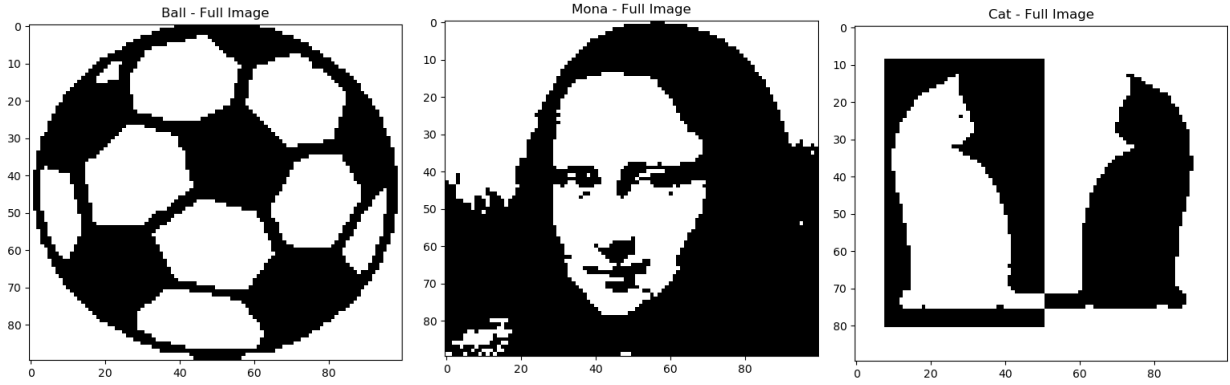
The visualized images are as follows:

Figure 1: Visualization of the images provided - Ball, Mona and Cat.

1.2 Hopfield Network

Both continuous and discrete hopfield networks were constructed. But as the discrete hopfield networks converged instantly, continuous hopfield networks were used.

The matrix equations used for discrete hopfield networks are as follows:

$$W = \frac{1}{N}SS^T \tag{1}$$

$$V(t+1) = \sigma(WV(t)) \tag{2}$$

The matrix equations used for continuous hopfield networks are as follows:

$$W = \frac{1}{N}SS^T \tag{3}$$

$$\frac{dU}{dt} = -U + WV \tag{4}$$

$$V = \tanh(\lambda U) \tag{5}$$

The discrete hopfield network is implemented using the function `discrete_hopfield` and the continuous hopfield network is implemented using the function `continuous_hopfield` inside the file `hopfield.py`

The parameters - λ and dt used is 20 and 0.01 respectively.

2 Question 2

2.1 Patch Generation

Patches with a minimum width of 20 pixels, maximum width of 45 pixels, minimum height of 15 pixels and maximum height of 45 pixels are generated at random positions of the image.

The patches are generated using the function `get_patches` in the file `hopfield.py`

2.2 Plot of Input Patch
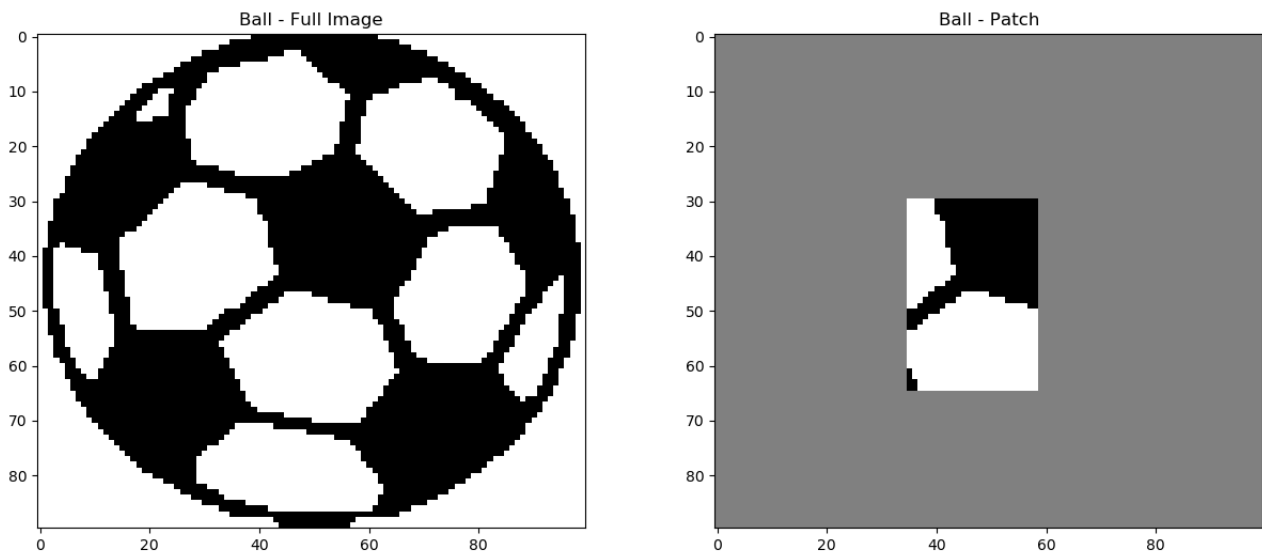
The patch generated is as follows:

Figure 2: Patch generated as inputs to the network. The image on the left was used as the input trigger.

2.3 Variation of RMSE across Iterations

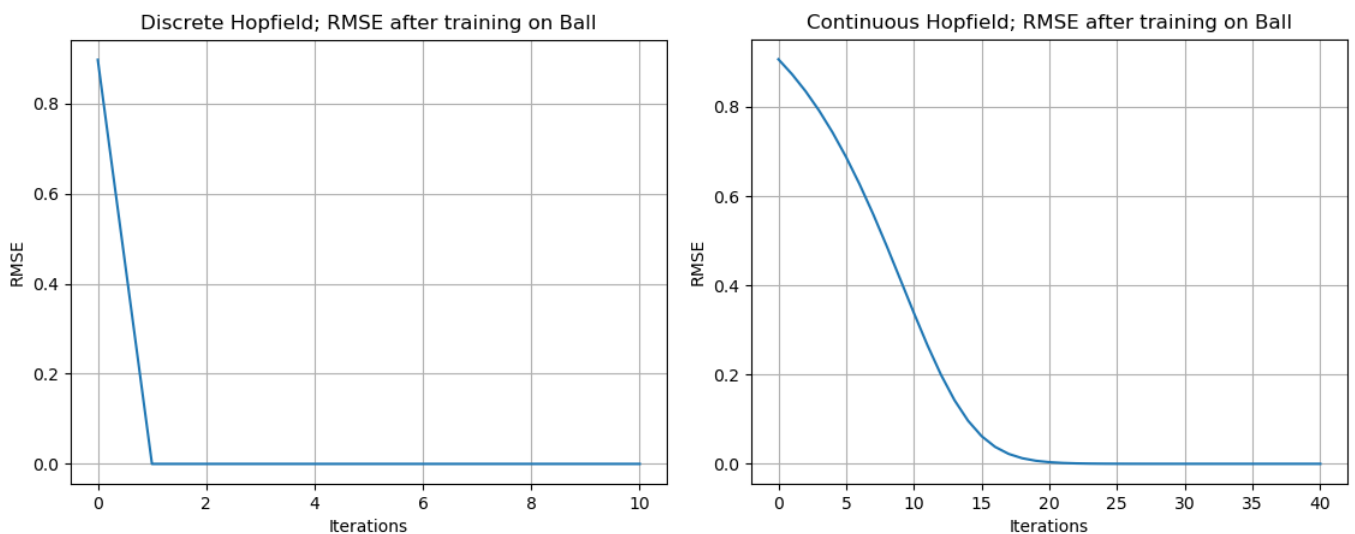The variation of RMSE across iterations is as follows:

Figure 3: RMSE variation when trained using a (A) Discrete (B) Continuous Hopfield Network

3 Question 3

3.1 Plot of Input Patches

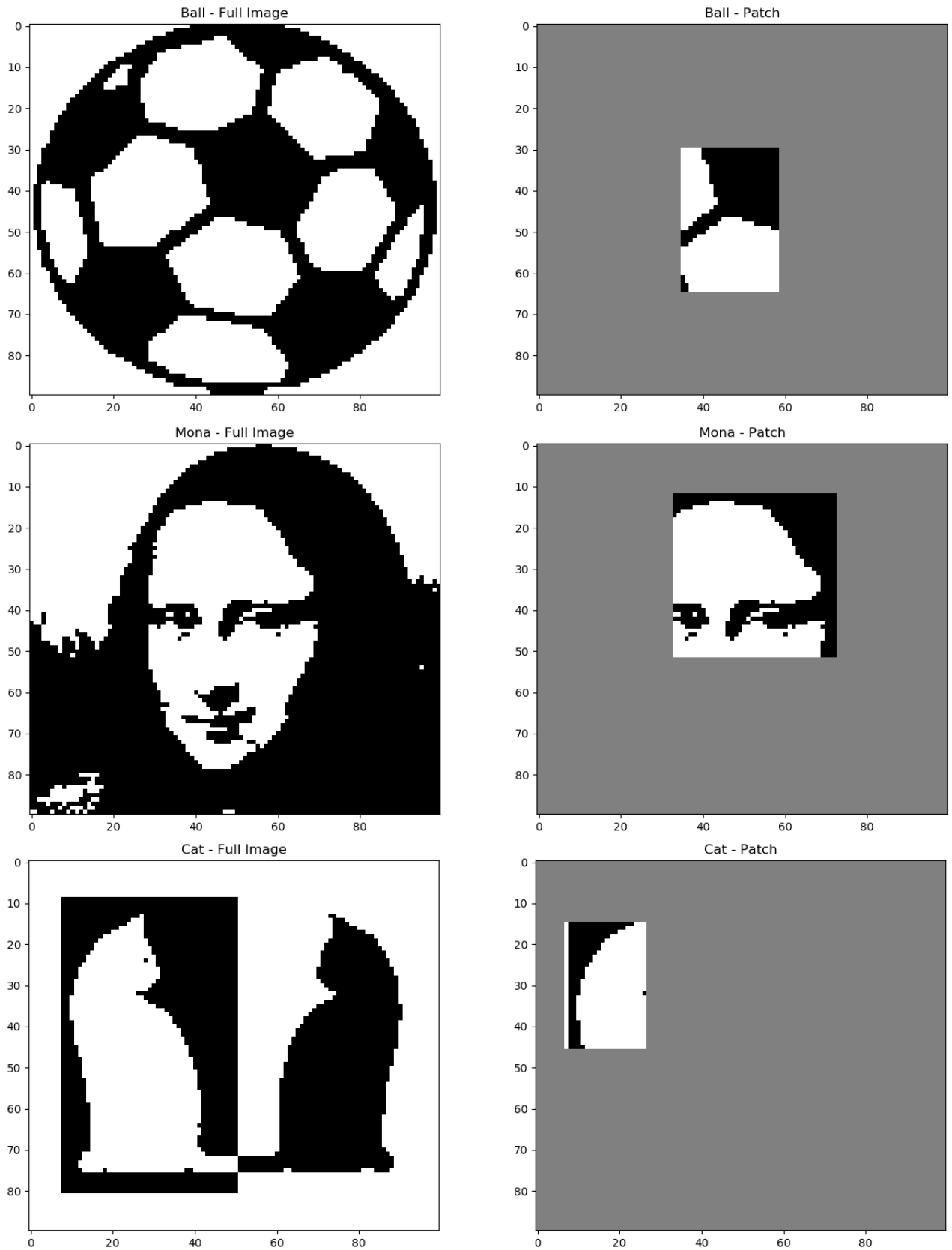The patches generated are as follows:

Figure 4: Patches generated as inputs to the network. The images on the left were used as input triggers.

3.2 Variation of RMSE across Iterations

3.2.1 Discrete Hopfield Network

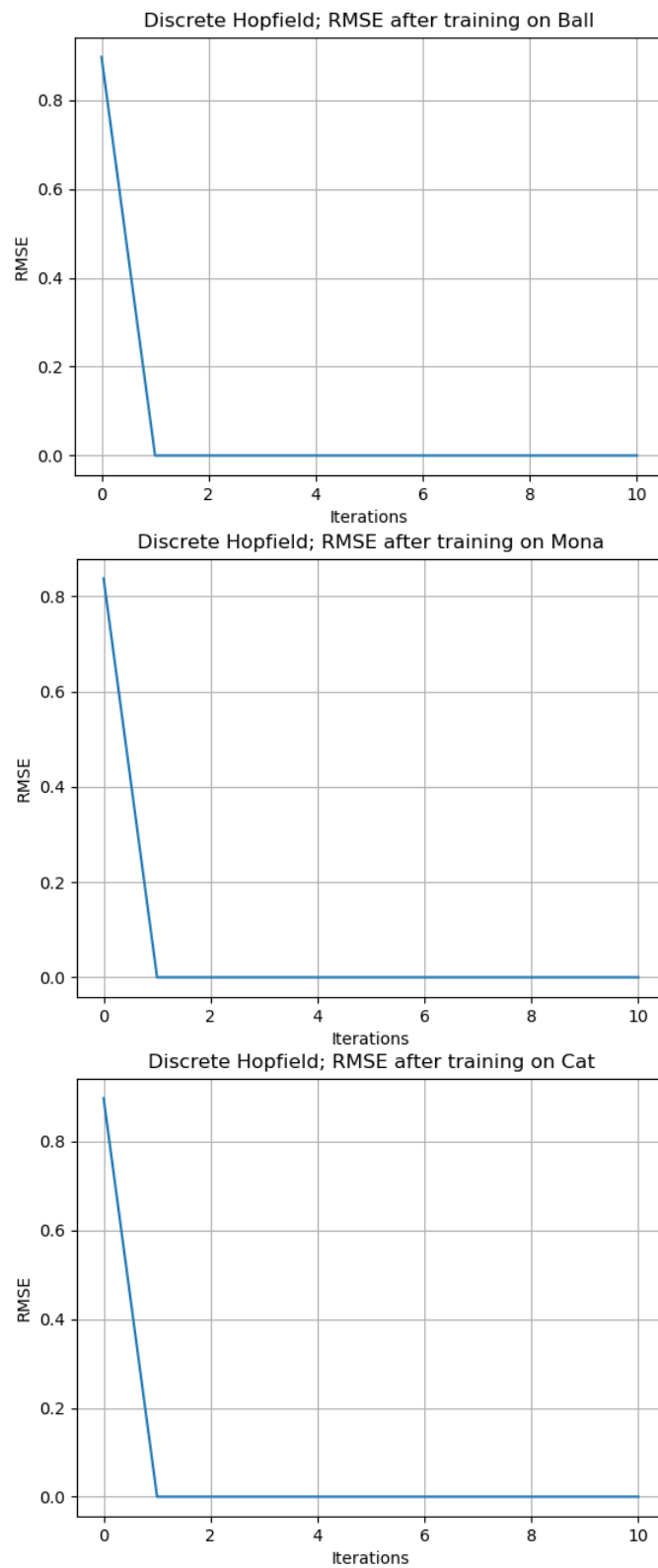The variation of RMSE across iterations using a discrete hopfield network is as follows:

Figure 5: RMSE variation when trained using a Discrete Hopfield Network

3.2.2 Continuous Hopfield Network

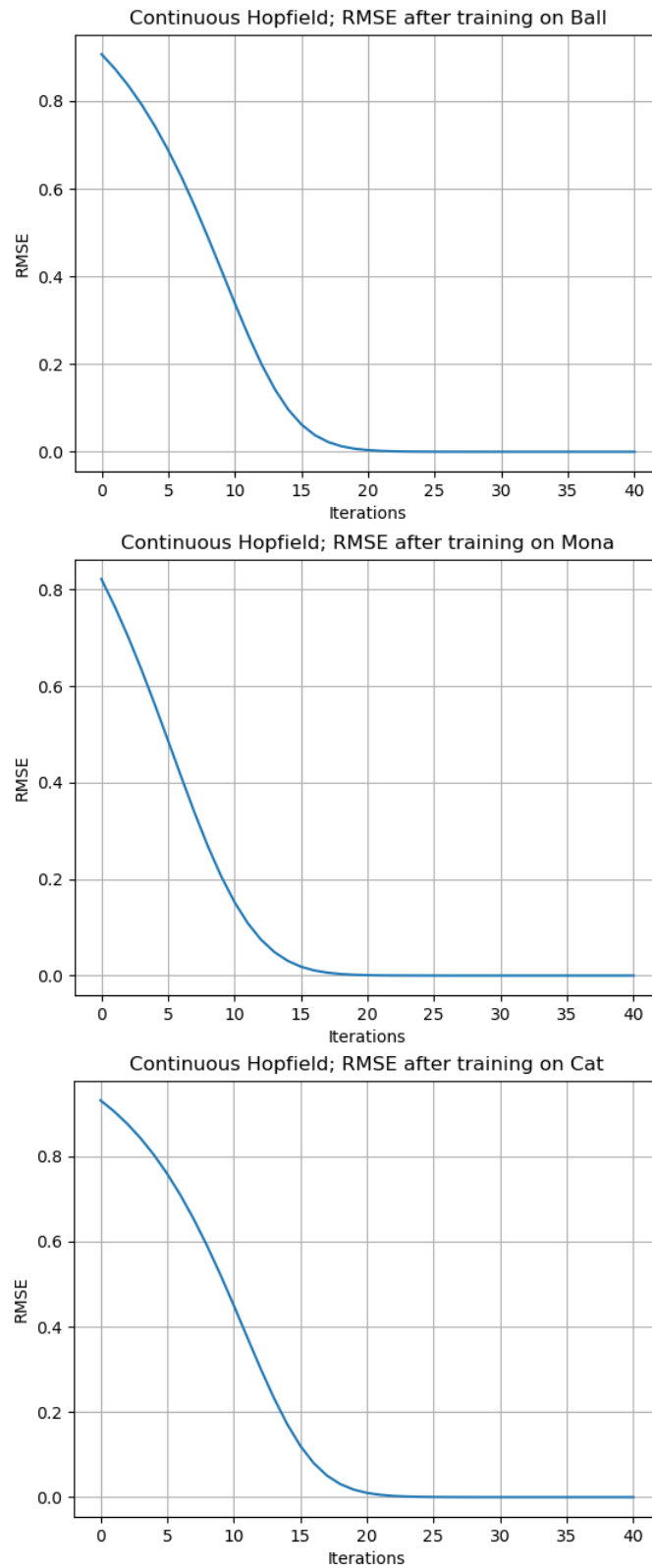The variation of RMSE across iterations using a continuous hopfield network is as follows:

Figure 6: RMSE variation when trained using a Continuous Hopfield Network

Due to the smooth nature of the RMSE plots in Continuous Hopfield Networks, only they were evaluated for image retrieval after weight damage.

3.3 Weight Damage

3.3.1 25% Weight damage

Variation of RMSE across Iterations
The variation of RMSE across iterations using a continuous hopfield network is as follows:
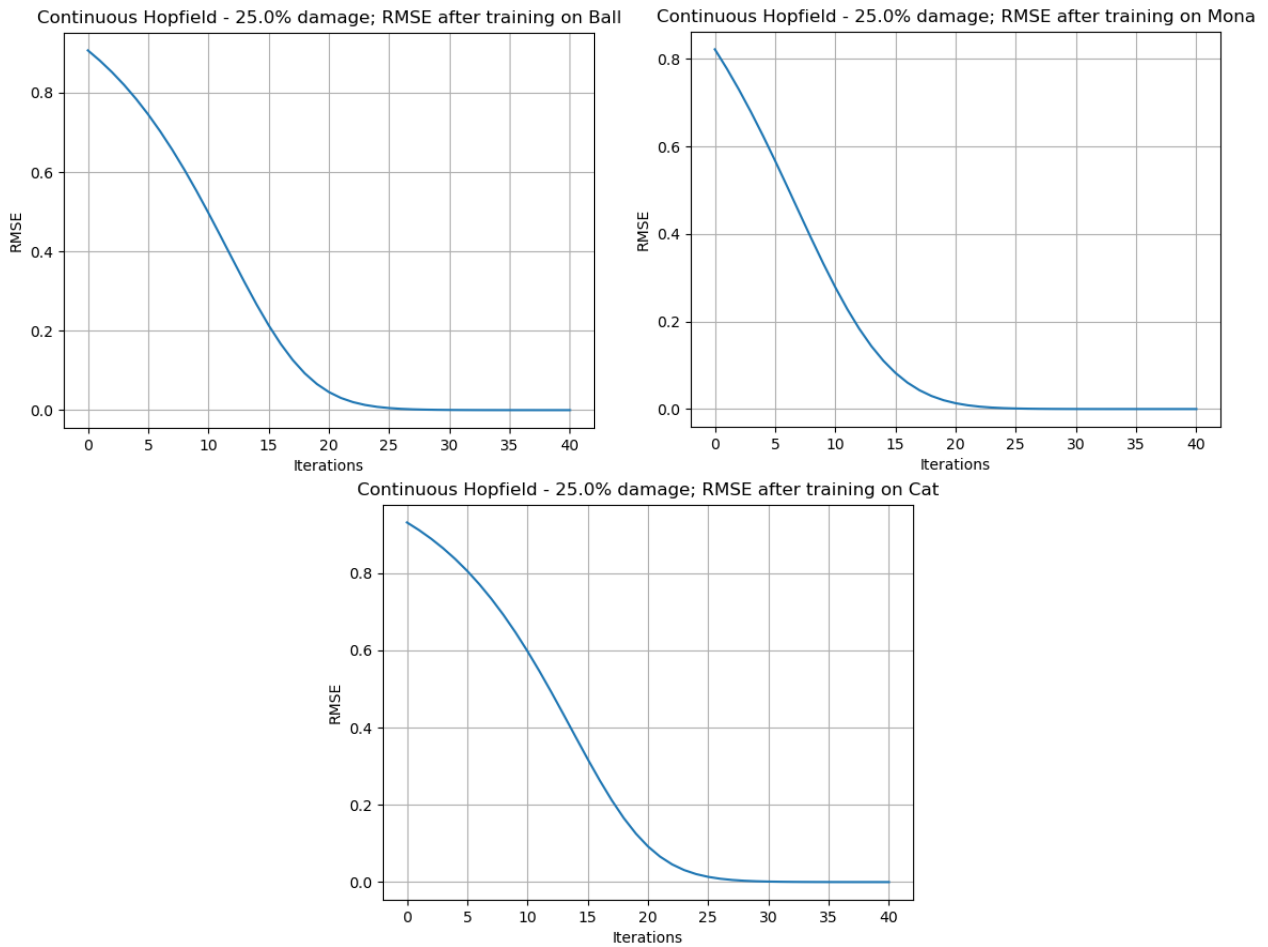

Figure 7: RMSE variation when trained using a Continuous Hopfield Network, with 25% Weight Damage

Final Image Reconstruction
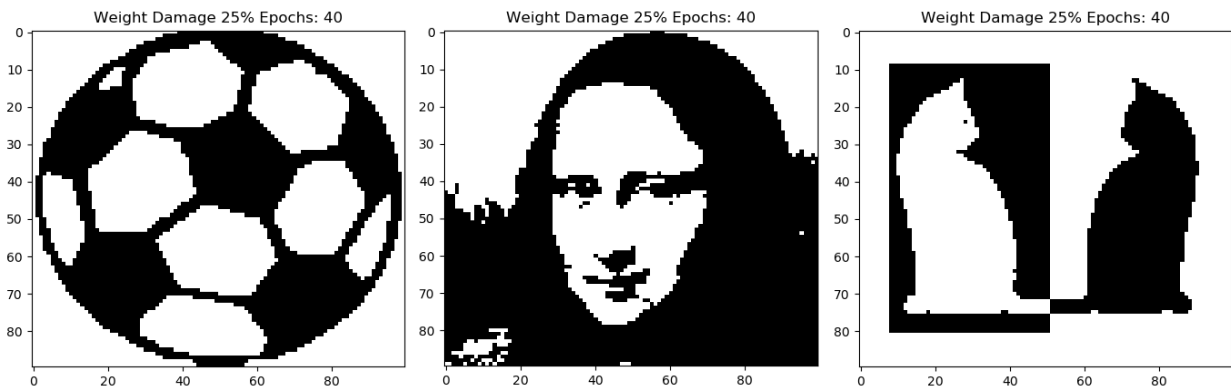The final images reconstructed using continuous hopfield networks is as follows:

Figure 8: RMSE variation when trained using a Continuous Hopfield Network, with 25% Weight Damage

Image Retrieval Video
The video of the image retrieval can be accessed in the files folder and are named: `ball_chn_25.mp4`, `mona_chn_25.mp4` and `cat_chn_25.mp4`.

3.3.2 50% Weight damage

Variation of RMSE across Iterations

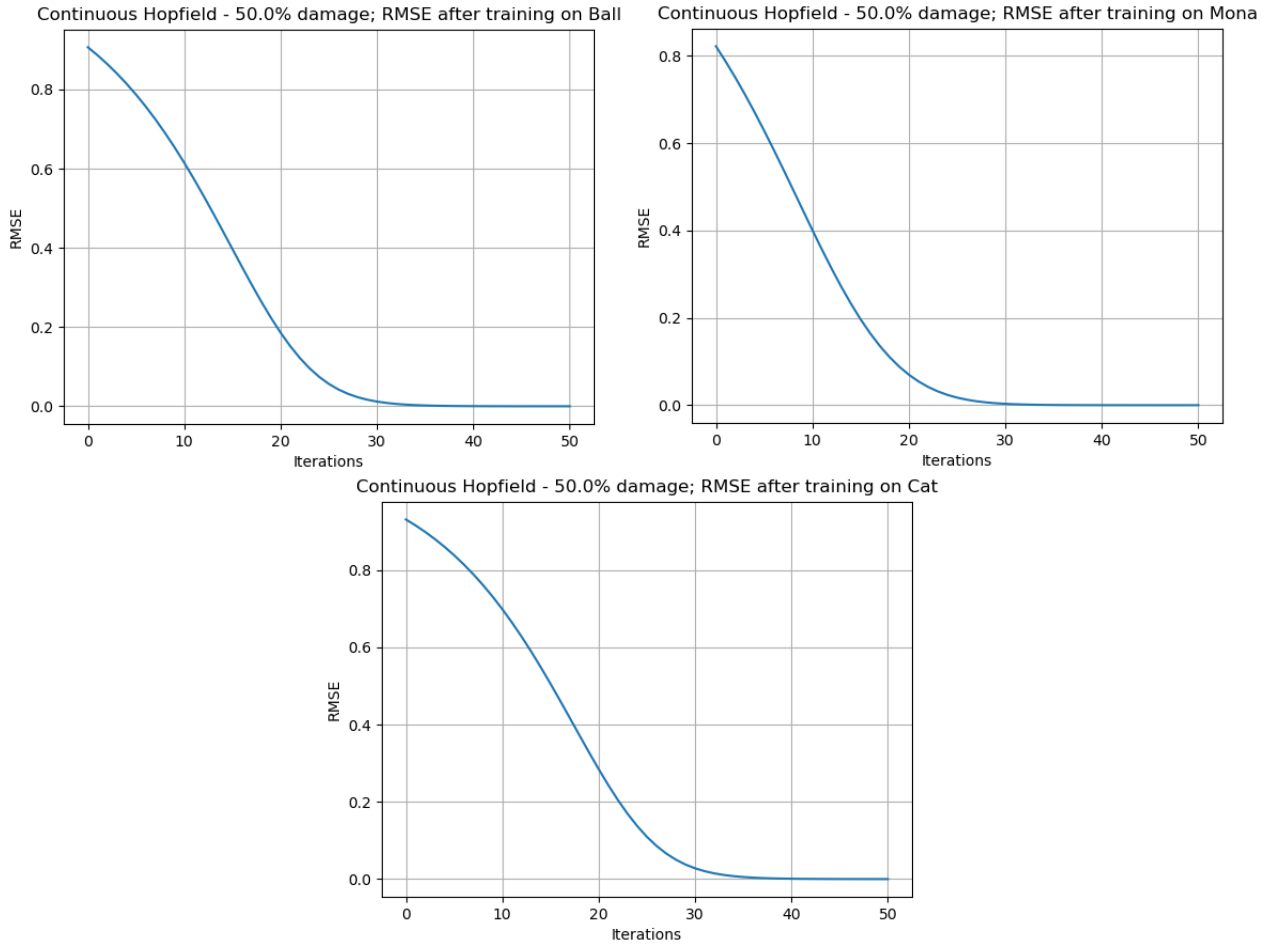The variation of RMSE across iterations using a continuous hopfield network is as follows:

Figure 9: RMSE variation when trained using a Continuous Hopfield Network, with 50% Weight Damage

Final Image Reconstruction

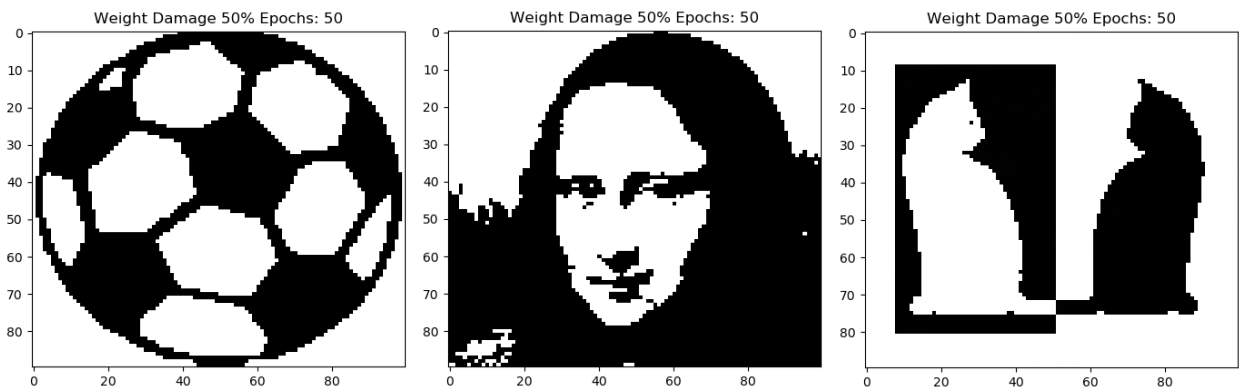The final images reconstructed using continuous hopfield networks is as follows:

Figure 10: RMSE variation when trained using a Continuous Hopfield Network, with 50% Weight Damage

Image Retrieval Video

The video of the image retrieval can be accessed in the files folder and are named: `ball_chn_50.mp4`, `mona_chn_50.mp4` and `cat_chn_50.mp4`.

3.3.3   80% Weight damage

Variation of RMSE across Iterations
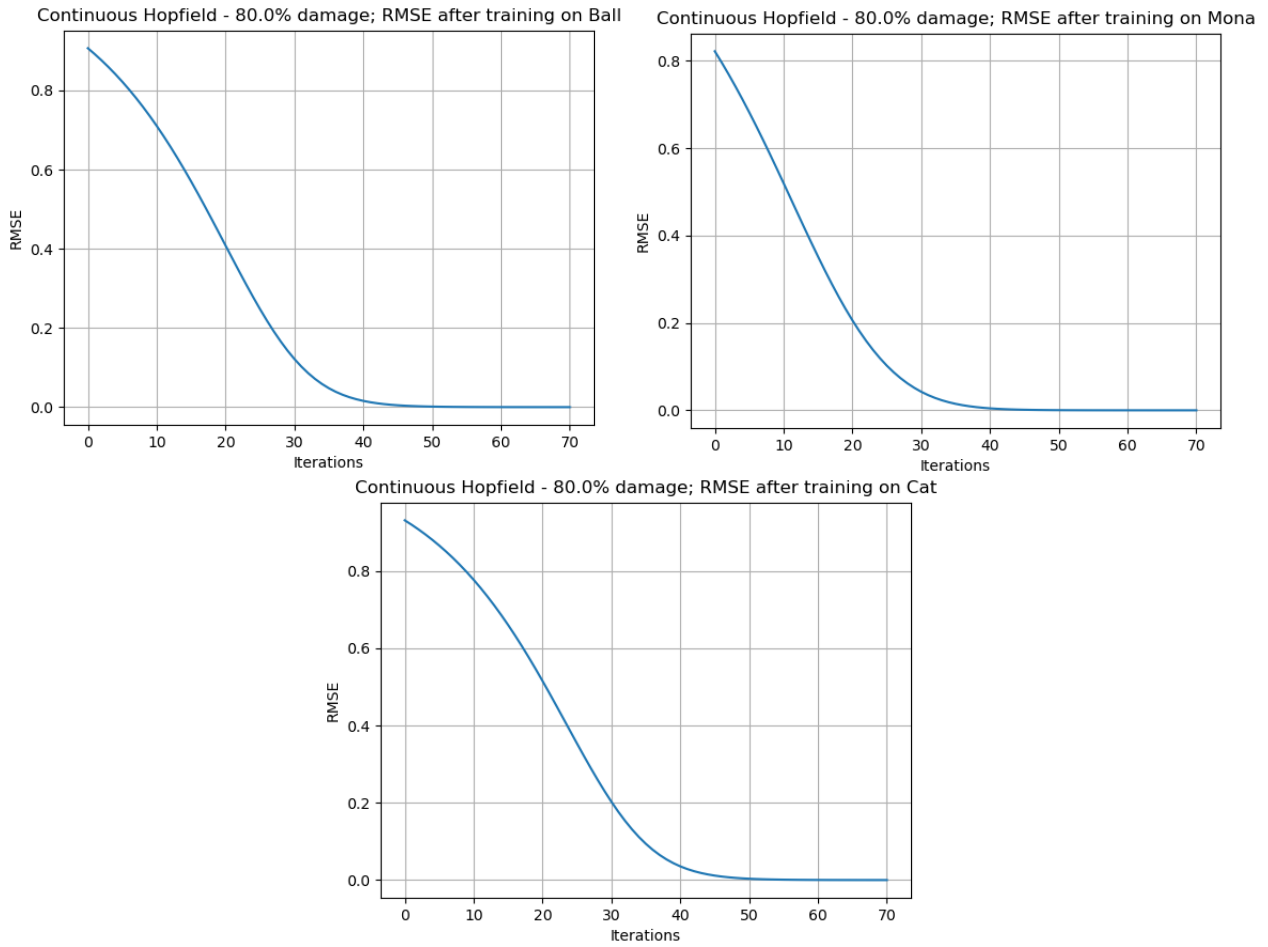The variation of RMSE across iterations using a continuous hopfield network is as follows:

Figure 11: RMSE variation when trained using a Continuous Hopfield Network, with 80% Weight Damage

Final Image Reconstruction
The final images reconstructed using continuous hopfield networks is as follows:

Figure 12: RMSE variation when trained using a Continuous Hopfield Network, with 80% Weight Damage

Image Retrieval Video
The video of the image retrieval can be accessed in the files folder and are named: `ball_chn_80.mp4`, `mona_chn_80.mp4` and `cat_chn_80.mp4`.

From the RMSE plots above, we can see that greater the fraction of damage, larger the number of epochs to retrieve the initial figure.