# Лабораторная работа № 6

**Вариант:** 9

[1]:

```
import numpy as np
import matplotlib.pyplot as plt
from random import choice
import matplotlib.animation as animation
from IPython.display import HTML
from tqdm import tqdm

from sklearn.datasets import make_blobs
from ipywidgets import interact, IntSlider
from matplotlib.collections import LineCollection
from PIL import Image
```

[2]:

```
%matplotlib inline
import matplotlib_inline
matplotlib_inline.backend_inline.set_matplotlib_formats('retina', 'pdf')
plt.rcParams['figure.dpi'] = 100
```

# Карта Кохонена

[58]:

```
class SOM:
    def __init__(self, width, height, dim, r=None, nodes=None):
        self.width = width
        self.height = height
        self.dim = dim
        self.nodes = (nodes.copy() if nodes is not None else np.random.rand(height,␣
↪width, dim)).reshape(-1, dim)
        self.indexes = np.stack(np.meshgrid(np.arange(height), np.arange(width),␣
↪indexing='ij'), axis=-1).reshape(-1, 2)
        self.lr = None
        self.r = r or max(width, height) / 2
        self._lr = None
        self._r = self.r

    def update(self, data):
        for x in data:
            dist = np.sum((self.nodes - x) ** 2, axis=1)
            node = np.argmin(dist)
            dist = np.sqrt(np.sum((self.indexes - self.indexes[node]) ** 2, axis=1))
            influence = np.exp(- dist / (2 * self.r))
            self.nodes += self.lr * (influence * (dist <= self.r))[:, np.newaxis] *␣
↪(x - self.nodes)
```

```
    def update_parameters(self, epoch, epochs):
        self.lr = max(0.01, self._lr * np.exp(-epoch / epochs))
        self.r = self._r * np.exp(-epoch * np.log(self._r) / epochs)

    def fit(self, data, epochs, lr=0.1, interval=1, verbose=False):
        self.lr = lr
        self._lr = lr
        nodes = [self.nodes.copy()]
        epochs_iter = range(epochs)
        if len(data.shape) == 1:
            data = data[np.newaxis, :]
        indexes = np.arange(len(data))
        if verbose:
            epochs_iter = tqdm(epochs_iter, ncols=70, desc='Epochs', ascii=True)
        for epoch in epochs_iter:
            np.random.shuffle(indexes)
            self.update(data[indexes])
            self.update_parameters(epoch+1, epochs)
            if (epoch+1) % interval == 0:
                nodes.append(self.nodes.copy())
        if verbose:
            epochs_iter.close()
        return nodes

    def predict(self, data):
        if len(data.shape) == 1:
            data = data[np.newaxis, :]
        res = np.zeros((data.shape[0],))
        for i, x in enumerate(data):
            res[i] = np.argmin(np.sum((self.nodes - x) ** 2, axis=1))
        return res
```

[5]:

```
def plot_parameters(som, epochs):
    fig = plt.figure(figsize=(10, 3))
    epoch = np.arange(epochs)
    fig.add_subplot(121)
    plt.title('Learning rate')
    plt.plot(som._lr * np.exp(-epoch / epochs))
    fig.add_subplot(122)
    plt.title('Radius')
    plt.plot(som._r * np.exp(-epoch * np.log(som._r) / epochs))
    plt.show()
```

## Кластеризация точек

[77]:

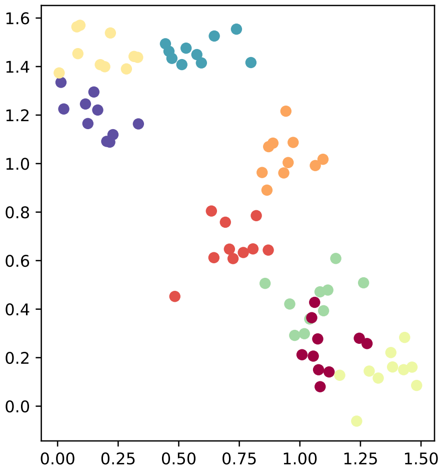
```python
def animate_points_and_nodes(som, points, nodes, lines=True, xlim=None, ylim=None, interval=100, video=False):
    def animate(i, ax):
        ax.clear()
        artists = [ax.scatter(points[:, 0], points[:, 1], c='tab:blue', animated=True)]
        artists.extend(ax.plot(nodes[i][:, 0], nodes[i][:, 1], c='red', marker='.', ls='', ms=10, animated=True))
        if lines:
            artists.append(ax.add_collection(LineCollection(nodes[i].reshape(som.height, som.width, -1), linewidth=1, colors=(1,0,0,0.5), animated=True)))
            artists.append(ax.add_collection(LineCollection(nodes[i].reshape(som.height, som.width, -1).transpose(1, 0, 2), linewidth=1, colors=(1,0,0,0.5), animated=True)))
        return artists

    fig = plt.figure()
    ax = fig.gca()
    ax.set(aspect='equal', xlim=xlim, ylim=ylim)
    anim = animation.FuncAnimation(fig, animate, frames=len(nodes), interval=interval, fargs=(ax, ), blit=False)
    plt.close()
    if video:
        return HTML(anim.to_html5_video())
    else:
        return HTML(anim.to_jshtml())

def plot_points_and_nodes(som, points, nodes, epochs, lines=True, interval=1):
    if isinstance(epochs, int):
        epochs = np.linspace(0, len(nodes)-1, epochs, dtype=int)
    else:
        epochs = np.array(epochs, dtype=int)

    w = min(5, int(np.ceil(np.sqrt(len(epochs)))))
    h = (len(epochs) - 1) // w + 1

    fig = plt.figure(figsize=(3 * w, 3 * h))
    for i, k in enumerate(epochs, 1):
        fig.add_subplot(h, w, i)
        ax = fig.gca()
        ax.get_xaxis().set_visible(False)
        ax.get_yaxis().set_visible(False)

        ax.set_title(f'Epoch {k*interval}', fontsize='medium')
        ax.scatter(points[:, 0], points[:, 1], c='tab:blue')
        ax.plot(nodes[k][:, 0], nodes[k][:, 1], c='red', marker='.', ls='', ms=10)
        if lines:
            ax.add_collection(LineCollection(nodes[k].reshape(som.height, som.width,␣
 ↪-1), linewidth=1, colors=(1,0,0,0.5)))
            ax.add_collection(LineCollection(nodes[k].reshape(som.height, som.width,␣
 ↪-1).transpose(1, 0, 2), linewidth=1, colors=(1,0,0,0.5)))

    fig.subplots_adjust(wspace=0.15, hspace=0.15)
    plt.show()

def plot_clusters(point, classes, som=None, nodes=True, lines=True):
    fig = plt.figure(figsize=(10,5))

    ax = fig.add_subplot(121)
    ax.set(aspect='equal')
    ax.scatter(points[:, 0], points[:, 1], c=classes, cmap='Spectral')

    if som is not None:
        ax.set_title('Actual clusters')
        pred = som.predict(points)
        ax = fig.add_subplot(122)
        ax.set_title('Predicted clusters')
        ax.set(aspect='equal')
        ax.scatter(points[:, 0], points[:, 1], c=pred, cmap='Spectral')
        if nodes:
            ax.plot(som.nodes[:, 0], som.nodes[:, 1], c='red', marker='.', ls='',␣
 ↪ms=10)
            if lines:
                ax.add_collection(LineCollection(som.nodes.reshape(som.height, som.
 ↪width, som.dim), linewidth=1, colors='red'))
                ax.add_collection(LineCollection(som.nodes.reshape(som.height, som.
 ↪width, som.dim).transpose(1, 0, 2), linewidth=1, colors=(1,0,0,0.5)))
    plt.show()

# Не используется, так как не сохраняет результаты после остановки ядра
def interact_plot_points_and_nodes(som, points, nodes, epochs, lines=True):
    @interact(epoch=IntSlider(0, 0, epochs, description='Epoch'))
    def plot_points_and_nodes(epoch):
        _, ax = plt.subplots()
        ax.set_aspect('equal')
        plt.scatter(points[:, 0], points[:, 1])
        plt.plot(nodes[epoch][:, 0], nodes[epoch][:, 1], c='red', marker='.', ls='',␣
 ↪ms=10)
        if lines:
            ax.add_collection(LineCollection(nodes[epoch].reshape(som.height, som.
 ↪width, som.dim), linewidth=1, colors='red'))
            ax.add_collection(LineCollection(nodes[epoch].reshape(som.height, som.
 ↪width, som.dim).transpose(1, 0, 2), linewidth=1, colors=(1,0,0,0.5)))
        plt.show()
```

[7]:
```
def generate_nodes(width, height, xlim=(0, 1), ylim=(0, 1)):
    x_linspace = np.linspace(xlim[0], xlim[1], height)
    y_linspace = np.linspace(ylim[0], ylim[1], width)
    nodes = np.stack(np.meshgrid(x_linspace, y_linspace, indexing='ij'), axis=-1).
↪reshape(-1, 2)
    return nodes
```

### Конфигурация $1 \times 8$

[97]:
```
n_clusters = 8
points_per_claster = 10
points, classes = make_blobs(n_clusters * points_per_claster, centers=n_clusters,␣
↪center_box=(0, 1.5), cluster_std=0.1)
```

[98]:
```
plot_clusters(points, classes)
```



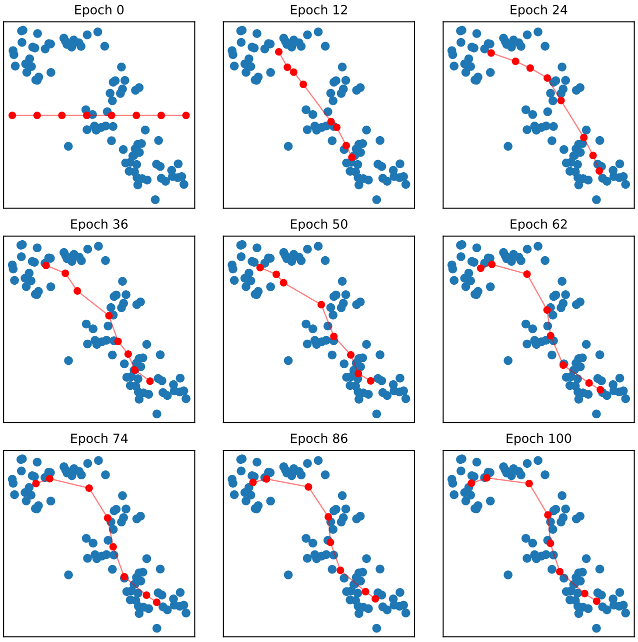
[99]:
```
start_nodes = generate_nodes(1, 8, (0, 1.5), (0.75, 0.75))
```

[100]:
```
som = SOM(1, 8, 2, nodes=start_nodes)

epochs = 100
nodes = som.fit(points, epochs, lr=0.2, interval=2)
```

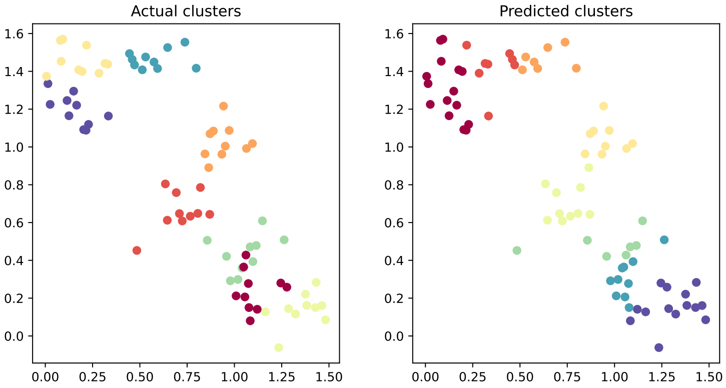
[103]:
```
animate_points_and_nodes(som, points, nodes, video=True)
```

[103]:
```
<IPython.core.display.HTML object>
```

[101]:
```
plot_points_and_nodes(som, points, nodes, 9, interval=2)
```



[102]:
```
plot_clusters(points, classes, som, nodes=False)
```

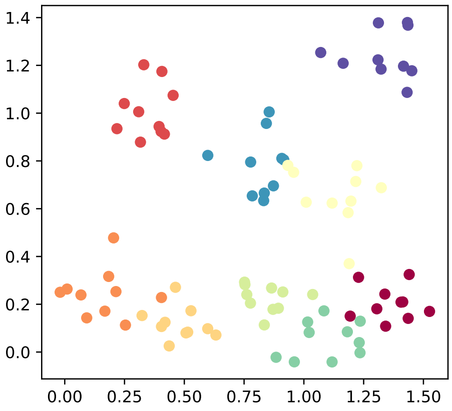


## Конфигурация $3 \times 3$

[104]:
```
n_clusters = 9
points_per_claster = 10
points, classes = make_blobs(n_clusters * points_per_claster, centers=n_clusters, center_box=(0, 1.5), cluster_std=0.1)
```

[105]:

```
plot_clusters(points, classes)
```



[106]:

```
start_nodes = generate_nodes(3, 3, (0.5, 1), (0.5, 1))
```

[107]:

```
som = SOM(3, 3, 2, nodes=start_nodes)

epochs = 100
nodes = som.fit(points, epochs, lr=0.1)
```

[110]:

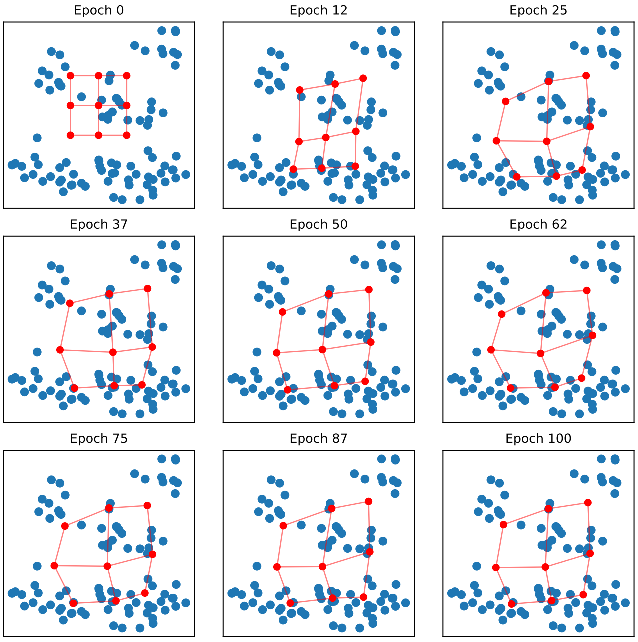
```
animate_points_and_nodes(som, points, nodes, video=True)
```

[110]:

```
<IPython.core.display.HTML object>
```

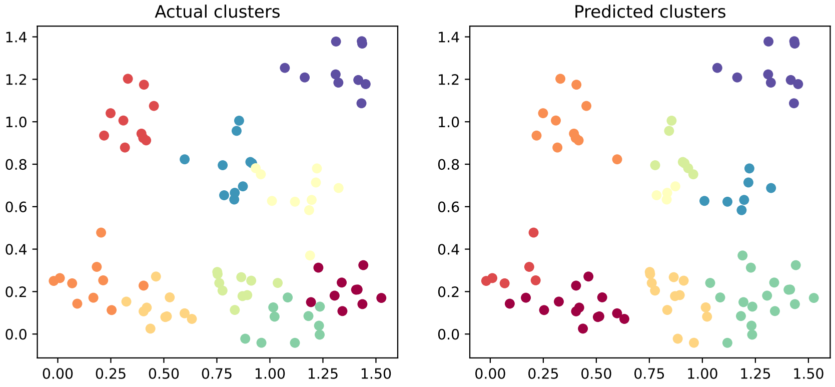
[108]:

```
plot_points_and_nodes(som, points, nodes, 9)
```



[109]:

```
plot_clusters(points, classes, som, nodes=False)
```



# Задача коммивояжера

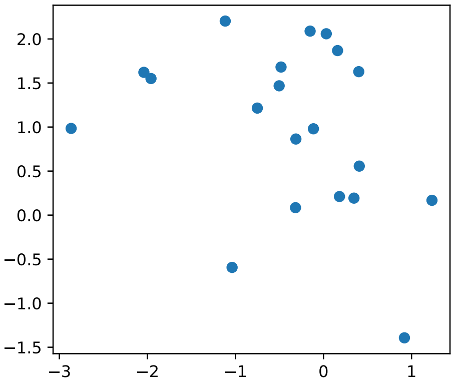
[113]:

```
cities, _ = make_blobs(20, centers=1, center_box=(-1.5, 1.5))
```

[114]:

```
_, ax = plt.subplots()
ax.set(aspect='equal')
```

```
plt.scatter(cities[:, 0], cities[:, 1])
plt.show()
```



```
[115]: start_nodes = generate_nodes(1, len(cities), (cities[:,0].min(), cities[:,0].max()),␣
        ↪(cities[:,1].mean(), cities[:,1].mean()))
```

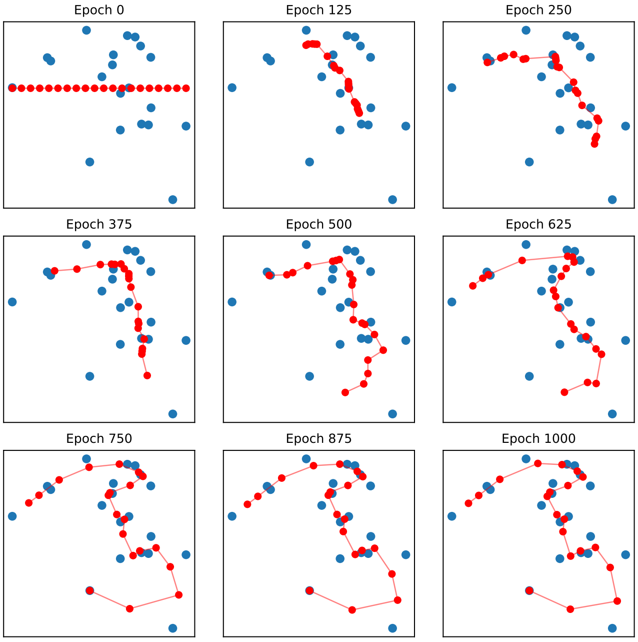
```
[116]: som = SOM(1, len(cities), 2, nodes=start_nodes)

       epochs = 1000
       nodes = som.fit(cities, epochs, lr=0.5, verbose=True)
```

```
Epochs: 100%|####################| 1000/1000 [00:03<00:00, 251.66it/s]
```

```
[121]: animate_points_and_nodes(som, cities, nodes, video=True)
```

```
[121]: <IPython.core.display.HTML object>
```

```
[118]: plot_points_and_nodes(som, cities, nodes, 9)
```



[126]:

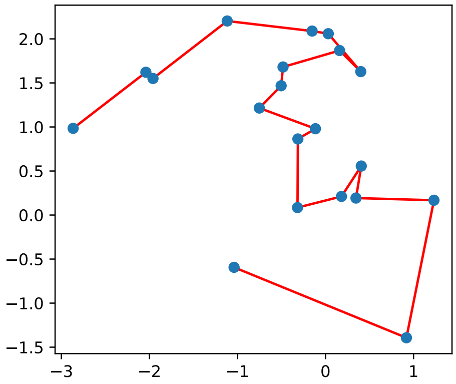
```
path = []
for node in som.nodes[::-1]:
    dist = np.sum((cities - node) ** 2, axis=1)
    dist[path] = dist.max()+1
    path.append(np.argmin(dist))
path
```

[126]:

```
[2, 5, 17, 9, 12, 8, 18, 16, 3, 1, 6, 19, 4, 10, 11, 0, 7, 14, 13, 15]
```

[127]:

```
_, ax = plt.subplots()
ax.set_aspect('equal')
plt.plot(cities[path, 0], cities[path, 1], c='red', zorder=0)
plt.scatter(cities[:, 0], cities[:, 1], zorder=1)
plt.show()
```



## Кластеризация цветов

[153]:
```
def animate_images(images, width, height, interval=75, video=False):
    def init():
        img.set_data(images[0].reshape(height, width, -1))
        return (img,)

    def animate(i):
        img.set_data(images[i].reshape(height, width, -1))
        return (img,)

    fig = plt.figure()
    ax = fig.gca()
    ax.get_xaxis().set_visible(False)
    ax.get_yaxis().set_visible(False)
    img = ax.imshow(images[0].reshape(height, width, -1))
    anim = animation.FuncAnimation(fig, animate, init_func=init,
                                   frames=len(images), interval=interval, blit=True)
    plt.close()
    if video:
        return HTML(anim.to_html5_video())
    else:
        return HTML(anim.to_jshtml())

def plot_images(images, width, height, epochs, interval=50, video=False):
    if isinstance(epochs, int):
        epochs = np.linspace(0, len(images)-1, epochs, dtype=int)
    else:
        epochs = np.array(epochs, dtype=int)

    w = min(5, int(np.ceil(np.sqrt(len(epochs)))))
    h = (len(epochs) - 1) // w + 1
    fig = plt.figure(figsize=(3 * w, 3 * h))
    for i, k in enumerate(epochs, 1):
        fig.add_subplot(h, w, i)
        ax = fig.gca()
        ax.get_xaxis().set_visible(False)
        ax.get_yaxis().set_visible(False)

        ax.set_title(f'Epoch {k}', fontsize='medium')
        ax.imshow(images[k].reshape(height, width, -1))

    fig.subplots_adjust(wspace=0.15, hspace=0.15)
    plt.show()
```

[154]:
```
def load_image(path, width=320, height=240):
    image = Image.open(path)
    image = image.convert('RGB')
    image = image.resize((width, height), Image.ANTIALIAS)
    image = np.asarray(image, dtype=np.float32)
    image /= 255
    return image
```

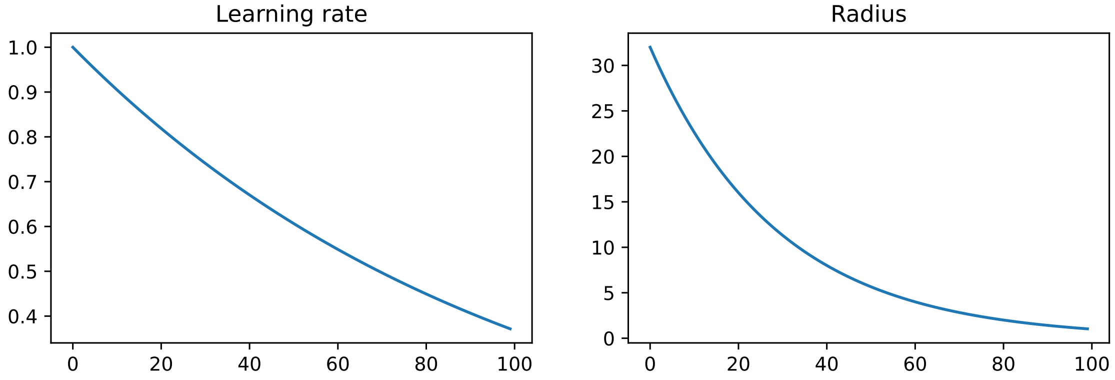
### Кластеризация по фиксированным цветам

[155]:
```
width = 64
height = 48
```

[156]:
```
data = np.array(((1, 0, 0), (0, 1, 0), (0, 0, 1), (1, 1, 0), (0, 1, 1)))
```

[157]:
```
som = SOM(width, height, 3)
```

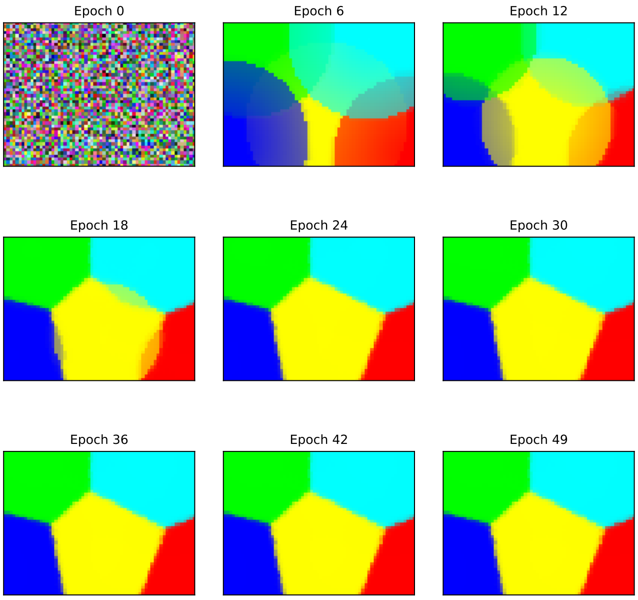
[158]:
```
epochs = 100
images = som.fit(data, epochs, lr=1, interval=1)
plot_parameters(som, epochs)
```



```
[160]: animate_images(images[:epochs//2], width, height, video=True)
```

```
[160]: <IPython.core.display.HTML object>
```

```
[161]: plot_images(images[:epochs//2], width, height, 9)
```



```
[174]: data = np.array(((1, 0, 0), (0, 1, 0), (0, 0, 1), (1, 1, 0), (0, 1, 1), (1, 0, 1),␣
        ↪(1, 1, 1), (0, 0, 0)))
```

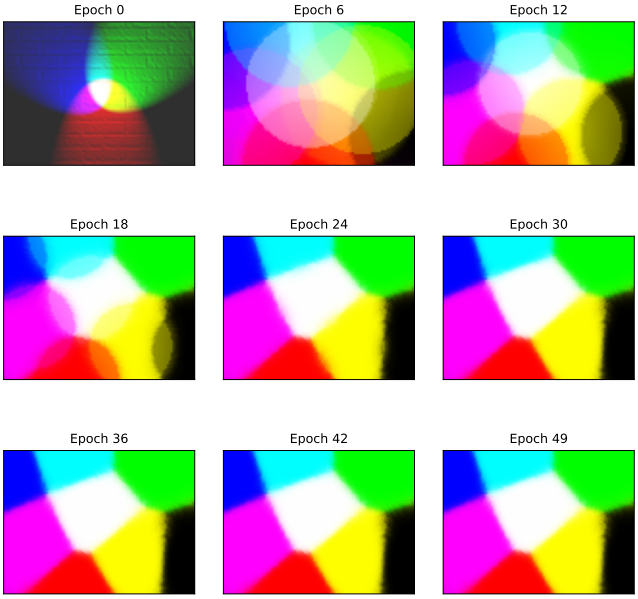
```
[175]: rgb = load_image('img/rgb.png', 100, 75)
```

```
[176]: som = SOM(rgb.shape[1], rgb.shape[0], rgb.shape[2], r=40, nodes=rgb)
       epochs = 100
       images = som.fit(data, epochs, lr=0.5)
```

```
[177]: animate_images(images[:epochs//2], rgb.shape[1], rgb.shape[0])
```

```
[177]: <IPython.core.display.HTML object>
```

```
[182]: plot_images(images[:epochs//2], rgb.shape[1], rgb.shape[0], 9)
```

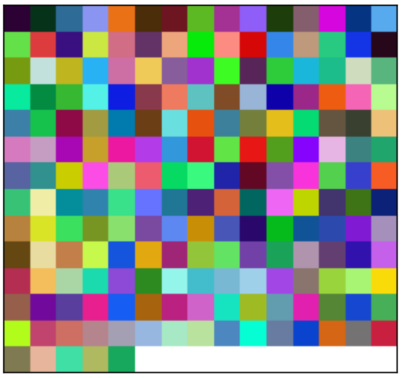


### Кластеризация по случайным цветам из изображения

[164]:
```
def colors_from_image(image, count):
    rng = np.random.default_rng()
    colors = rng.choice(image.reshape(-1, 3), count, replace=False, shuffle=True)
    return colors
```

[165]:
```
def plot_colors(colors):
    w = int(np.ceil(np.sqrt(len(colors))))
    h = (len(colors) - 1) // w + 1
    m = np.concatenate((colors, np.full((w * h - len(colors), 3), 1)))
    fig = plt.gcf()
    ax = fig.gca()
    ax.get_xaxis().set_visible(False)
    ax.get_yaxis().set_visible(False)
    ax.imshow(m.reshape(h, w, 3))
    plt.show()
```

[190]:
```
width = 120
height = 80
nodes = np.random.rand(height, width, 3)
colors = colors_from_image(nodes, 200)
plot_colors(colors)
```



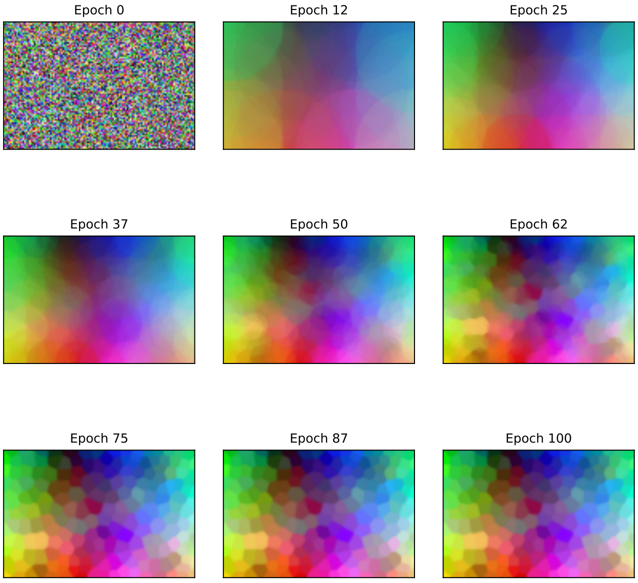
```
[191]: som = SOM(width, height, 3, nodes=nodes)

       epochs = 500
       images = som.fit(colors, epochs, lr=0.1, interval=5, verbose=True)
```

```
Epochs: 100%|######################| 500/500 [03:30<00:00,  2.37it/s]
```

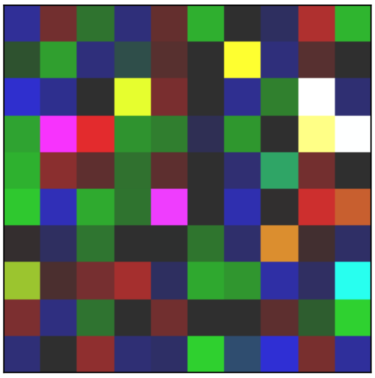
```
[192]: animate_images(images, width, height, interval=100)
```

```
[192]: <IPython.core.display.HTML object>
```

```
[193]: plot_images(images, width, height, 9)
```



```
[185]: colors = colors_from_image(rgb, 100)
       plot_colors(colors)
```



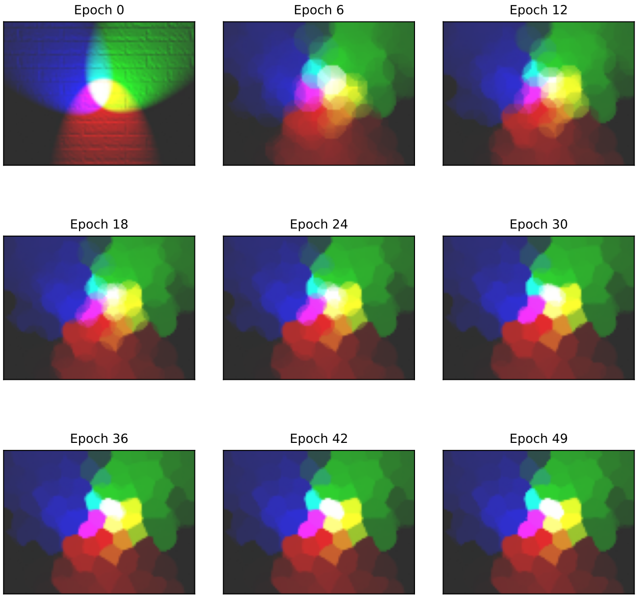
```
[187]: som = SOM(rgb.shape[1], rgb.shape[0], rgb.shape[2], r=np.sqrt(rgb.shape[1] * rgb.
        ↪shape[0] / len(colors)), nodes=rgb)

       epochs = 100
       images = som.fit(colors, epochs, lr=0.5, verbose=True)
```

```
Epochs: 100%|######################| 100/100 [00:18<00:00,  5.40it/s]
```

```
[ ]: animate_images(images[:len(images)//2], rgb.shape[1], rgb.shape[0], interval=100)
```

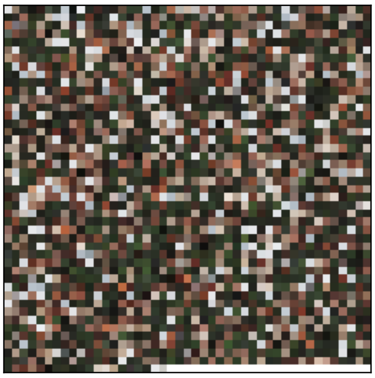
```
[ ]: <IPython.core.display.HTML object>
```

```
[189]: plot_images(images[:len(images)//2], rgb.shape[1], rgb.shape[0], 9)
```



```
[162]: image = load_image('img/town.png', 200, 150)
       height, width, _ = image.shape
```

```
[166]: colors = colors_from_image(image, 2000)
       plot_colors(colors)
```



```
[167]: som = SOM(width, height, 3, r=np.sqrt(width * height / len(colors)), nodes=image)
       epochs = 100
       images = som.fit(colors, epochs, lr=0.5, verbose=True)
```

```
Epochs: 100%|#######################| 100/100 [18:00<00:00, 10.81s/it]
```

```
[168]: animate_images(images[:len(images)//2], width, height, interval=100, video=True)
```

```
[168]: <IPython.core.display.HTML object>
```

```
[169]: plot_images(images[:len(images)//2], width, height, 9)
```