SOM

November 23, 2022

[1]:
```
from skimage import io
from tqdm import tqdm

import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import warnings
```

[2]:
```
warnings.filterwarnings("ignore")
```

[3]:
```
np.random.seed(42)
```

[4]:
```
NEIGHBOR_SCALE_FACTOR = 10  # the bigger this value, the lesser the weights of␣
↪neighbours are updated
```

[5]:
```
LR_DECAY = 5  # the bigger this value, the slower the learning rate decays
```

[6]:
```
# lattice dimensions: M x M
M = 3
```

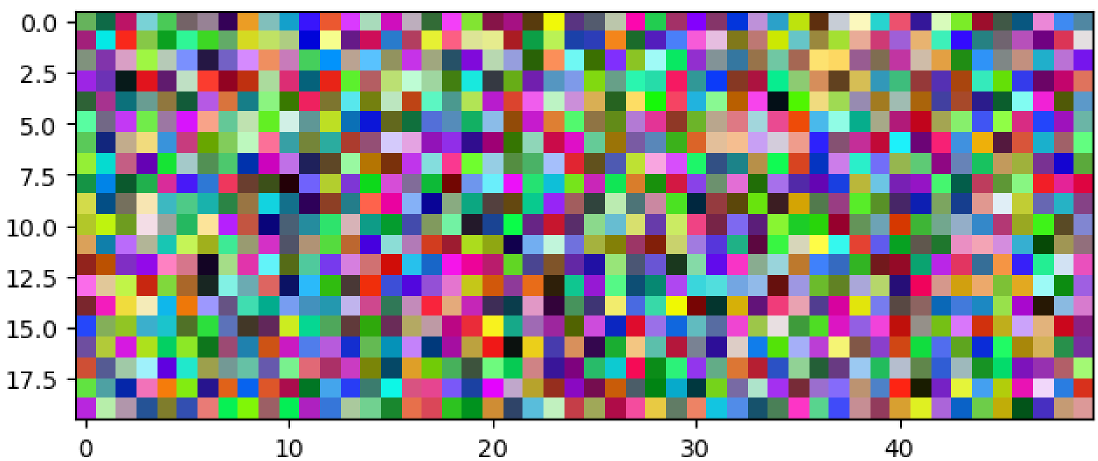
[7]:
```
def euclidean(x, w):
    """
    Returns euclidean distance.
    For computation efficiency, square root is not done.

    """
    n = len(x)
    dist = 0
    for i in range(n):
        dist += (x[i] - w[i]) ** 2
    return dist
```

[8]:
```
X = np.random.randint(low=0, high=255, size=(1000, 3))
```

[9]:
```
io.imshow(np.uint8(X.reshape(20, len(X)//20, 3)))
```

[9]:
```
<matplotlib.image.AxesImage at 0x2b56202e6a30>
```

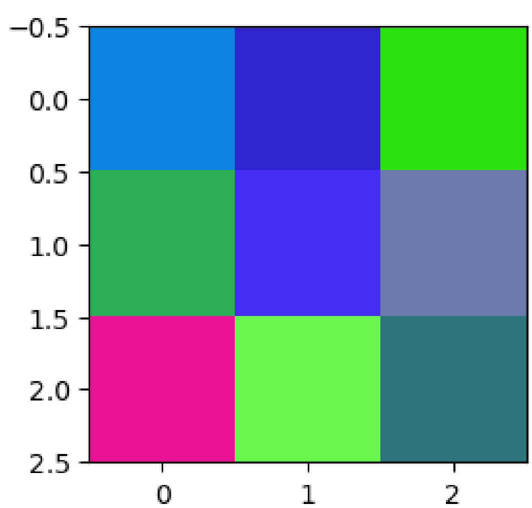


```
[10]: X = X / 255  # scale values
```

```
[11]: W = np.random.randint(low=0, high=255, size=(9, 3))
```

```
[12]: # initialized lattice wihth random weights
      plt.figure(figsize=(3, 3))
      io.imshow(np.uint8(W.reshape(3, 3, 3)))
```

```
[12]: <matplotlib.image.AxesImage at 0x2b56203fe940>
```



```
[13]: W = W / 255
```

```
[14]: W
```

[14]: array([[0.04313725, 0.51764706, 0.88235294],
       [0.18431373, 0.14117647, 0.80784314],
       [0.16862745, 0.89019608, 0.05490196],
       [0.16470588, 0.68627451, 0.3372549],
       [0.27058824, 0.17647059, 0.94509804],
       [0.41960784, 0.47843137, 0.66666667],
       [0.9254902 , 0.07843137, 0.58823529],
       [0.41568627, 0.96470588, 0.30980392],
       [0.18039216, 0.45490196, 0.48235294]])

[15]:
```
def find_neighbourhood_radius(step):
    """
    Returns the radius that is considered the neigbourhood.
    It decreases with each step/iteration.

    """
    return M - step
```

[16]:
```
def find_bmu(x):
    """
    Find the best matching unit by computing euclidean distance
    and then return its index.

    """
    distances = [euclidean(w, x) for w in W]
    closest_node = pd.Series(distances).idxmin()
    return closest_node
```

[17]:
```
def update_wt(i, x, lr, scale=1):
    """
    Update the weight at index i based on input x.
    The weight can belong to the BMU node or one of its neighbours.
    For the neighbours, we use scale to update their weights based on
    how far/close they are to BMU.

    """
    lr /= scale   # if neighbours are far we'd update their weights weakly
    w_updated = (W[i] + (lr * (x - W[i])))
    W[i] = w_updated
```

[18]:
```
# for simplicity it's precomputed which nodes are within the neighbourhood for
# each radius of each node as a BMU, alongwith how close they are.
# for example, for radius 3 node 0 (as BMU) has node 1 in the neighbourhood at
# distance 1 and node 8 in the neigbourhood at distance 2.
# similarly, for radius 2 node 0 (as BMU) has node 1 in the neighbourhood at
# distance 1 but node 8 is not in the neigbourhood anymore.
neigbourhood_dist_map = {
```

```
    3: {
        0: [(1, 1), (2, 2), (3, 1), (4, 1), (5, 2), (6, 2), (7, 2), (8, 2)],
        1: [(0, 1), (2, 1), (3, 1), (4, 1), (5, 1), (6, 2), (7, 2), (8, 2)],
        2: [(0, 2), (1, 1), (3, 2), (4, 1), (5, 1), (6, 2), (7, 2), (8, 2)],
        3: [(0, 1), (1, 1), (2, 2), (4, 1), (5, 2), (6, 1), (7, 1), (8, 2)],
        4: [(0, 1), (1, 1), (2, 1), (3, 1), (5, 1), (6, 1), (7, 1), (8, 1)],
        5: [(0, 2), (1, 1), (2, 1), (3, 2), (4, 1), (6, 2), (7, 1), (8, 1)],
        6: [(0, 2), (1, 2), (2, 2), (3, 1), (4, 1), (5, 2), (7, 1), (8, 2)],
        7: [(0, 2), (1, 2), (2, 2), (3, 1), (4, 1), (5, 1), (6, 1), (8, 1)],
        8: [(0, 2), (1, 2), (2, 2), (3, 2), (4, 1), (5, 1), (6, 2), (7, 1)],
    },
    2: {
        0: [(1, 1), (3, 1), (4, 1)],
        1: [(0, 1), (2, 1), (3, 1), (4, 1), (5, 1)],
        2: [(1, 1), (4, 1), (5, 1)],
        3: [(0, 1), (1, 1), (4, 1), (6, 1), (7, 1)],
        4: [(0, 1), (1, 1), (2, 1), (3, 1), (5, 1), (6, 1), (7, 1), (8, 1)],
        5: [(1, 1), (2, 1), (4, 1), (7, 1), (8, 1)],
        6: [(3, 1), (4, 1), (7, 1)],
        7: [(3, 1), (4, 1), (5, 1), (6, 1), (8, 1)],
        8: [(4, 1), (5, 1), (7, 1)]
    }
}
```

[19]:

```python
def update_neighbourhood_wts(radius, x, bmu_idx, lr):
    """
    For BMU we update the weights of its neighbours within given
    radius.

    """
    if radius == 1:  # bmu has no neighbours
        return
    neigbours = neigbourhood_dist_map[radius][bmu_idx]
    for j, dist in neigbours:  # node at index j is a neighbour at distance dist
        update_wt(j, x, lr, dist * NEIGHBOR_SCALE_FACTOR)
```

[20]:

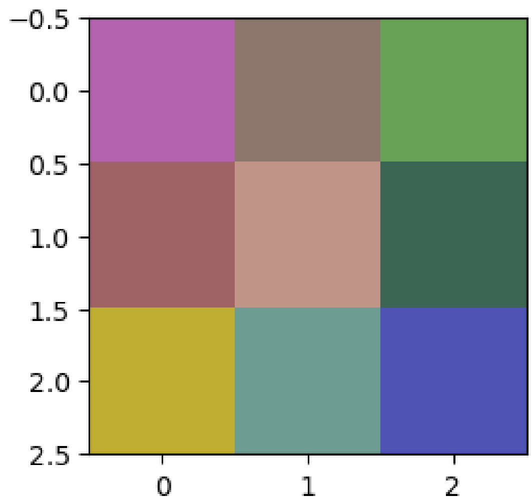
```python
lr = 0.5  # learning rate
no_of_epochs = 3

# training
for epoch in tqdm(range(no_of_epochs)):
    lr = lr * np.exp(-epoch / 5)  # exponentially decay the learning rate
    for x in X:
        bmu_idx = find_bmu(x)
        update_wt(bmu_idx, x, lr)  # update weight of bmu
        update_neighbourhood_wts(find_neighbourhood_radius(epoch), x, bmu_idx,␣
 ↪lr)  # update neighbourhood weights
```

```
    print(f"[{epoch}/{no_of_epochs}]:")
    print(f"learning rate: {lr}")
    _W = W * 255
    plt.figure(figsize=(3, 3))
    io.imshow(np.uint8(_W.reshape(3, 3, 3)))
    plt.show()
```

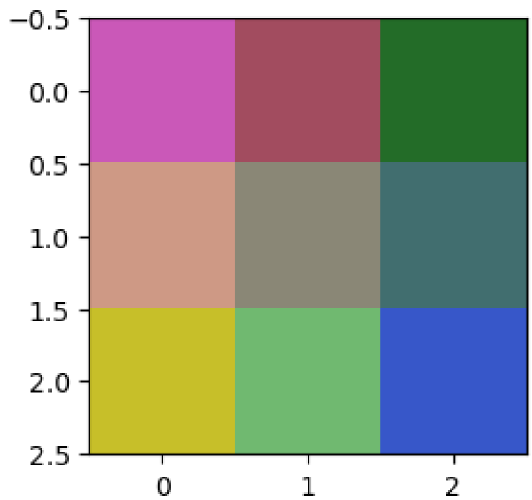
```
  0%|          | 0/3 [00:00<?, ?it/s]

[0/3]:
learning rate: 0.5
```



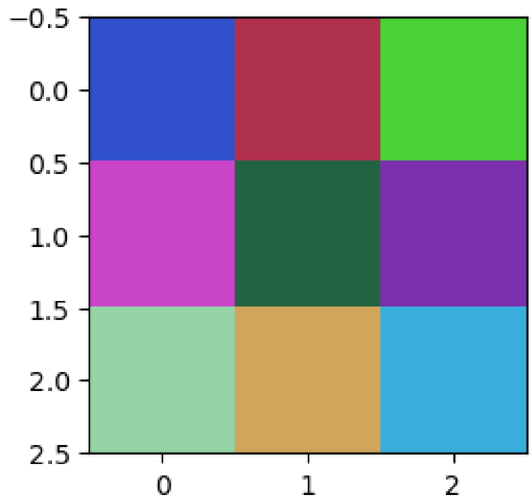

```
 33%|          | 1/3 [00:00<00:00,  3.60it/s]

[1/3]:
learning rate: 0.4093653765389909
```



67%| | 2/3 [00:00<00:00, 3.90it/s]

[2/3]:
learning rate: 0.2744058180470132



100%| | 3/3 [00:00<00:00, 4.03it/s]

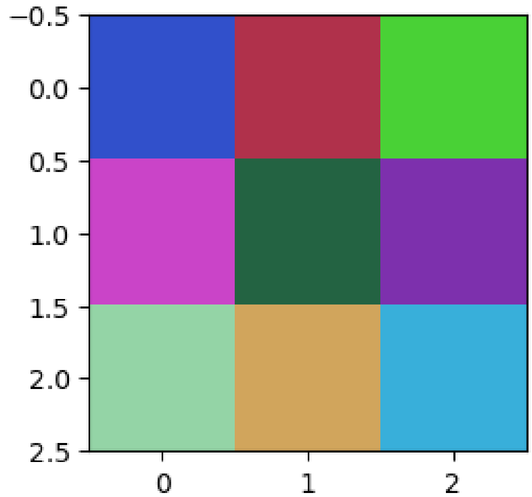
[21]:
```
W
```

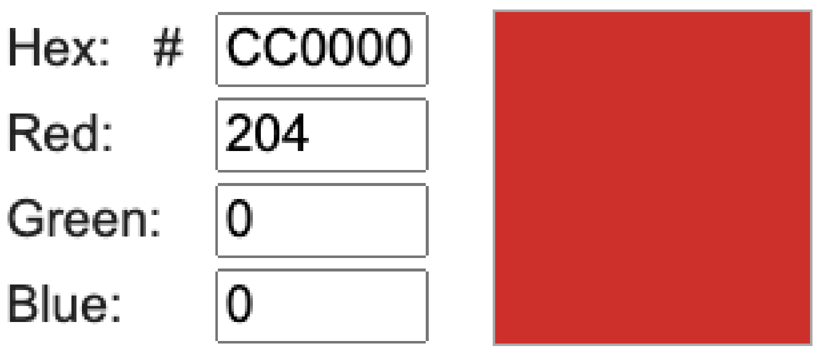
[21]:
```
array([[0.19605144, 0.314093  , 0.79781748],
       [0.69175651, 0.19554462, 0.29511884],
       [0.28822626, 0.82166184, 0.21398881],
       [0.79546632, 0.26781963, 0.78729553],
       [0.14087631, 0.39119698, 0.26081086],
       [0.49394394, 0.18983355, 0.68000121],
       [0.58162156, 0.83314085, 0.65367297],
       [0.8222953 , 0.64972292, 0.36366554],
       [0.22059098, 0.6882557 , 0.85609524]])
```

[22]:
```
W = W * 255
```

[23]:
```
# final lattice
plt.figure(figsize=(3, 3))
io.imshow(np.uint8(W.reshape(3, 3, 3)))
```

[23]:
```
<matplotlib.image.AxesImage at 0x2b56207da220>
```

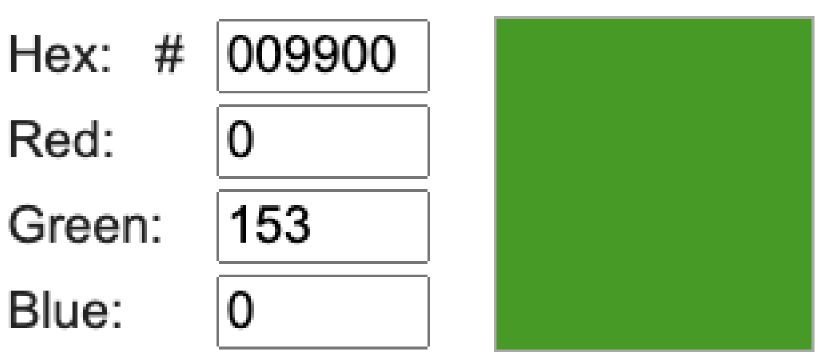




[24]:
```
x_test = [204, 0, 0]   # shade of red
```

[25]:
```
find_bmu(x_test)   # the node at index 1 in our final lattice above has dark red shade :)
```

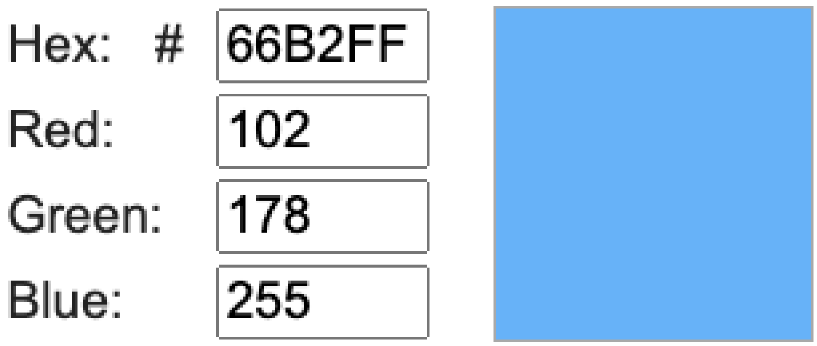
[25]: 1



[26]:
```
x_test = [0, 153, 0]  # shade of green
```

[27]:
```
find_bmu(x_test)   # the node at index 4 in our final lattice above has dark green shade :)
```

[27]: 4



[28]:
```
x_test = [102, 178, 255]  # shade of blue
```

[29]:
```
find_bmu(x_test) # the node at index 8 in our final lattice above has bright blue shade :)
```

[29]: 8