Kohonen self organizing map (SOM)

In [24]:

```
import numpy as np
import matplotlib.pyplot as plt
from IPython.display import Image
```

Utilities used for manipulation of data/matrices in the task

In [25]:

```
def generateInputWith24Shades():
    colorInputs = []
    colorInputs.append([236, 28, 28])
    colorInputs.append([153, 255, 51])
    colorInputs.append([51, 153, 255])
    colorInputs.append([255, 255, 153])
    colorInputs.append([0, 204, 204])
    colorInputs.append([255, 102, 255])
    colorInputs.append([198, 18, 18])
    colorInputs.append([31, 154, 199])
    colorInputs.append([255, 244, 71])
    colorInputs.append([255, 0, 127])
    colorInputs.append([93, 209, 124])
    colorInputs.append([0, 76, 153])
    colorInputs.append([255, 153, 153])
    colorInputs.append([255, 204, 255])
    colorInputs.append([153, 0, 0])
    colorInputs.append([229, 255, 204])
    colorInputs.append([76, 153, 0])
    colorInputs.append([76, 0, 153])
    colorInputs.append([255, 0, 0])
    colorInputs.append([0, 255, 0])
    colorInputs.append([0, 0, 255])
    colorInputs.append([153, 0, 76])
    colorInputs.append([153, 76, 0])
    colorInputs.append([255, 255, 0])
    showInputColors(colorInputs)
    return np.array(colorInputs)/255
```

In [26]:

```
# Utility to generate input colors taken for training the network
def showInputColors(colors):
    grid = []
    for color in colors:
        rowGrid = []
        for x in range(len(colors)):
            rowGrid.append(color)
        grid.append(rowGrid)
    print('Colors selected as inputs....')
    plt.figure(figsize=(5,5))
    plt.imshow(grid)
    plt.show()
```

In [27]:

```
# Given RGB 3D matrix, This utility shows the pattern of colors
def showGridColor(rgbInput):
    print('Color Pattern....')
    plt.figure(figsize=(5,5))
```

```
    plt.imshow(rgbInput.astype(np.uint8))
    plt.show()
```

In [28]:
```
Image(filename='img/q4_1.png')
```

Out[28]:

Using a time varying learning rate $\boldsymbol{\alpha}(\boldsymbol{k}) = \boldsymbol{\alpha_0 exp}(-\frac{\boldsymbol{k}}{\boldsymbol{T}})$

In [29]:
```
# Returns learning rate of an epoch
# Return value is based on above equation
def getLearningRate(initialAlpha, currentIteration, totalIteration):
    return initialAlpha*np.exp(-currentIteration/totalIteration)
```

In [30]:
```
Image(filename='img/q4_2.png')
```

Out[30]:

$$\sigma(k) = \sigma_0 \exp\left(-\frac{k}{T}\right)$$

In [31]:
```
# Returns Sigma/Distance factor of an epoch
# Return value is calculated analogous to above equation
def getDistanceFactor(initialDistance, currentIteration, totalIteration):
    return initialDistance*np.exp(-currentIteration/totalIteration)
```

In [32]:
```
Image(filename='img/q4_3.png')
```

Out[32]:

$$N_{i,j}(k) = \exp\left(-\frac{d_{i,j}^2}{2\sigma^2(k)}\right)$$

In [33]:
```
# Returns neighborhood factor of a node, given winner node
def getNeighbourFactor(winnerNode, distanceFactor):
    indexGrid = getIndexGrid()
    distance = (np.sum((indexGrid-winnerNode)**2,axis=2))/(-2*(distanceFactor ** 2))
    return np.exp(distance)
```

In [34]:
```
# Returns a 100X100X3 3D matrix pointing out index of row and column of each element
# Return value is used to calculate distance of every node on the grid from the winn
def getIndexGrid():
    grid = []
    for i in range(100):
        row = []
        for j in range(100):
            row.append([i,j])
        grid.append(row)
    return np.array(grid)
```

In [35]:

```
# Returns euclidean distance between the weights of the target neurons/nodes and inp
def calculateDistance(inputMatrix, targetMatrix):
    distance = np.sum((targetMatrix-inputMatrix) ** 2,axis = 2)
    return distance
```

In [36]:

```
# Returns indexes of winner node/neuron
def getWinnerNodeIndex(inputMatrix, targetMatrix):
    distances = calculateDistance(inputMatrix, targetMatrix)
    winner = np.where(distances == np.min(distances))
    return np.array([winner[0][0], winner[1][0]])
```

In [37]:

```
Image(filename='img/q4_5.png')
```

Out[37]:

$$w_{ij}(k+1) = \begin{cases} w_{ij}(k) + \alpha(k)h_{i,j}(K)[x - w_{ij}(k)] & \text{if} \quad (i,j) \in N_c(k), \\ w_{ij}(k) & \text{otherwise.} \end{cases}$$

where

$$\alpha(k) = \alpha(0)exp(\frac{-k}{\tau_\alpha})$$

$$h_{i,j}(k) = exp(\frac{-d_{i,j}}{2\sigma(k)^2})$$

In [38]:

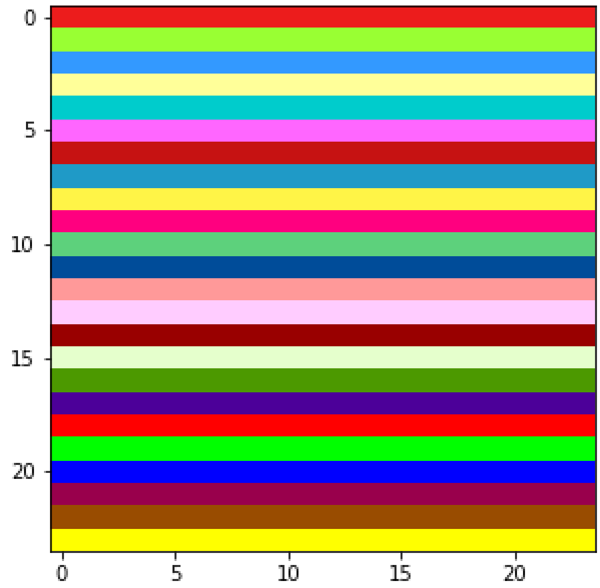
```
# Returns Delta W for an instance of an epoch, given epoch parameters, weights and i
# Return value is calculated analogous to above equation
def getDeltaW(initialAlpha, initialDistance,
              currentIteration, totalIteration,
              winnerNode, weights, inputMatrix):
    learningRate = getLearningRate(initialAlpha=initialAlpha,
                                   currentIteration=currentIteration,
                                   totalIteration=totalIteration)
    distanceFactor = getDistanceFactor(initialDistance=initialDistance,
                                       currentIteration=currentIteration,
                                       totalIteration=totalIteration)
    neighborFactor = getNeighbourFactor(winnerNode, distanceFactor)
    deltaW = learningRate*((-1*(weights - inputMatrix)).transpose()*
                           neighborFactor.transpose()).transpose()
    return deltaW
```

Considering 24 sample input colors

In [39]:

```
inputColors = generateInputWith24Shades()
```

```
Colors selected as inputs....
```



Initializing weights for 100x100 nodes

In [45]:

```
W =  np.random.rand(100, 100, 3)
initialRate = 0.8 # Initial alpha value
```

Training of network

In [41]:

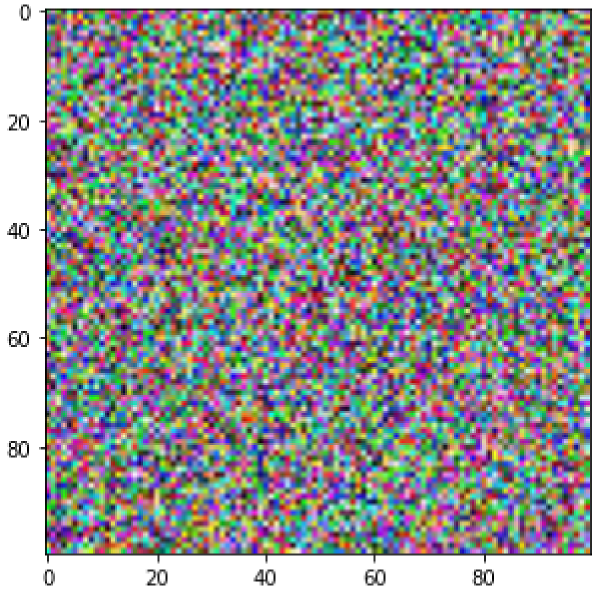
```
def trainNetwork(iterations, initialSigma, weights):
    print('Training.... Please wait... this may take some time....')
    for i in range(iterations):
        for color in inputColors:
            winner = getWinnerNodeIndex(color, weights)
            deltaW = getDeltaW(initialAlpha=initialRate,
                               initialDistance=initialSigma,
                               currentIteration=i,
                               totalIteration=iterations,
                               winnerNode=winner,
                               weights=weights,
                               inputMatrix=color)
            weights = weights + deltaW
    print('Training ends....')
    print('Pattern generated after training')
    showGridColor(np.around(weights*255))
```

Initial pattern of 100x100 output neurons/nodes

In [43]:

```
showGridColor(np.around(W*255))
```

```
Color Pattern....
```



Case studies taking above conditions of epochs and distance values

Case study [CS 1]

note: initialSigma, iterations are the variables for training the network

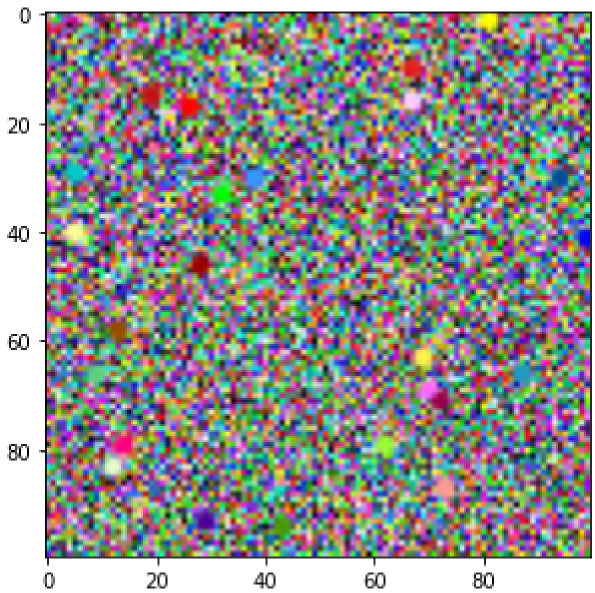
No of epochs = 20

[CS-1a] epochs=20 sigma=1

In [46]:

```
wtrain = W
trainNetwork(iterations=20, initialSigma=1, weights=wtrain)
```

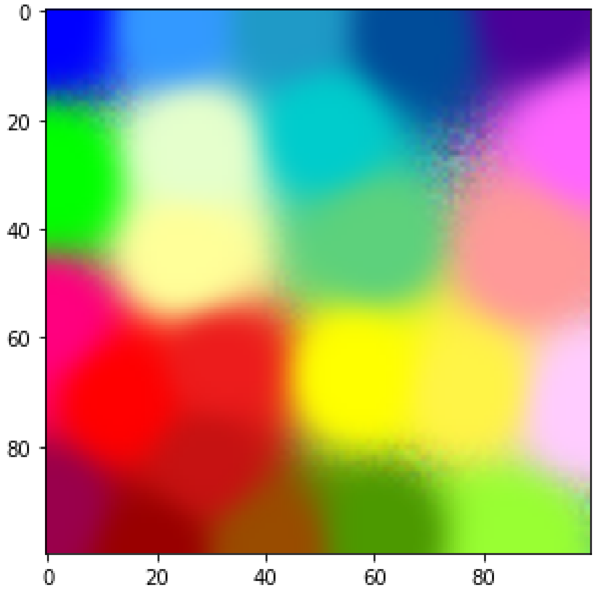
```
Training.... Please wait... this may take some time....
Training ends....
Pattern generated after training
Color Pattern....
```



[CS-1b] epochs=20 sigma=10

In [22]:
```
wtrain = W
trainNetwork(iterations=20, initialSigma=10, weights=wtrain)
```

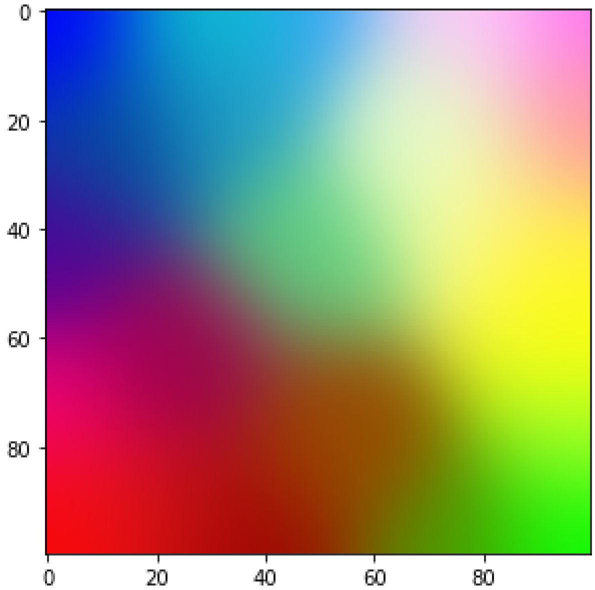
```
Training.... Please wait... this may take some time....
Training ends....
Pattern generated after training
Color Pattern....
```



[CS-1c] epochs=20 sigma=30

In [23]:
```
wtrain = W
trainNetwork(iterations=20, initialSigma=30, weights=wtrain)
```

```
Training.... Please wait... this may take some time....
Training ends....
Pattern generated after training
Color Pattern....
```

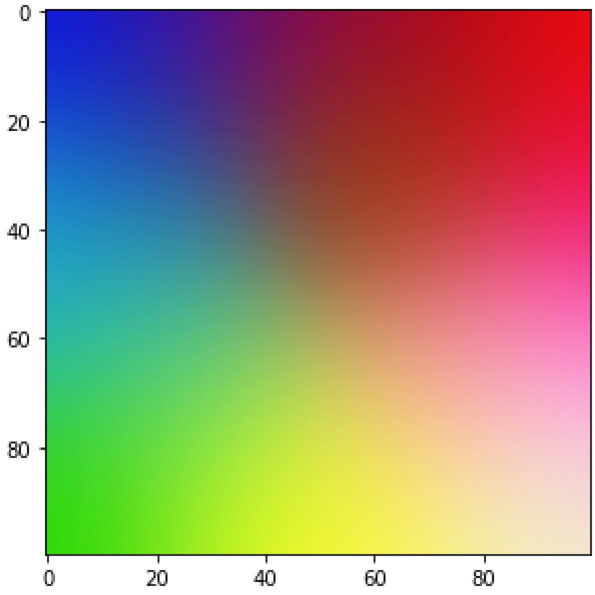


[CS-1d] epochs=20 sigma=50

In [176…
```
wtrain = W
trainNetwork(iterations=20, initialSigma=50, weights=wtrain)
```

```
Training.... Please wait... this may take some time....
Training ends....
```

```
Pattern generated after training
Color Pattern....
```

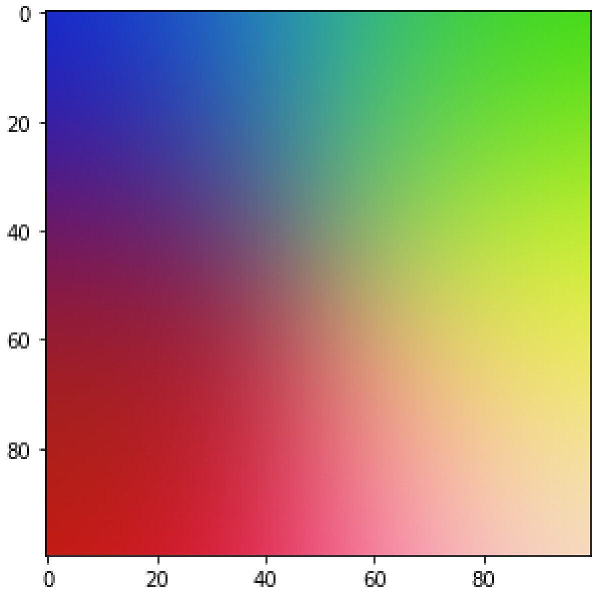


[CS-1e] epochs=20 sigma=70

In [177…

```
wtrain = W
trainNetwork(iterations=20, initialSigma=70, weights=wtrain)
```

```
Training.... Please wait... this may take some time....
Training ends....
Pattern generated after training
Color Pattern....
```



Case study [CS 2]

No of epochs = 40

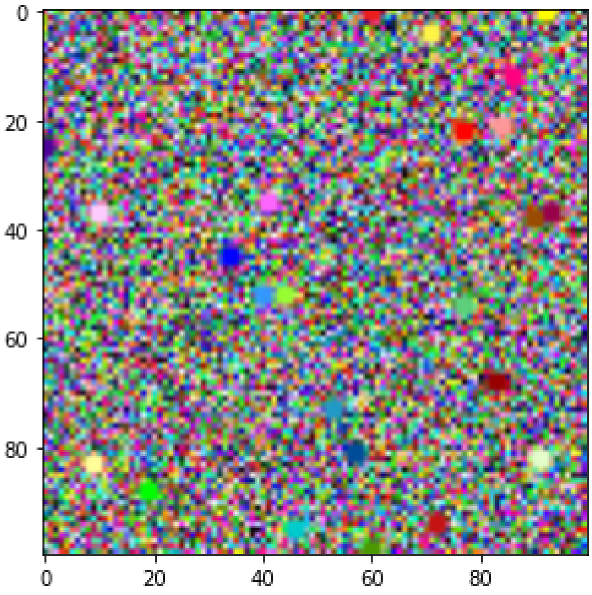
[CS-2a] epochs=40 sigma=1

In [178…

```
wtrain = W
trainNetwork(iterations=40, initialSigma=1, weights=wtrain)
```

```
Training.... Please wait... this may take some time....
Training ends....
```

```
Pattern generated after training
Color Pattern....
```

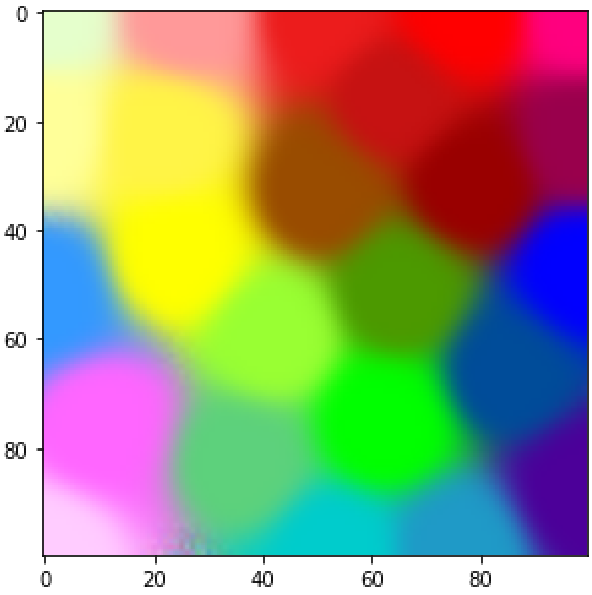


[CS-2b] epochs=40 sigma=10

In [179…

```
wtrain = W
trainNetwork(iterations=40, initialSigma=10, weights=wtrain)
```

```
Training.... Please wait... this may take some time....
Training ends....
Pattern generated after training
Color Pattern....
```

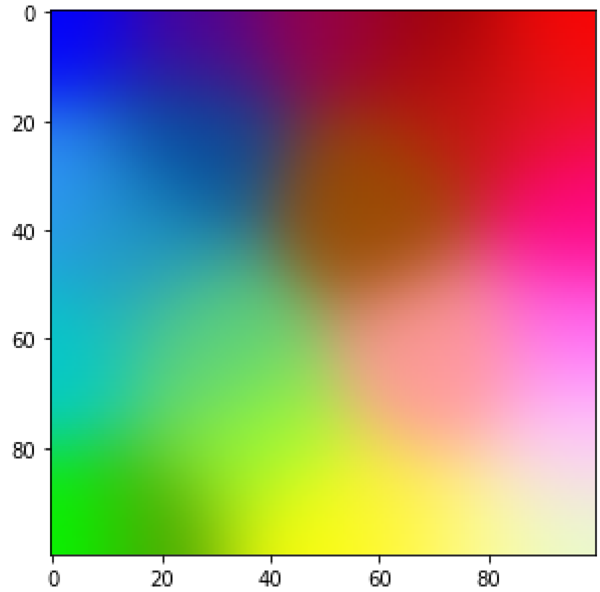


[CS-2c] epochs=40 sigma=30

In [180…

```
wtrain = W
trainNetwork(iterations=40, initialSigma=30, weights=wtrain)
```

```
Training.... Please wait... this may take some time....
Training ends....
Pattern generated after training
Color Pattern....
```

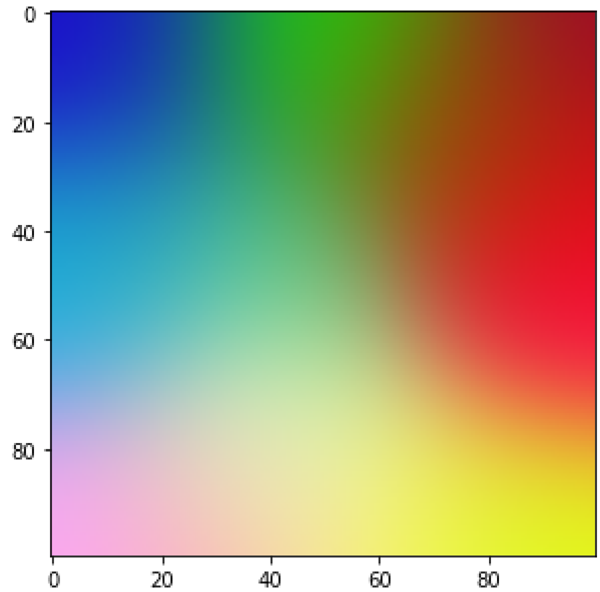


[CS-2d] epochs=40 sigma=50

In [181…

```
wtrain = W
trainNetwork(iterations=40, initialSigma=50, weights=wtrain)
```

```
Training.... Please wait... this may take some time....
Training ends....
Pattern generated after training
Color Pattern....
```

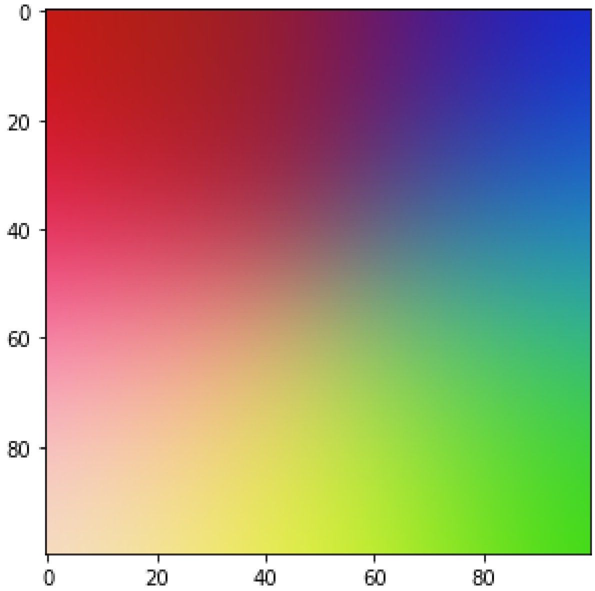


[CS-2e] epochs=40 sigma=70

In [182…

```
wtrain = W
trainNetwork(iterations=40, initialSigma=70, weights=wtrain)
```

```
Training.... Please wait... this may take some time....
Training ends....
Pattern generated after training
Color Pattern....
```



Case study [CS 3]

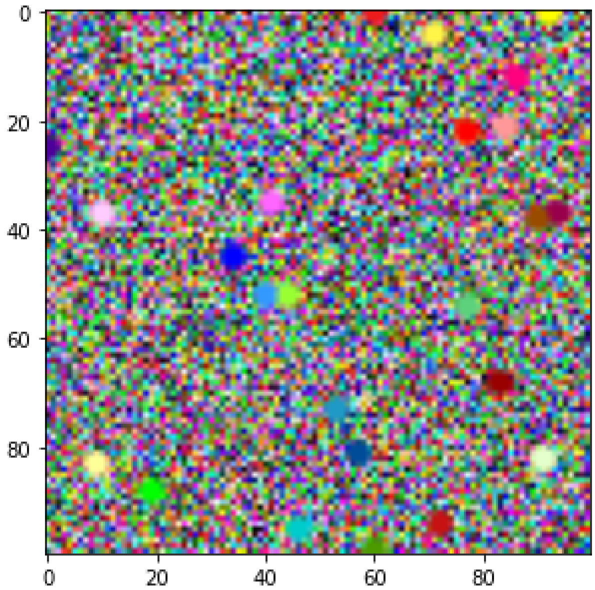
No of epochs = 100

[CS-3a] epochs=100 sigma=1

In [183…

```
wtrain = W
trainNetwork(iterations=100, initialSigma=1, weights=wtrain)
```

```
Training.... Please wait... this may take some time....
Training ends....
Pattern generated after training
Color Pattern....
```

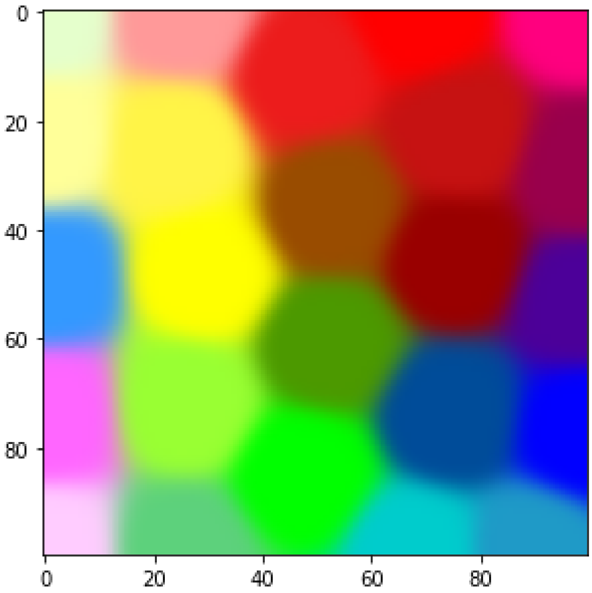


[CS-3b] epochs=100 sigma=10

In [184…

```
wtrain = W
trainNetwork(iterations=100, initialSigma=10, weights=wtrain)
```

```
Training.... Please wait... this may take some time....
Training ends....
Pattern generated after training
Color Pattern....
```

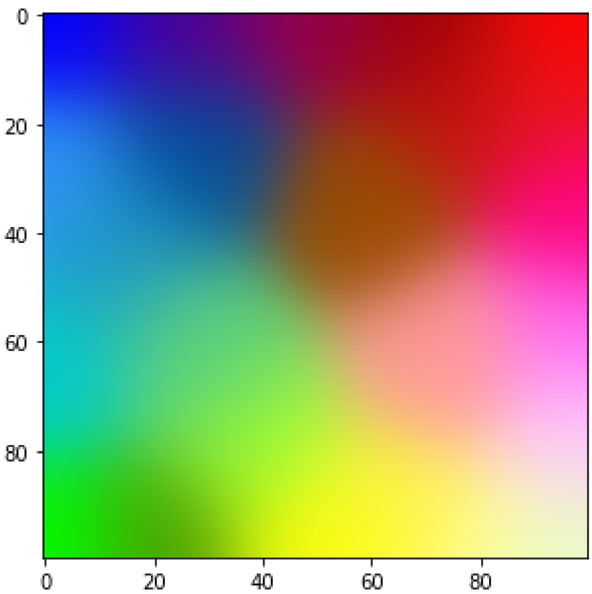


[CS-3c] epochs=100 sigma=30

In [185…

```
wtrain = W
trainNetwork(iterations=100, initialSigma=30, weights=wtrain)
```

```
Training.... Please wait... this may take some time....
Training ends....
Pattern generated after training
Color Pattern....
```

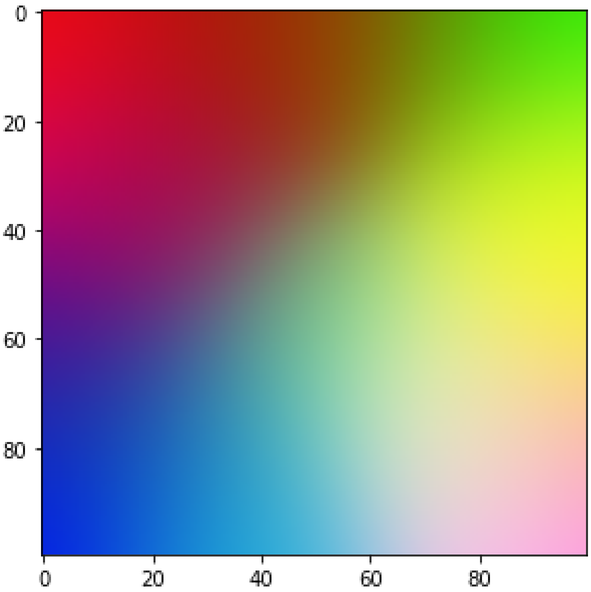


[CS-3d] epochs=100 sigma=50

In [186…

```
wtrain = W
trainNetwork(iterations=100, initialSigma=50, weights=wtrain)
```

```
Training.... Please wait... this may take some time....
Training ends....
Pattern generated after training
Color Pattern....
```

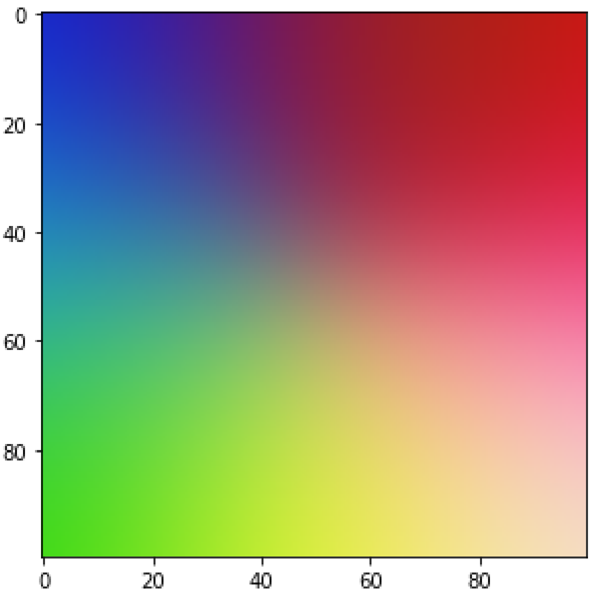


[CS-3e] epochs=100 sigma=70

In [187…

```
wtrain = W
trainNetwork(iterations=100, initialSigma=70, weights=wtrain)
```

```
Training.... Please wait... this may take some time....
Training ends....
Pattern generated after training
Color Pattern....
```



Case study [CS 4]

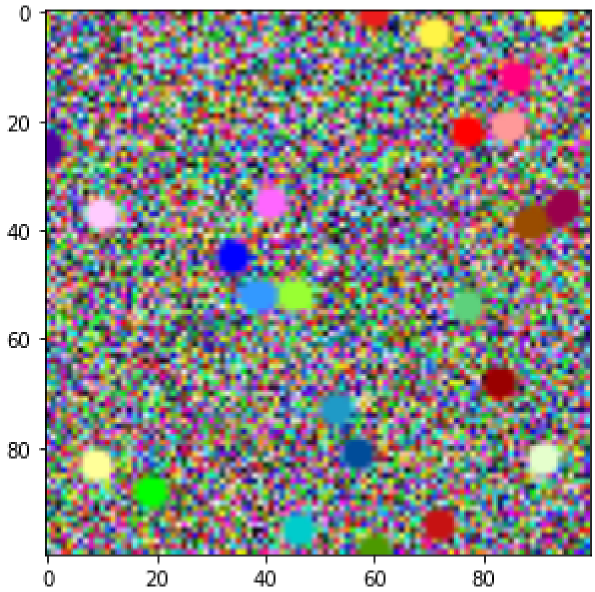
No of epochs = 1000

[CS-4a] epochs=1000 sigma=1

In [188…

```
wtrain = W
trainNetwork(iterations=1000, initialSigma=1, weights=wtrain)
```

```
Training.... Please wait... this may take some time....
Training ends....
Pattern generated after training
Color Pattern....
```

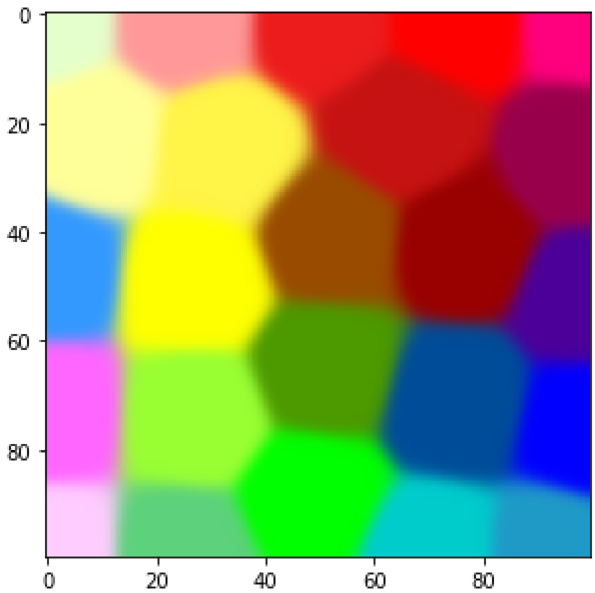


[CS-4b] epochs=1000 sigma=10

In [189…

```
wtrain = W
trainNetwork(iterations=1000, initialSigma=10, weights=wtrain)
```

```
Training.... Please wait... this may take some time....
Training ends....
Pattern generated after training
Color Pattern....
```

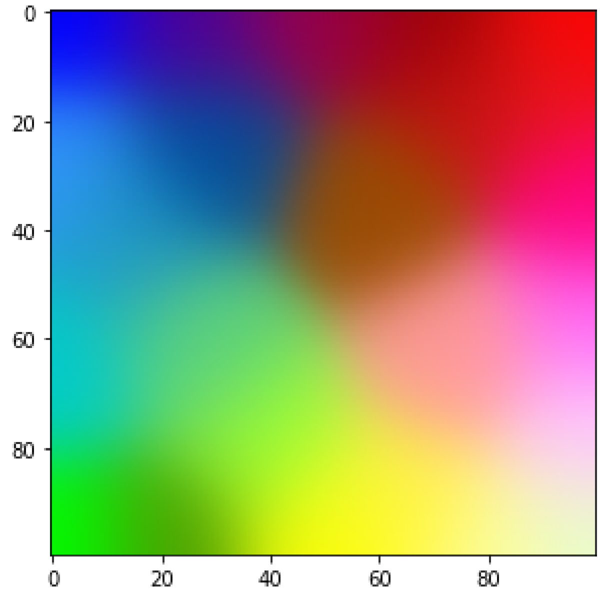


[CS-4c] epochs=1000 sigma=30

In [190…

```
wtrain = W
trainNetwork(iterations=1000, initialSigma=30, weights=wtrain)
```

```
Training.... Please wait... this may take some time....
Training ends....
Pattern generated after training
Color Pattern....
```

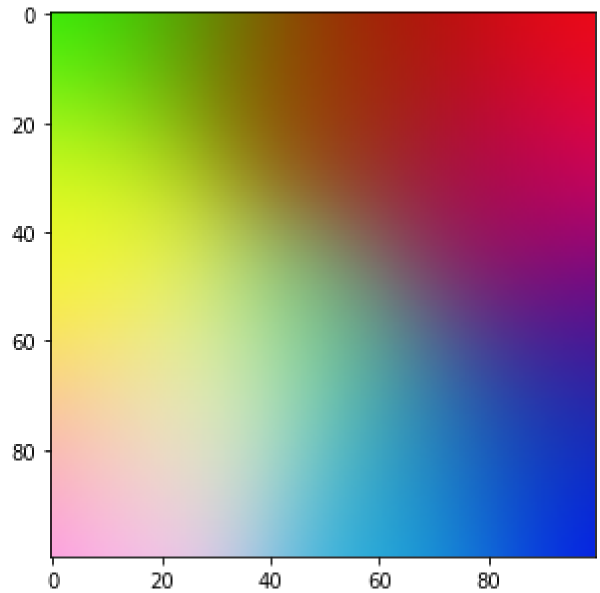


[CS-4d] epochs=1000 sigma=50

In [191…

```
wtrain = W
trainNetwork(iterations=1000, initialSigma=50, weights=wtrain)
```

```
Training.... Please wait... this may take some time....
Training ends....
Pattern generated after training
Color Pattern....
```

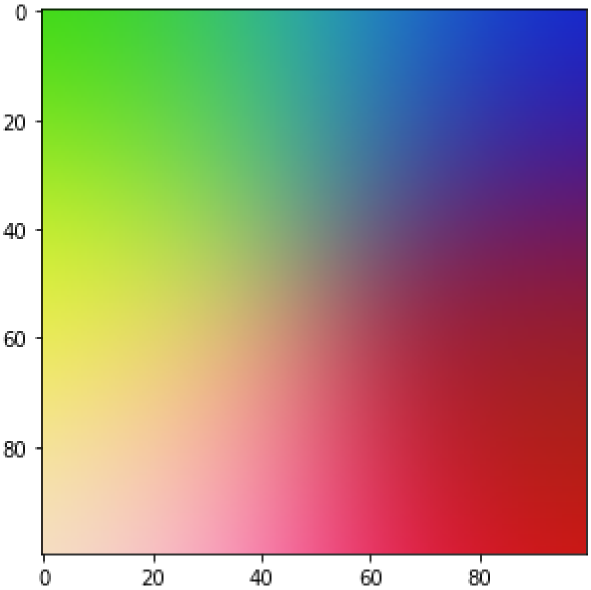


[CS-4e] epochs=1000 sigma=70

In [192…

```
wtrain = W
trainNetwork(iterations=1000, initialSigma=70, weights=wtrain)
```

```
Training.... Please wait... this may take some time....
Training ends....
Pattern generated after training
Color Pattern....
```



Takeaway

1. With a small distance (sigma) parameter,

the network makes the classification within a smaller radius around the winner nodes.

As the weigths are updated around winner node within a small radius,

Hence, forming distinct bounadries of classification

2. With a larger distance parameter,

the network makes the classification for a bigger radius around the winner nodes,

Hence the colors/classification show cascading effect in the network

3. As we increase the epochs, The classification of network becomes more clear and explicit,

as weights are updated more number of times around the winner nodes