

# Clustering Part 2

```
In [ ]: import math
import random
import matplotlib
import numpy as np
import pandas as pd
import seaborn as sns
from tqdm.notebook import tqdm
import matplotlib.pyplot as plt
from sklearn.datasets import make_circles
matplotlib.rcParams['figure.figsize'] = (10, 7)
```

## DBSCAN Algorithm

DBSCAN(Density-Based Spatial Clustering of Applications with Noise) is a commonly used unsupervised clustering algorithm. DBSCAN does not need to specify the number of clusters. It can automatically detect the number of clusters based on your input data and parameters. More importantly, DBSCAN can find arbitrary shape clusters that k-means are not able to find.

## Algorithm:

- The algorithm proceeds by arbitrarily picking up a point in the dataset (until all points have been visited).
- If there are at least 'minPoint' points within a radius of ' $\epsilon$ ' to the point then we consider all these points to be part of the same cluster.
- The clusters are then expanded by recursively repeating the neighborhood calculation for each neighboring point

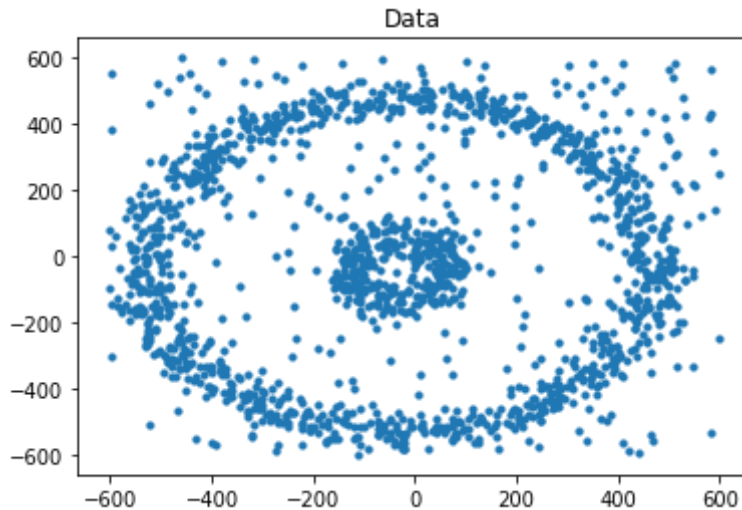
### A. Generate "N" spherical training data points.

```
In [ ]: ## write your code here
#### x = R * sin(theta) ; y = R * cos(theta) ; as x --> (1, n) ==> theta --> (0
def Circle(r,n=100):
    return [(math.cos(2*math.pi/n*x)*r+np.random.normal(-30,30),math.sin(2*math.pi/n
df=pd.DataFrame(Circle(500,1000))
df=df.append(Circle(100,300))
df=df.append([(np.random.randint(-600,600),np.random.randint(-600,600)) for i in ran

plt.scatter(df[0],df[1],s=10)
plt.title('Data')
plt.show()

data = df.to_numpy()
```

```
C:\Users\Shashank\AppData\Local\Temp\ipykernel_26768\3063699069.py:6: FutureWarning:
The frame.append method is deprecated and will be removed from pandas in a future ve
rsion. Use pandas.concat instead.
df=df.append(Circle(100,300))
C:\Users\Shashank\AppData\Local\Temp\ipykernel_26768\3063699069.py:7: FutureWarning:
The frame.append method is deprecated and will be removed from pandas in a future ve
rsion. Use pandas.concat instead.
df=df.append([(np.random.randint(-600,600),np.random.randint(-600,600)) for i in r
ange(300)])
```



### B. Perform DBSCAN Algorithm on the above generated data to obtain clusters

```
In [ ]: ## Write your code here
def plot_label(label, data, title):
    for c in np.unique(label):
        x_temp = data[label==c, 0]
        y_temp = data[label==c, 1]
        plt.scatter(x_temp, y_temp, c=np.random.rand(3,))
    plt.xlabel('x')
    plt.ylabel('y')
    plt.title(title)
    plt.show()

def neighbours(p, data, eps):
    neigs = []
    for i in range(len(data)):
        if np.linalg.norm(np.array(data[i]) - np.array(data[p]), ord=2) <= eps:
            neigs.append(i)
    return neigs

def expand_cluster(data, labels, p, neigs, cluster_id, eps, min_points):
    labels[p] = cluster_id
    i = 0
    while i < len(neigs):
        p_next = neigs[i]
        if labels[p_next] == -1: labels[p_next] = cluster_id
        elif labels[p_next] == 0:
            labels[p_next] = cluster_id
            p_next_neigs = neighbours(p_next, data, eps)
            if len(p_next_neigs) >= min_points:
                neigs += p_next_neigs
        i += 1

def DB_SCAN(eps, min_points, d):
    data = d.tolist()
    labels = [0] * len(data)
```

```

cluster_id = 0
for p in tqdm(range(len(data))):
    if labels[p]: continue
    neigs = neighbours(p, data, eps)
    if len(neigs) < min_points:
        labels[p] = -1
    else:
        cluster_id += 1
        expand_cluster(data, labels, p, neigs, cluster_id, eps, min_points)

data = np.array(data)
labels = np.array(labels)
title = f'epsilon = {eps}, min_points = {min_points}, clusters = {cluster_id}'
plot_label(labels, data, title)
return labels

labels = DB_SCAN(40, 6, data)

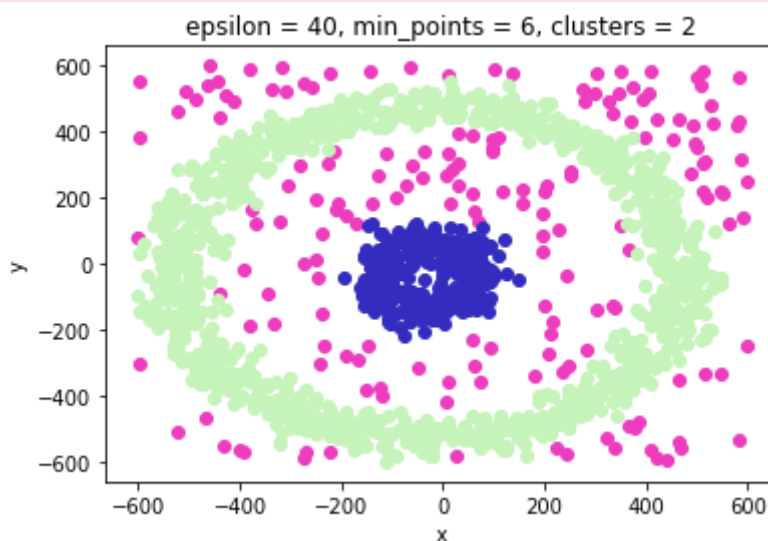
```

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### C. Experiment by varying the number of min points and epsilon radius and plot your observations

```

In [ ]: ## write your code here
labels = DB_SCAN(30, 7, data)
labels = DB_SCAN(50, 4, data)
labels = DB_SCAN(100, 10, data)

```

0%| | 0/1600 [00:00<?, ?it/s]

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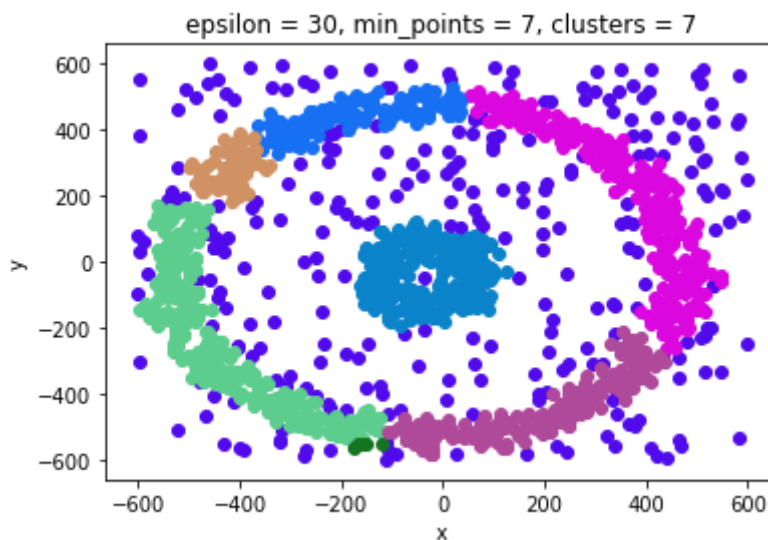
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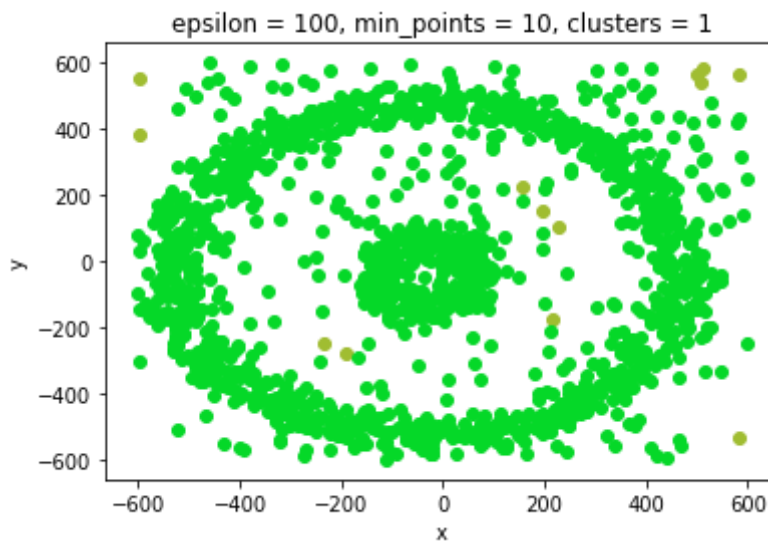


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#### D. Compare your model with the built in DBSCAN in Sci-kit Learn. Also compare you results with GMM and the K-means Algorithm

```
In [ ]: from sklearn.cluster import DBSCAN
        ## write your code here

        labels = DBSCAN(eps=40, min_samples=7).fit(data).labels_
        plot_label(labels, data, 'Sklearn DBSCAN')

        #####
        from sklearn.mixture import GaussianMixture
        ## write your code here
        labels = GaussianMixture(n_components=2, random_state=0).fit(data).predict(data)
        plot_label(labels, data, 'Sklearn GMM')

        #####
        from sklearn.cluster import KMeans
        ## write your code here
        labels = KMeans(n_clusters=2, random_state=0).fit(data).labels_
        plot_label(labels, data, 'Sklearn KMeans')
```

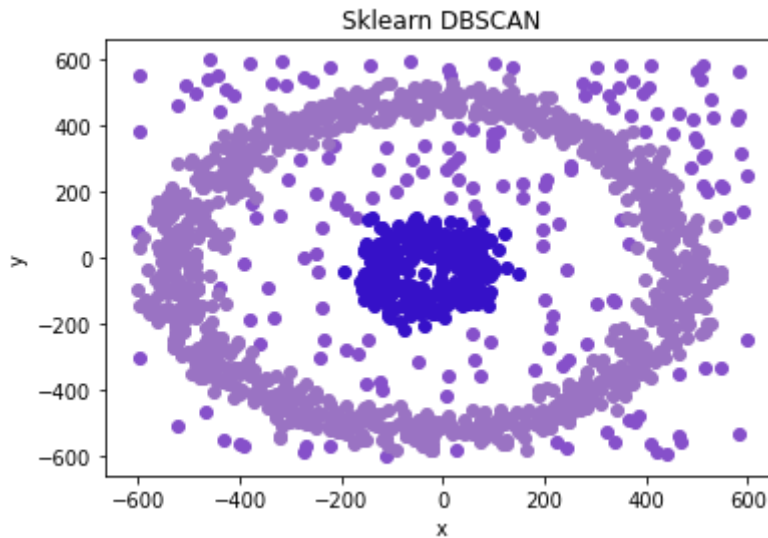
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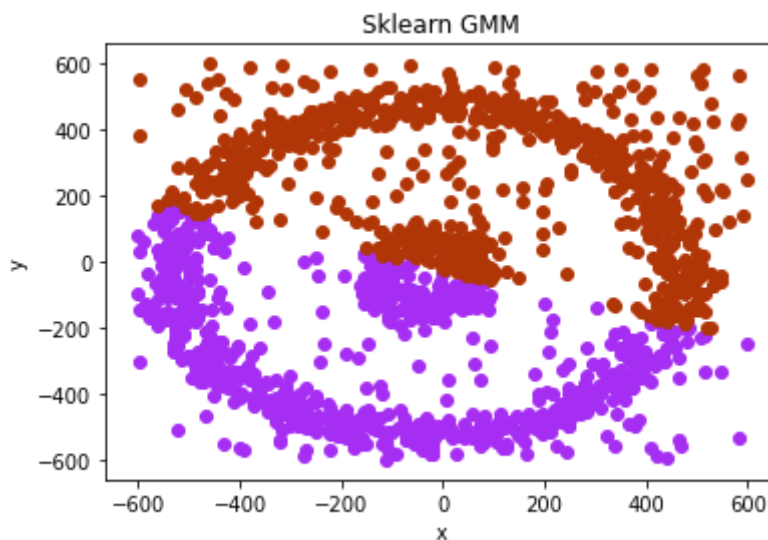
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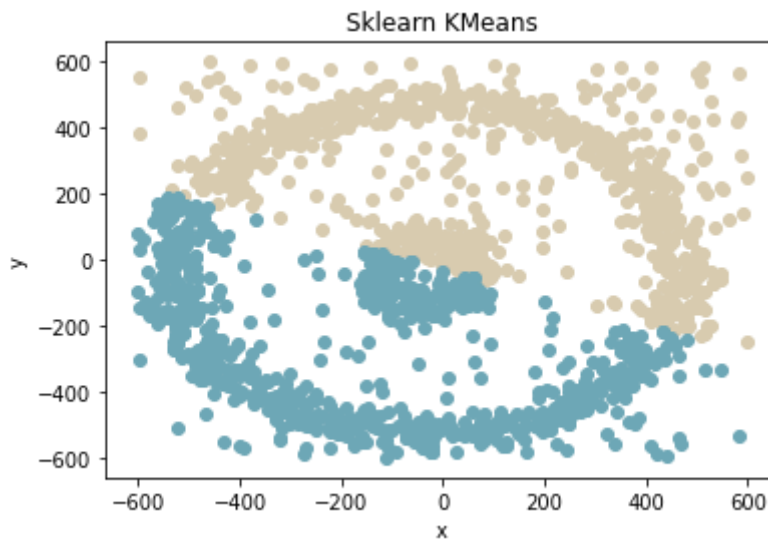
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## Fuzzy C-Means Based clustering

1. Randomly initialize the centroids and clusters K, and compute the probability that each data point  $x_i$  is a member of a given cluster k,  $P(\text{point } x_i \text{ has label } k | x_i, k)$ .
2. Iteration: Recalculate the centroids of the clusters as the weighted centroid given the probabilities of membership of all data points  $x_i$ :

$$\mu_k(n+1) = \frac{\sum_{x_i \in k} x_i * P(\mu_k | x_i)^b}{\sum_{x_i \in k} P(\mu_k | x_i)^b}$$

1. Implement it on the data for which Kmeans was implemented.

```
In [ ]: class FuzzyC:
    # works for only 2D
    """ TODO :
        1 ) first find c centers randomly and calc dist matr and membership matr
        2 ) find new centers
        3 ) find dist matrix
        4 ) find new membership matrix
        5 ) Do it till convergence
    """
    def __init__(self, clus, d):
        self.no_clusters = clus
        self.data = d
        self.M = data.shape[0]
        self.means = np.array(random.sample(data.tolist(), self.no_clusters))
        self.cols = np.random.rand(self.no_clusters, 3)
        self.labels = np.zeros(self.M,)

    def get_dist_matrix(self):
        dist_matrix = np.zeros((self.M, self.no_clusters))
        for i in range(self.M):
            for j in range(self.no_clusters):
                tot_den = 0
                for k in range(self.no_clusters):
                    num = np.linalg.norm(data[i]-self.means[j], ord=2)
                    den = np.linalg.norm(data[i]-self.means[k], ord=2)+(1e-15)
                    tot_den += (num/den)**2
                dist_matrix[i][j] = 1/(tot_den+1e-15)
```



```

        return dist_matrix

    def get_new_mean(self, dist_matrix):
        label = self.get_labels(dist_matrix)
        new_means = np.zeros((self.no_clusters, 2))
        for j in range(self.no_clusters):
            sum = 0
            for i in range(self.M):
                new_means[j] += self.data[i]*(dist_matrix[i][j]**2)
                sum += dist_matrix[i][j]**2
            new_means[j] /= sum+1e-15
        return new_means

    def get_cost(self, dist_matrix):
        cost = 0
        for k in range(self.no_clusters):
            for i in range(self.M):
                cost += dist_matrix[i][k] * np.linalg.norm(data[i]-self.means[k], or
        return cost / (self.M * self.no_clusters)

    def get_labels(self, dist_matrix):
        return np.argmax(dist_matrix, axis=1)

    def doFCM(self):
        present_cost = float('inf')
        delta = present_cost
        it = 1
        while(delta>=1e-15):
            print(self.means)
            dist_mat = self.get_dist_matrix()
            self.means = self.get_new_mean(dist_mat)
            temp_cost = self.get_cost(dist_mat)
            delta = abs(present_cost-temp_cost)
            present_cost = temp_cost
            self.labels = self.get_labels(dist_mat)
            title = f'Iteration: {it}, delta: {delta}'
            self.showGraph(title)
            it+=1

    def showGraph(self, title):
        plt.scatter(self.means[:, 0], self.means[:, 1], c='black', marker='x')
        for k in range(self.no_clusters):
            x_temp = data[self.labels==k, 0]
            y_temp = data[self.labels==k, 1]
            plt.scatter(x_temp, y_temp, c=self.cols[k], marker='+')
        plt.xlabel('x')
        plt.ylabel('y')
        plt.title(title)
        plt.show()

K = 4

data = []
means = [(0.5, 0), (5, 5), (5, 1), (10, 1.5)]

for i in range(K):
    d = np.random.multivariate_normal(mean=means[i], cov=np.identity(2), size=100)
    data.append(d)

data = np.vstack(data)

# write your code here
fcm = FuzzyC(4, data)

```

```
fcm.doFCM()
fcm.showGraph("Final Clustering")
```

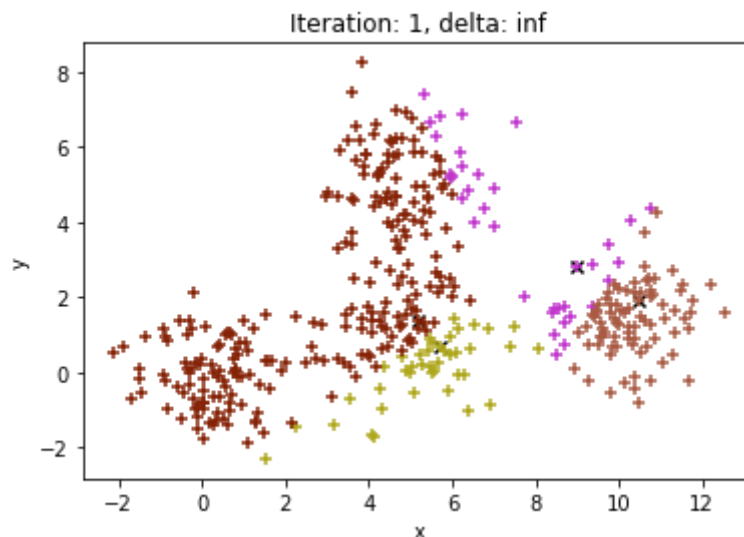
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```
[[ 5.72035875  0.65426631]
 [ 8.98228383  2.8174128 ]
 [10.4702039  1.93149102]
 [ 5.18426374  1.38046469]]
```



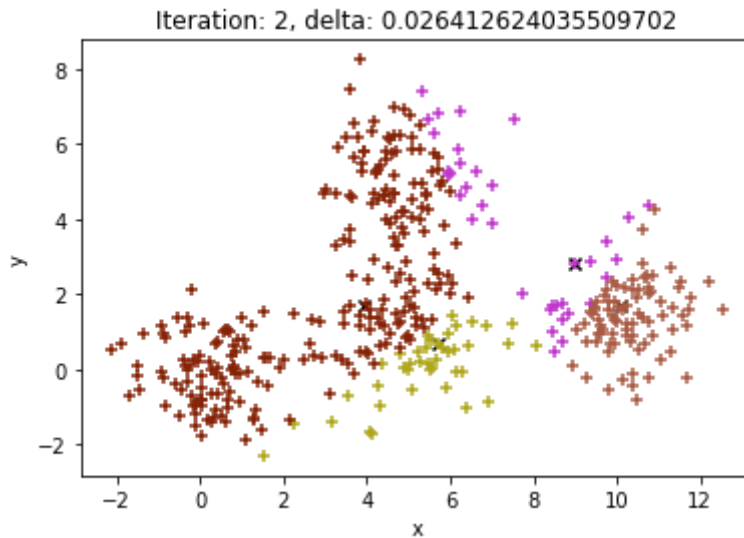
```
[[ 5.72035875  0.65426631]
 [ 8.98228383  2.8174128 ]
 [10.4702039  1.93149102]
 [ 5.18426374  1.38046469]]
```

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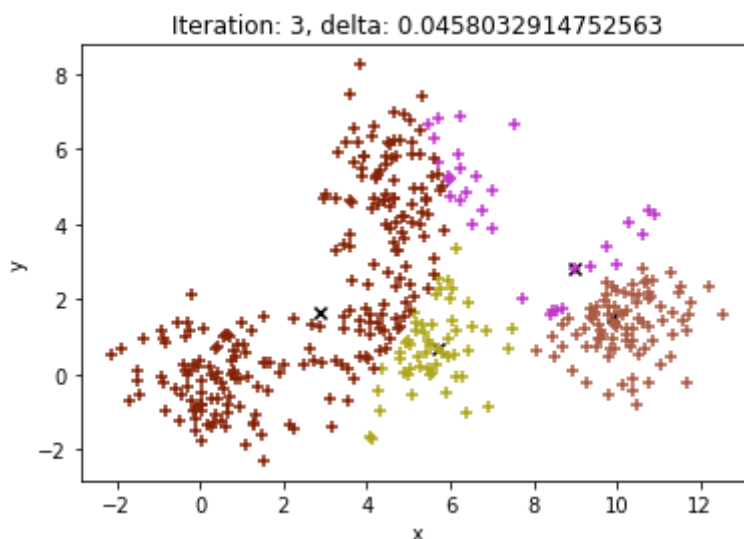
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```
[[ 5.72035875  0.65426631]
 [ 8.98228383  2.8174128 ]
 [10.07623905  1.68171851]
 [ 3.95221593  1.67812685]]
```



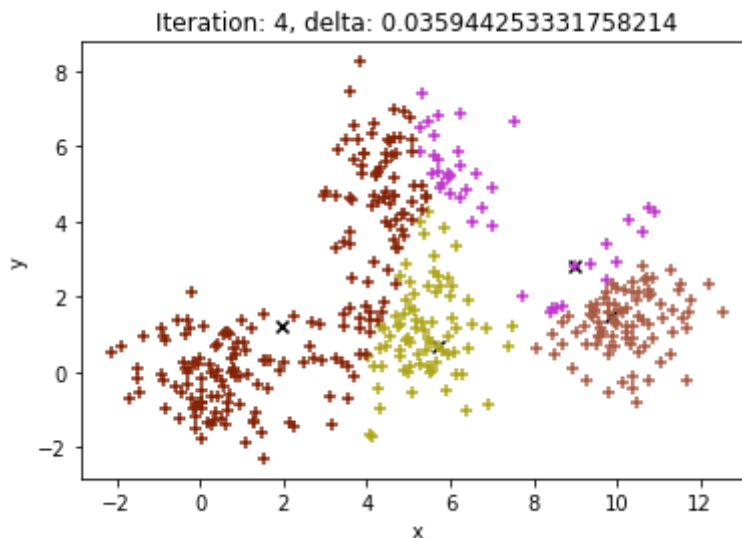
```
[[5.72035875 0.65426631]
 [8.98228383 2.8174128 ]
 [9.92089512 1.53344824]
 [2.85512617 1.65290238]]
```

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```
[[5.72035875 0.65426631]
 [8.98228383 2.8174128 ]
 [9.8707813  1.49171328]
 [1.96555914 1.20637571]]
```

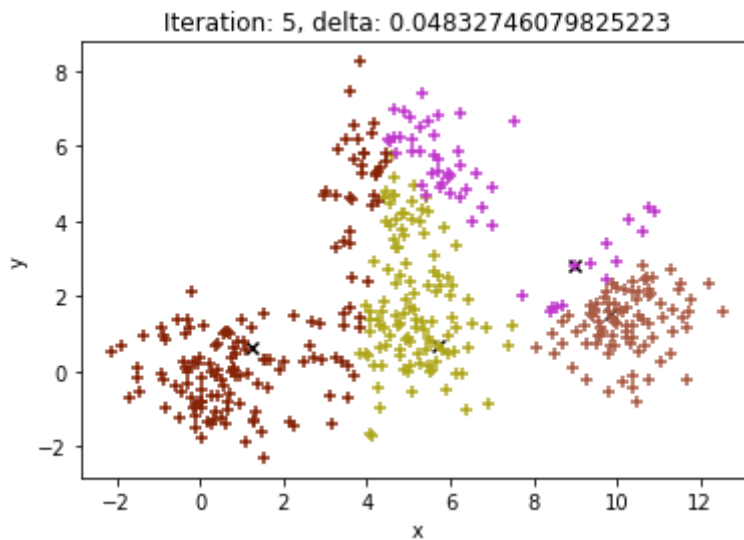
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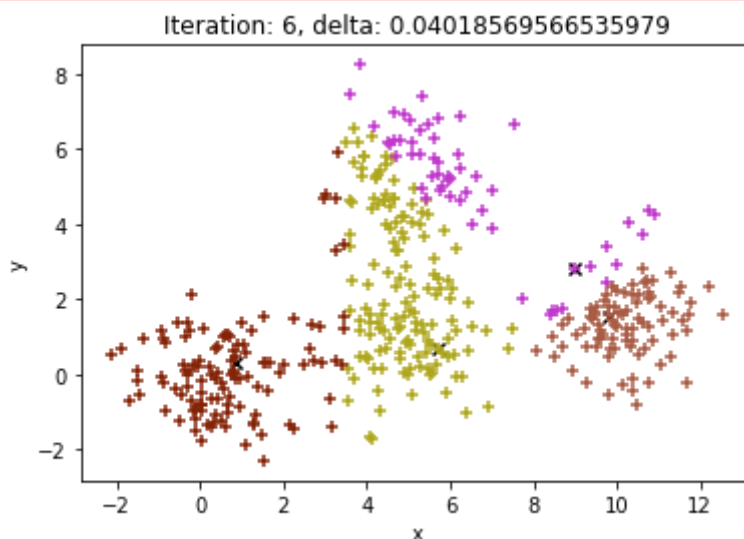
```
[[5.72035875 0.65426631]
 [8.98228383 2.8174128 ]
 [9.84455927 1.51217609]
 [1.24602356 0.6504245 ]]
```

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\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.



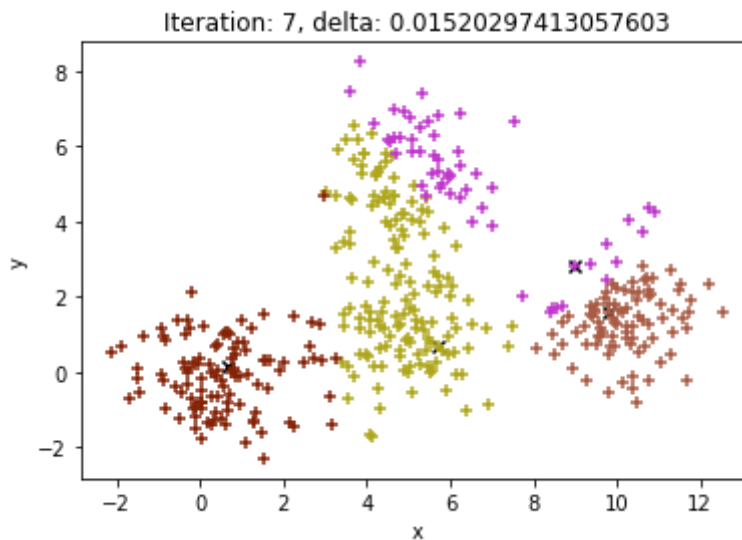
```
[[5.72035875 0.65426631]
 [8.98228383 2.8174128 ]
 [9.81407354 1.55094301]
 [0.82856803 0.3071851 ]]
```

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.



```
[[5.72035875 0.65426631]
 [8.98228383 2.8174128 ]
 [9.78143171 1.5822272 ]
 [0.65573534 0.16738889]]
```

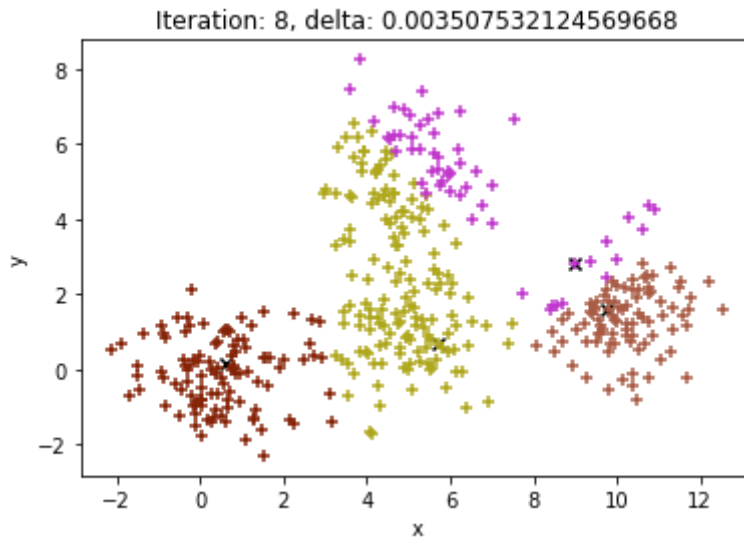
\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.



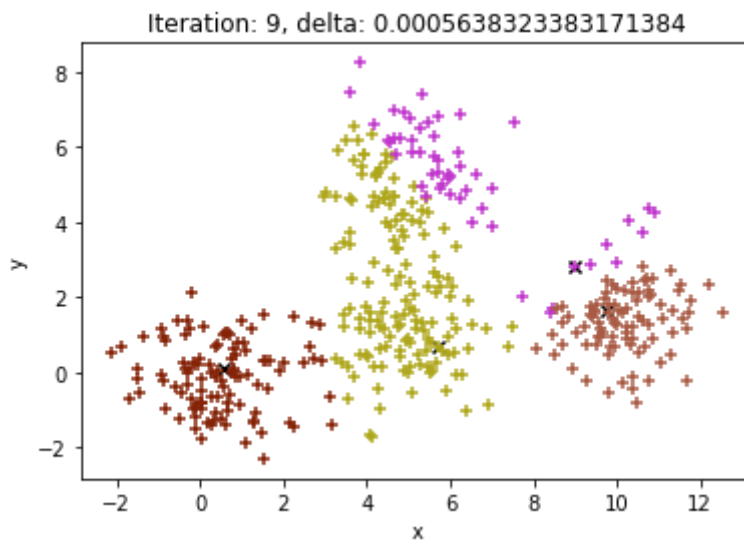
\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

```
[[5.72035875 0.65426631]
 [8.98228383 2.8174128 ]
 [9.75478109 1.60207176]
 [0.59517124 0.11951615]]
```



```
[[5.72035875 0.65426631]
 [8.98228383 2.8174128 ]
 [9.73585737 1.61367048]
 [0.57501871 0.10380209]]
```

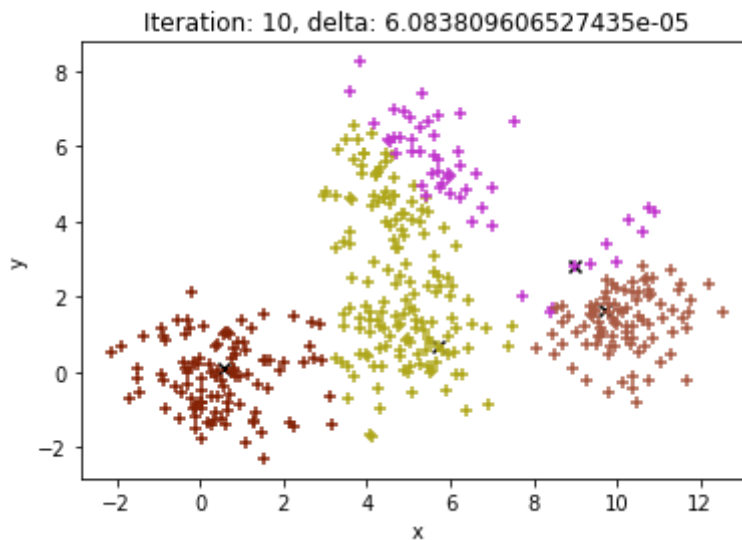


\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.



```
[[5.72035875 0.65426631]
 [8.98228383 2.8174128 ]
 [9.72323754 1.62029861]
 [0.56828378 0.09853613]]
```

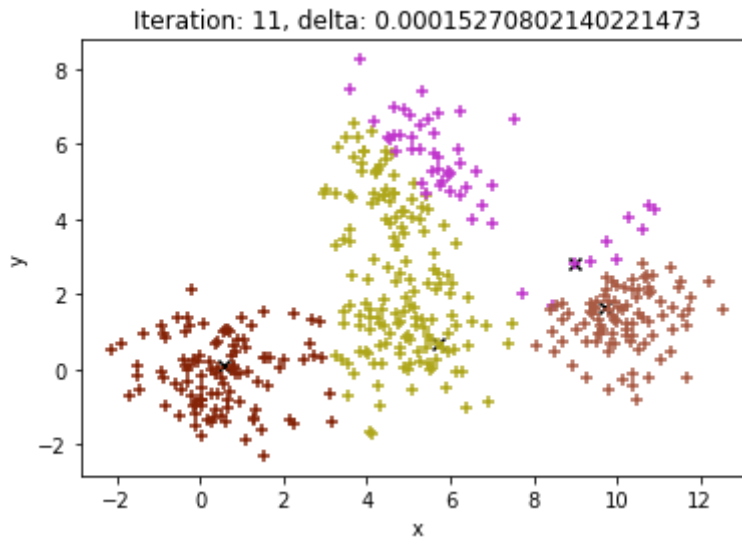
\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.



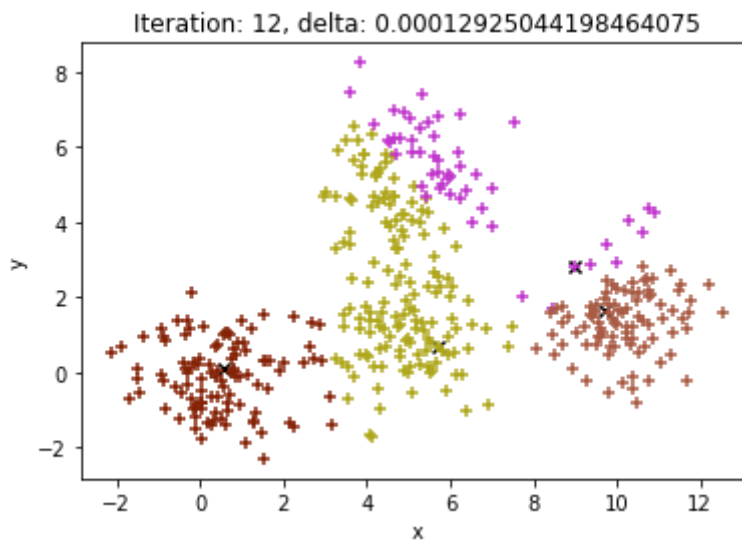
\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

```
[[5.72035875 0.65426631]
 [8.98228383 2.8174128 ]
 [9.71506037 1.62409613]
 [0.56593708 0.09666044]]
```



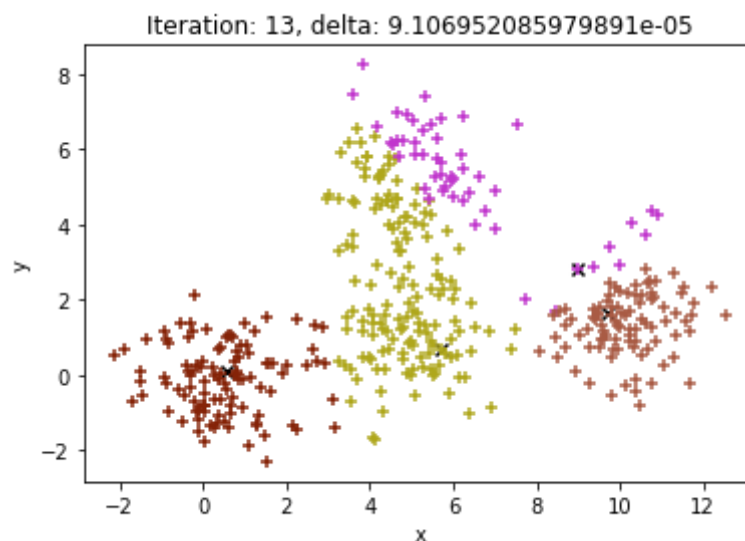
\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

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\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

```
[[5.72035875 0.65426631]
 [8.98228383 2.8174128 ]
 [9.70983444 1.62630038]
 [0.56505357 0.09592549]]
```



\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

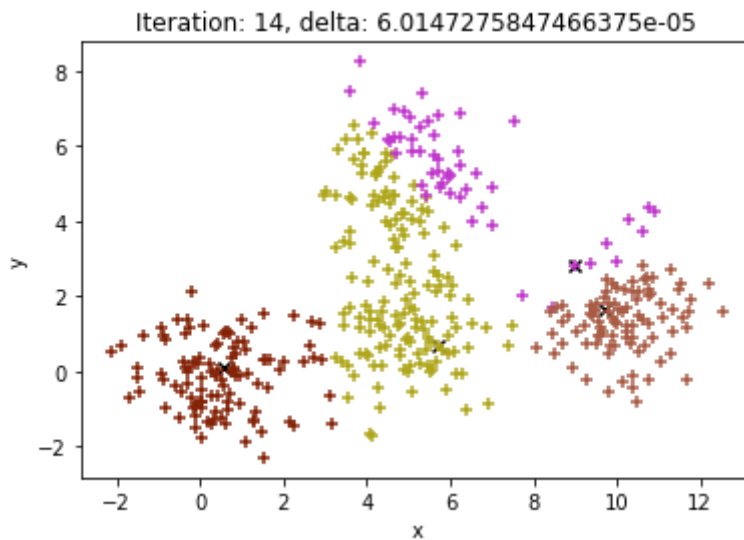
\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

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\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

```
[[5.72035875 0.65426631]
 [8.98228383 2.8174128 ]
 [9.70651763 1.62760054]
 [0.56468284 0.09560143]]
```



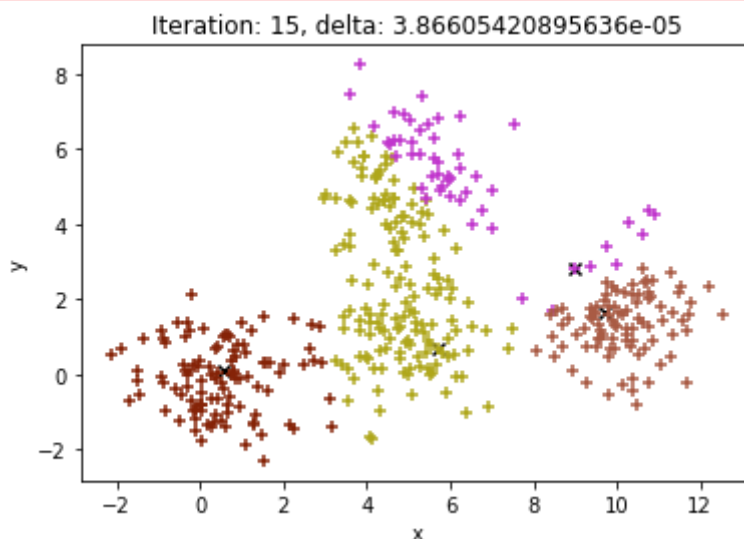
```
[[5.72035875 0.65426631]
 [8.98228383 2.8174128 ]
 [9.70442012 1.62837926]
 [0.56450738 0.09544079]]
```

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.



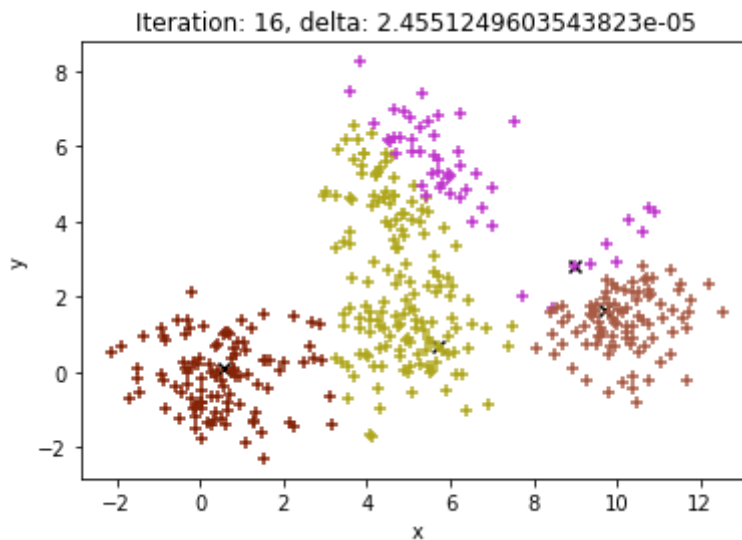
```
[[5.72035875 0.65426631]
 [8.98228383 2.8174128 ]
 [9.70309632 1.62885176]
 [0.56441507 0.09535336]]
```

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

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\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.



```
[[5.72035875 0.65426631]
 [8.98228383 2.8174128 ]
 [9.70226178 1.6291414 ]
 [0.56436267 0.09530269]]
```

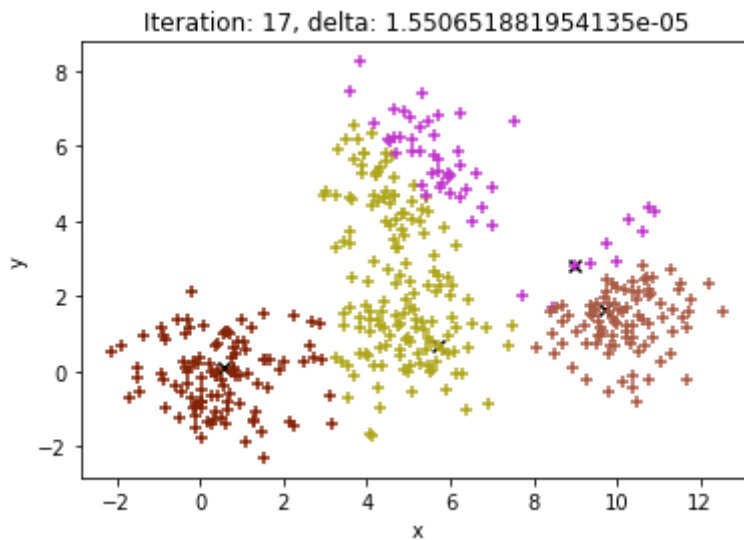
\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.



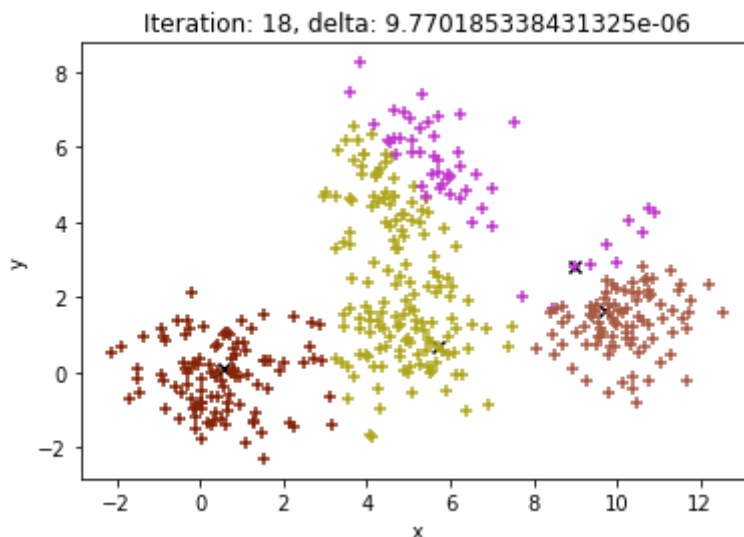
```
[[5.72035875 0.65426631]
 [8.98228383 2.8174128 ]
 [9.70173604 1.62932032]
 [0.5643315  0.09527221]]
```

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.



```
[[5.72035875 0.65426631]
 [8.98228383 2.8174128 ]
 [9.70140498 1.62943145]
 [0.56431246 0.09525349]]
```

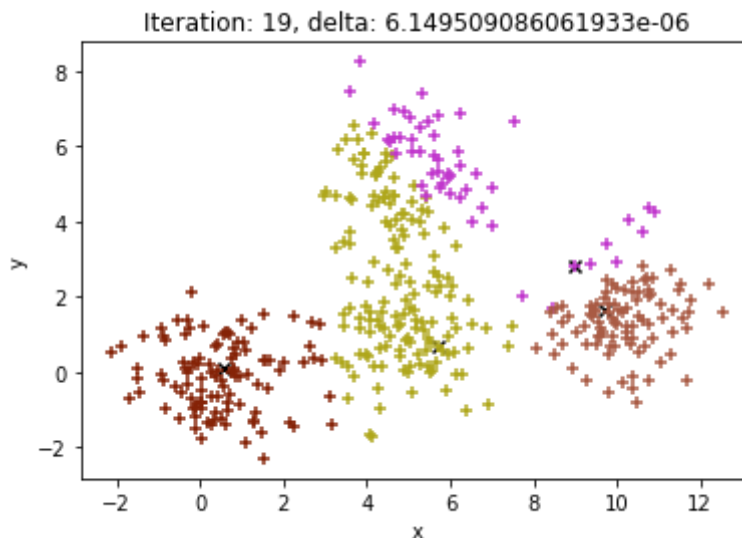


\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.



```
[[5.72035875 0.65426631]
 [8.98228383 2.8174128 ]
 [9.70119657 1.62950075]
 [0.56430067 0.09524186]]
```

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

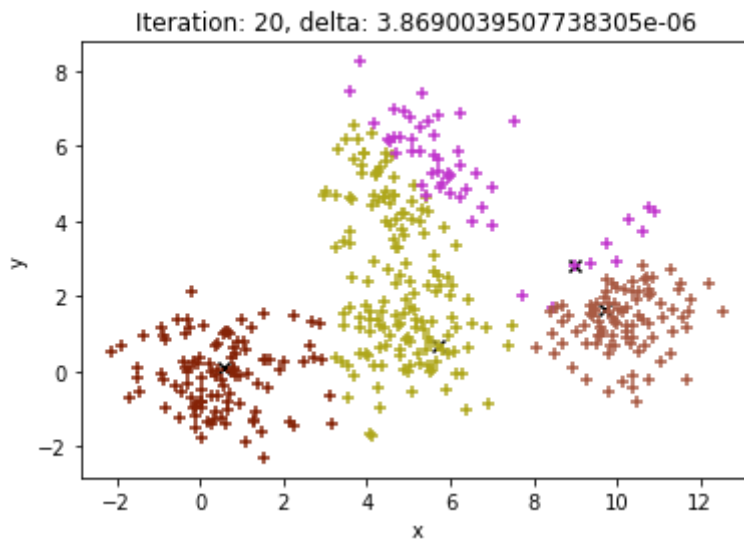
\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.





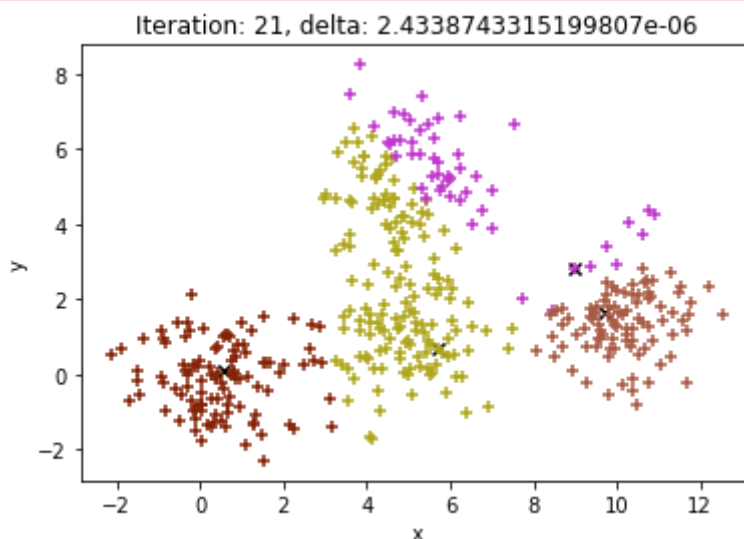
```
[[5.72035875 0.65426631]
 [8.98228383 2.8174128 ]
 [9.7010654  1.62954409]
 [0.56429331 0.09523459]]
```

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.



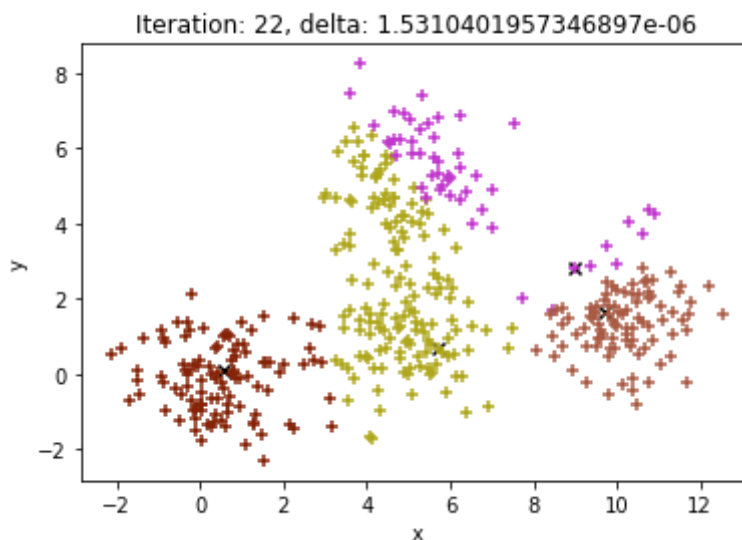
```
[[5.72035875 0.65426631]
 [8.98228383 2.8174128 ]
 [9.70098284 1.62957125]
 [0.5642887  0.09523004]]
```

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.



```
[[5.72035875 0.65426631]
 [8.98228383 2.8174128 ]
 [9.7009309  1.62958828]
 [0.5642858  0.09522718]]
```

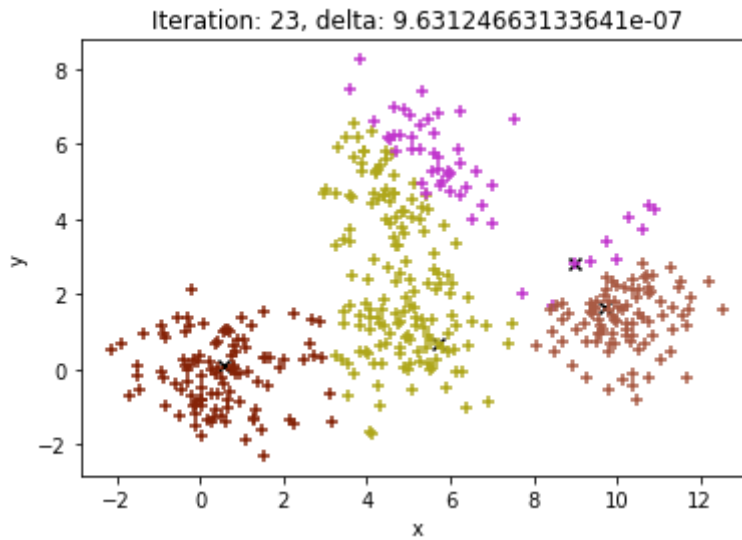
\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.



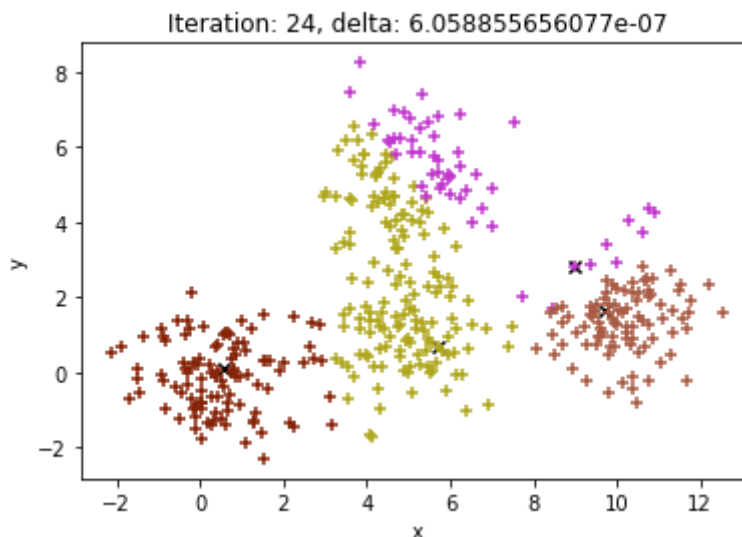
```
[[5.72035875 0.65426631]
 [8.98228383 2.8174128 ]
 [9.70089821 1.62959898]
 [0.56428398 0.09522539]]
```

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.



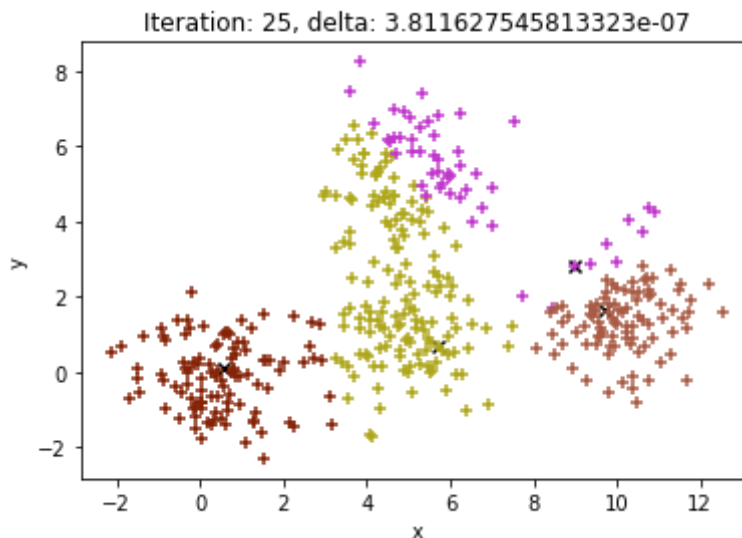
```
[[5.72035875 0.65426631]
 [8.98228383 2.8174128 ]
 [9.70087764 1.6296057 ]
 [0.56428284 0.09522426]]
```

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.



```
[[5.72035875 0.65426631]
 [8.98228383 2.8174128 ]
 [9.7008647  1.62960993]
 [0.56428212 0.09522355]]
```

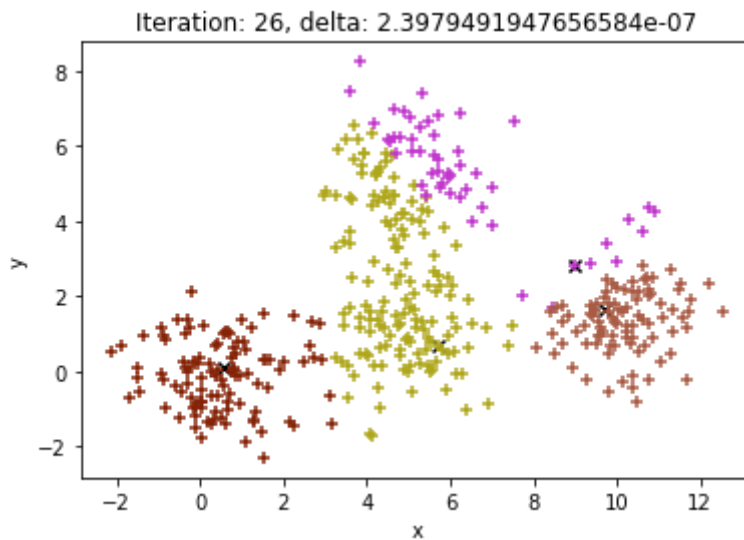
\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.



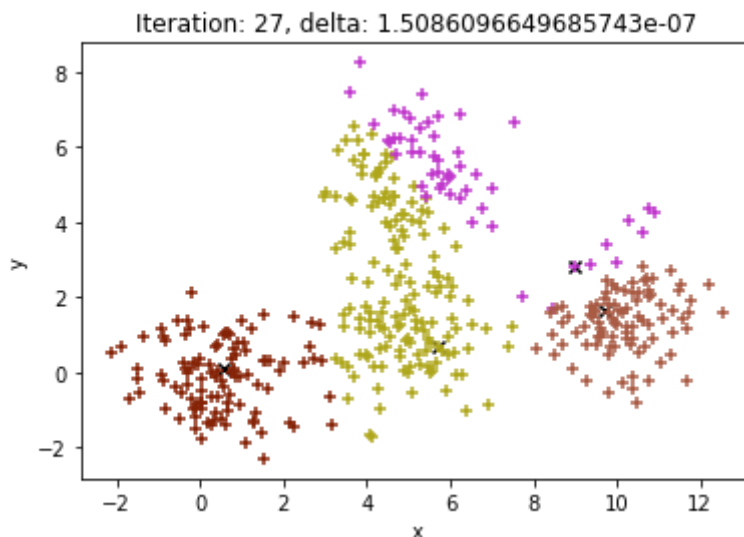
```
[[5.72035875 0.65426631]
 [8.98228383 2.8174128 ]
 [9.70085656 1.62961258]
 [0.56428167 0.0952231 ]]
```

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.



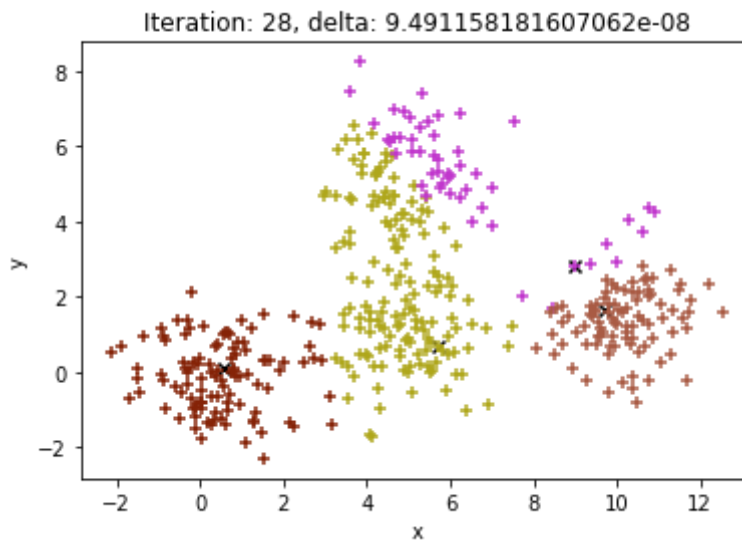
```
[[5.72035875 0.65426631]
 [8.98228383 2.8174128 ]
 [9.70085143 1.62961425]
 [0.56428138 0.09522282]]
```

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.



\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

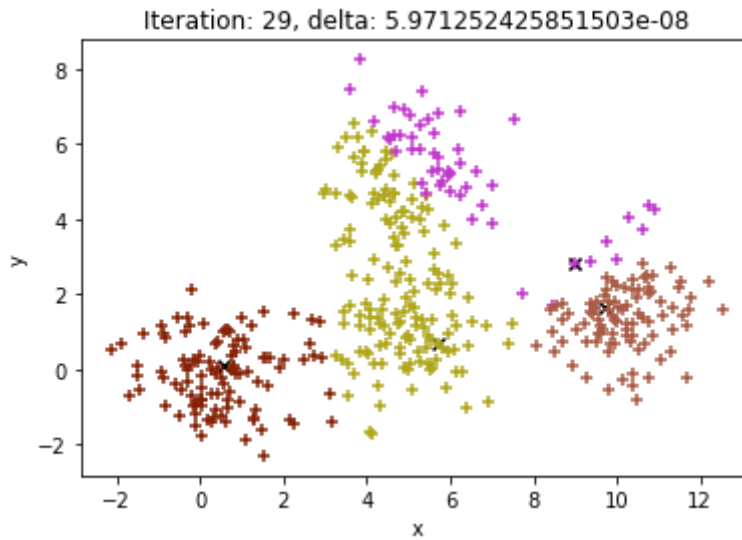
\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

```
[[5.72035875 0.65426631]
 [8.98228383 2.8174128 ]
 [9.70084821 1.6296153 ]
 [0.56428121 0.09522264]]
```



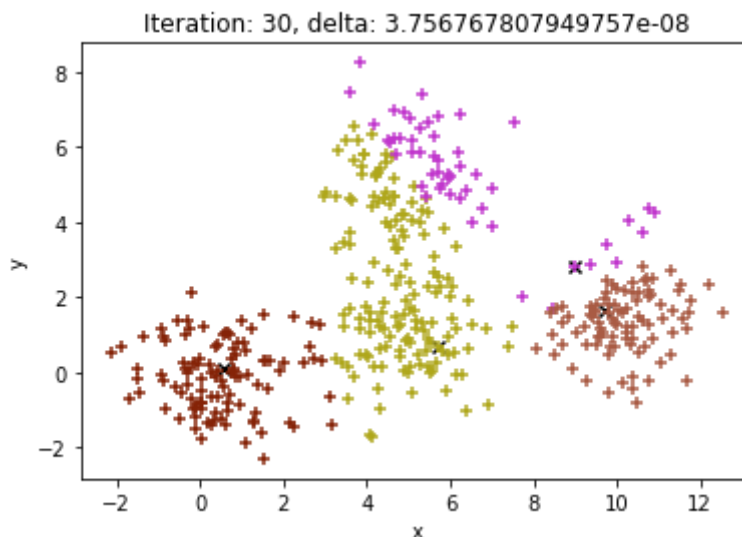
```
[[5.72035875 0.65426631]
 [8.98228383 2.8174128 ]
 [9.70084618 1.62961597]
 [0.56428109 0.09522253]]
```

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.





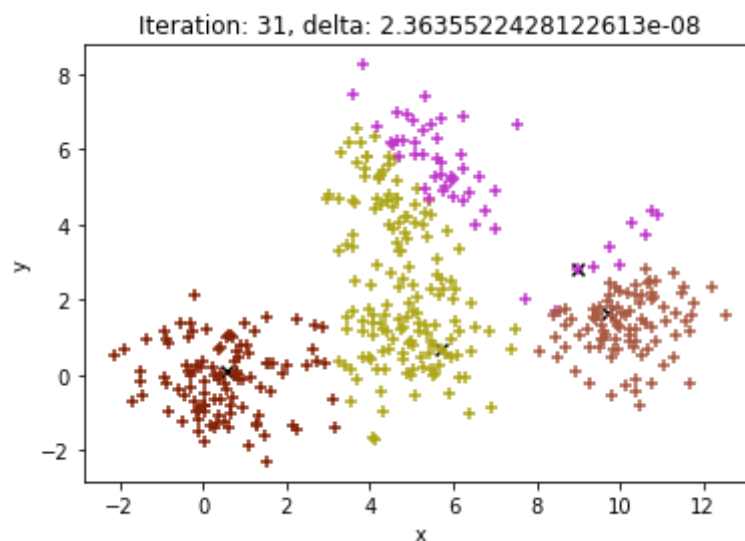
\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

```
[[5.72035875 0.65426631]
 [8.98228383 2.8174128 ]
 [9.70084491 1.62961638]
 [0.56428102 0.09522246]]
```



```
[[5.72035875 0.65426631]
 [8.98228383 2.8174128 ]
 [9.7008441  1.62961664]
 [0.56428098 0.09522242]]
```

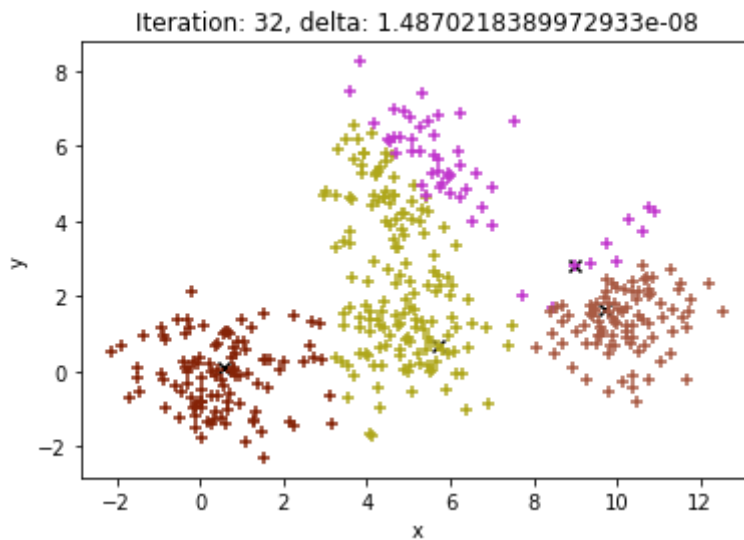
\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

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\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.



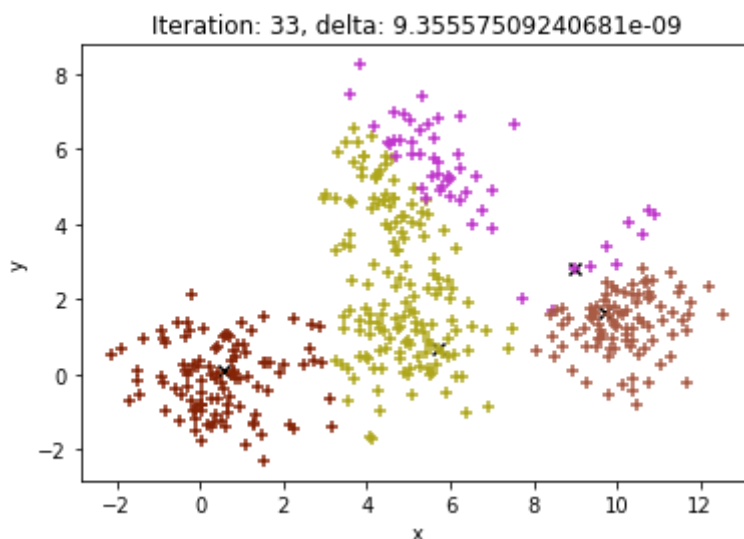
\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

```
[[5.72035875 0.65426631]
 [8.98228383 2.8174128 ]
 [9.7008436  1.62961681]
 [0.56428095 0.09522239]]
```



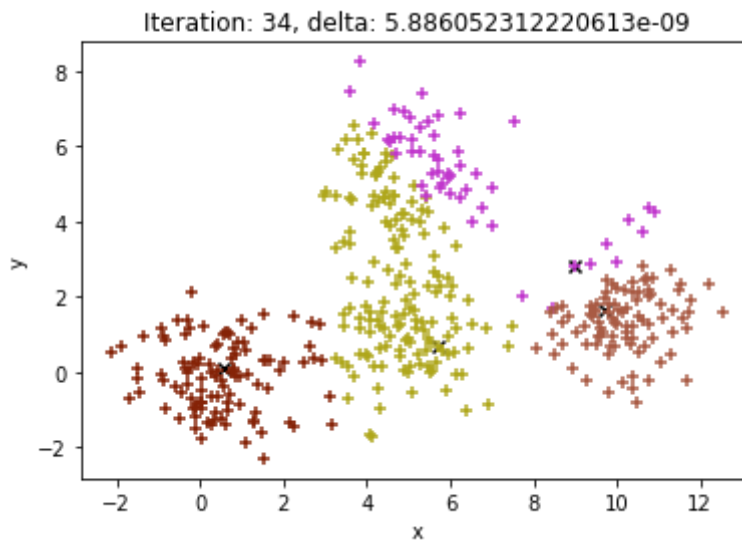
```
[[5.72035875 0.65426631]
 [8.98228383 2.8174128 ]
 [9.70084328 1.62961691]
 [0.56428093 0.09522237]]
```

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.



\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

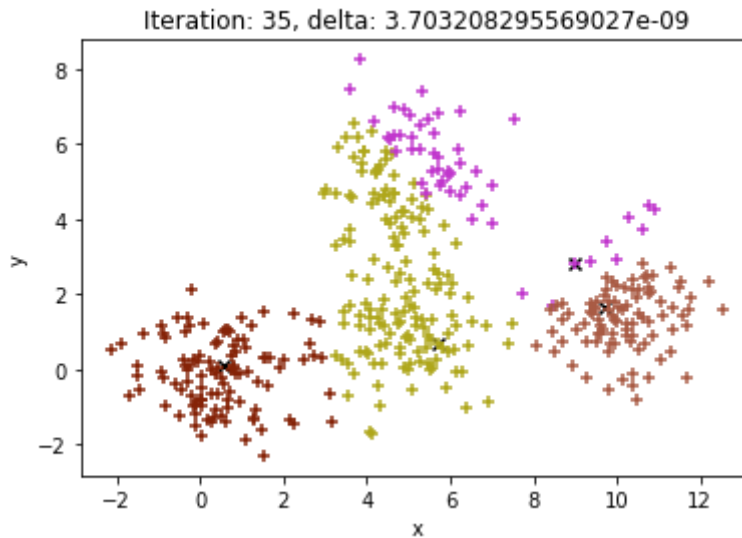
\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

```
[[5.72035875 0.65426631]
 [8.98228383 2.8174128 ]
 [9.70084308 1.62961698]
 [0.56428092 0.09522236]]
```



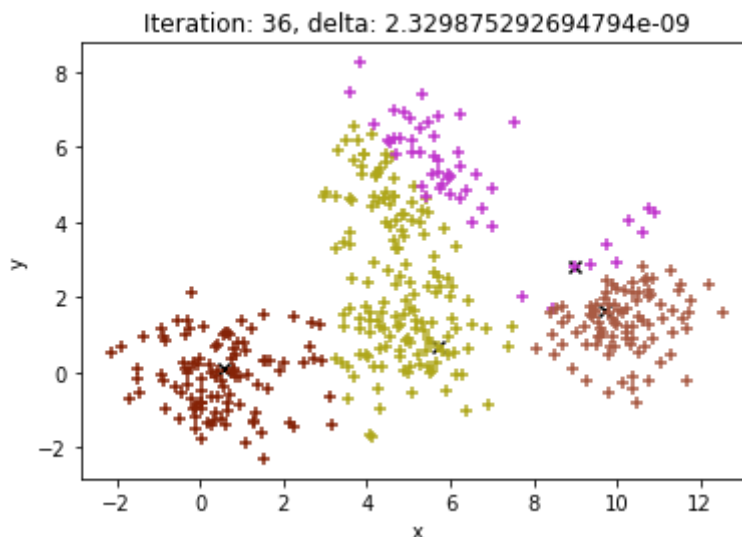
```
[[5.72035875 0.65426631]
 [8.98228383 2.8174128 ]
 [9.70084296 1.62961702]
 [0.56428091 0.09522235]]
```

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.



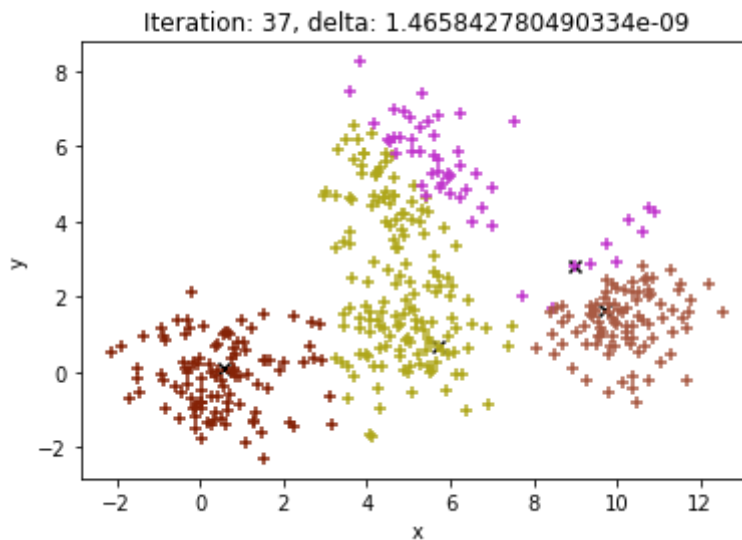
```
[[5.72035875 0.65426631]
 [8.98228383 2.8174128 ]
 [9.70084288 1.62961704]
 [0.56428091 0.09522235]]
```

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.



\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

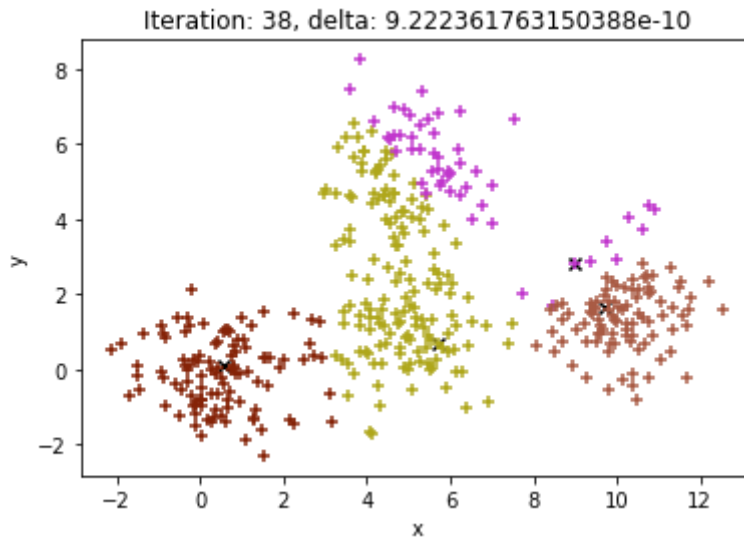
\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

```
[[5.72035875 0.65426631]
 [8.98228383 2.8174128 ]
 [9.70084283 1.62961706]
 [0.56428091 0.09522235]]
```



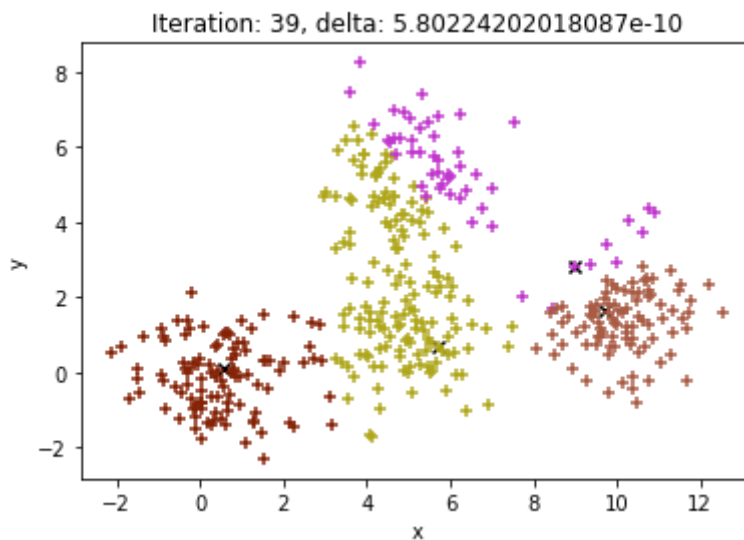
\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

\*c\* argument looks like a single numeric RGB or RGBA sequence, which should be avoided as value-mapping will have precedence in case its length matches with \*x\* & \*y\*. Please use the \*color\* keyword-argument or provide a 2D array with a single row if you intend to specify the same RGB or RGBA value for all points.

```
[[5.72035875 0.65426631]
 [8.98228383 2.8174128 ]
 [9.70084279 1.62961707]
 [0.5642809  0.09522234]]
```



```
[[5.72035875 0.65426631]
 [8.98228383 2.8174128 ]
 [9.70084278 1.62961708]
 [0.5642809  0.09522234]]
```

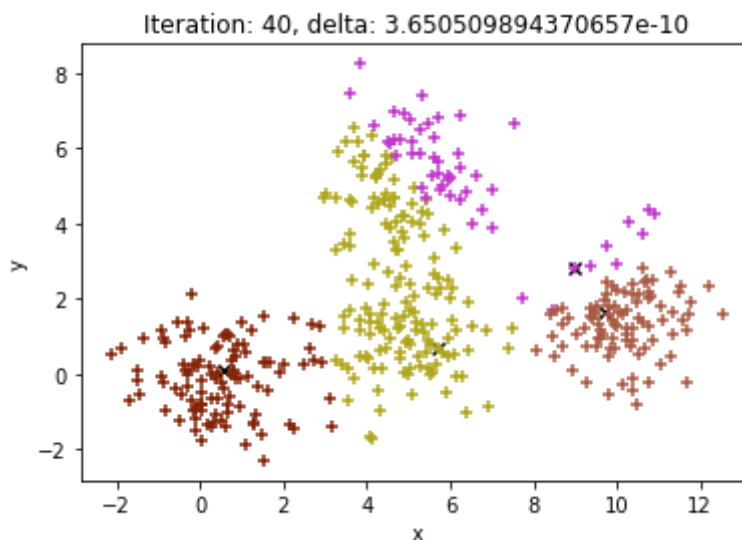


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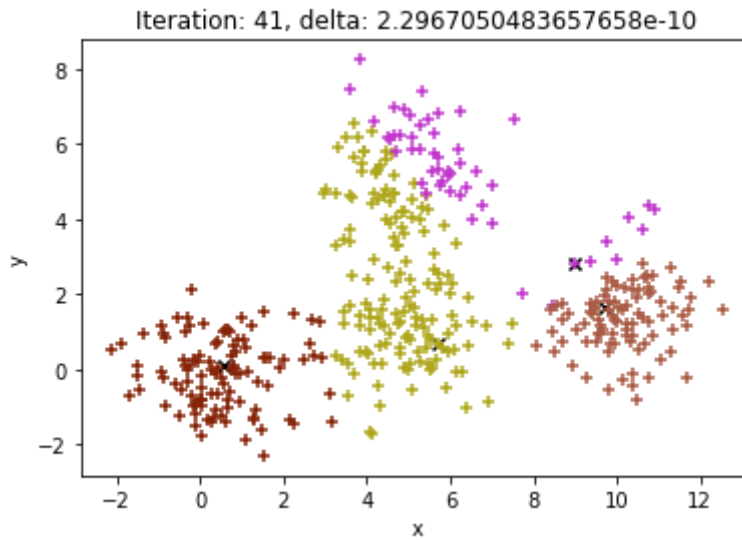
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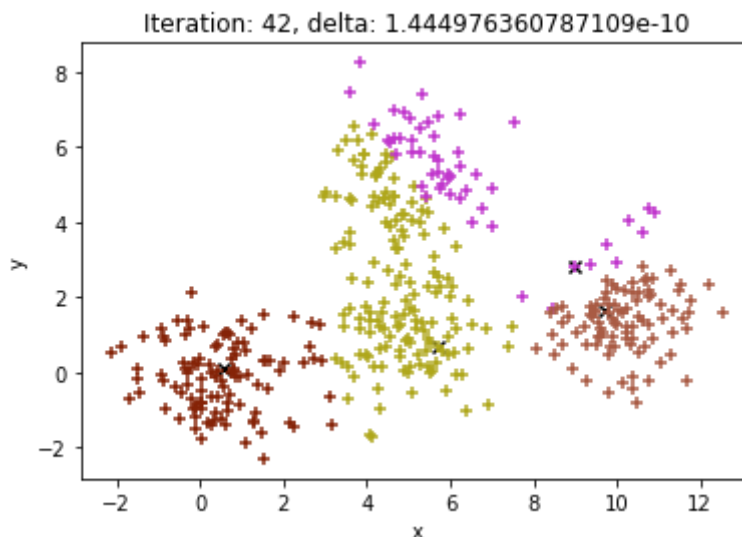
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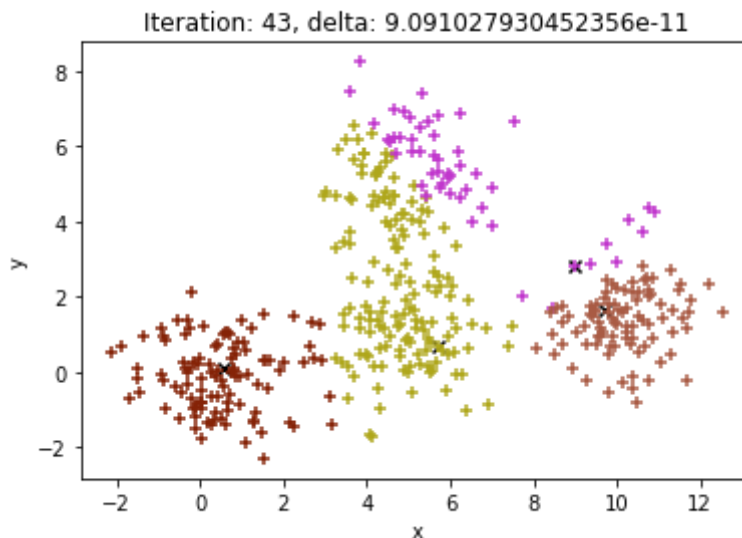
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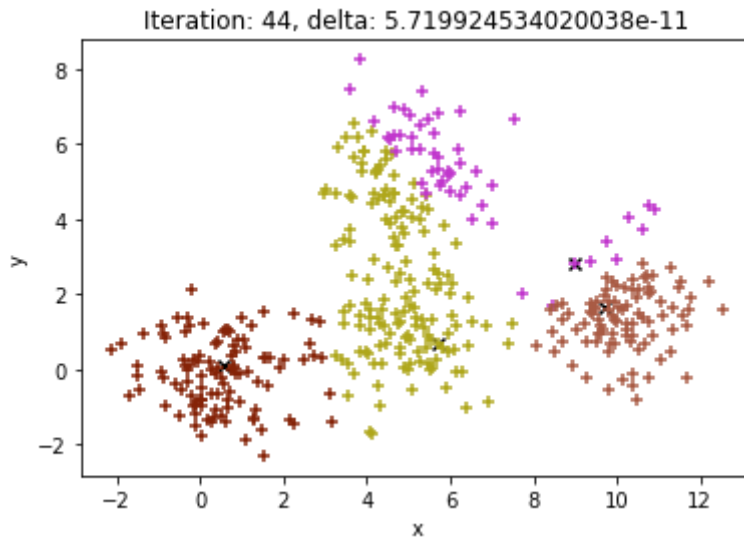
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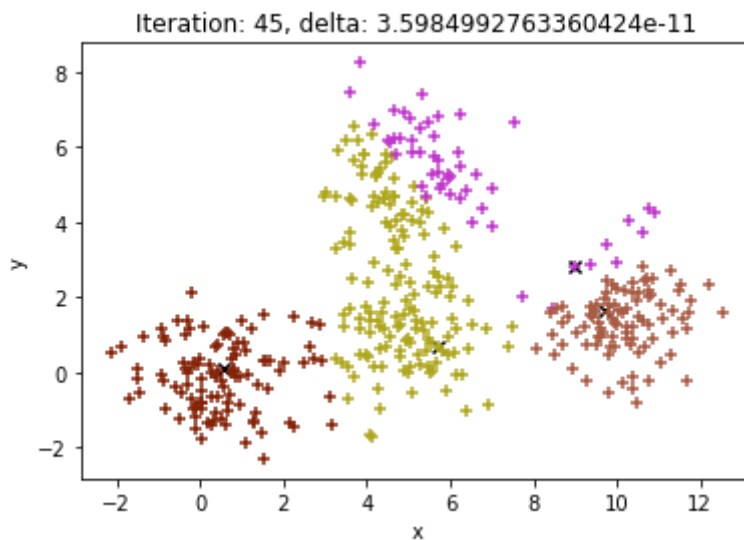
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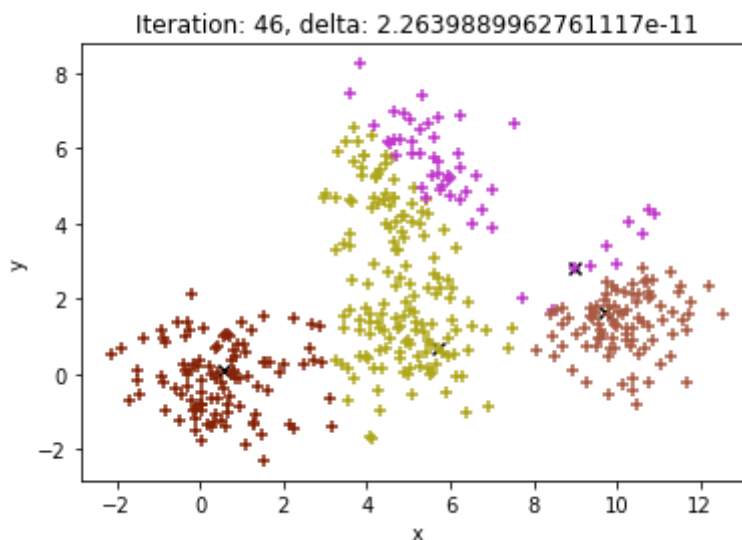
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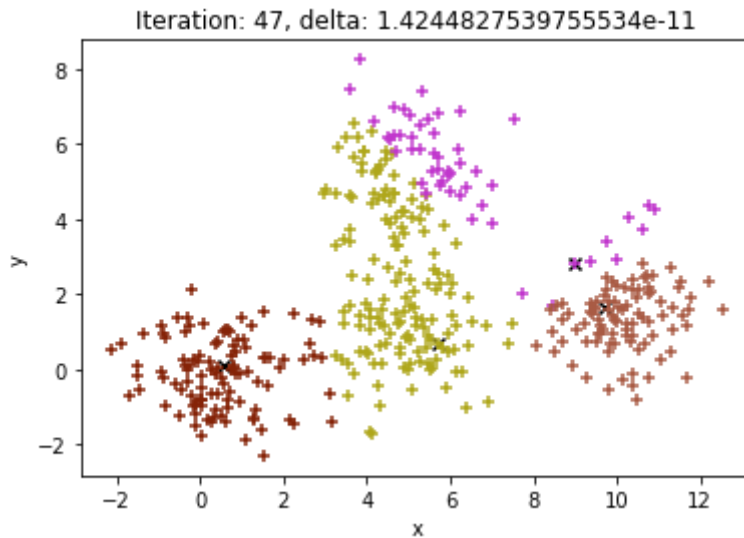
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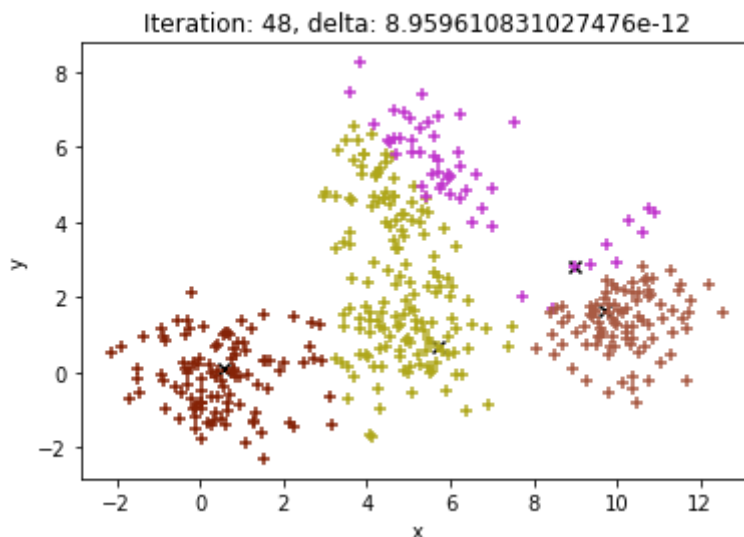
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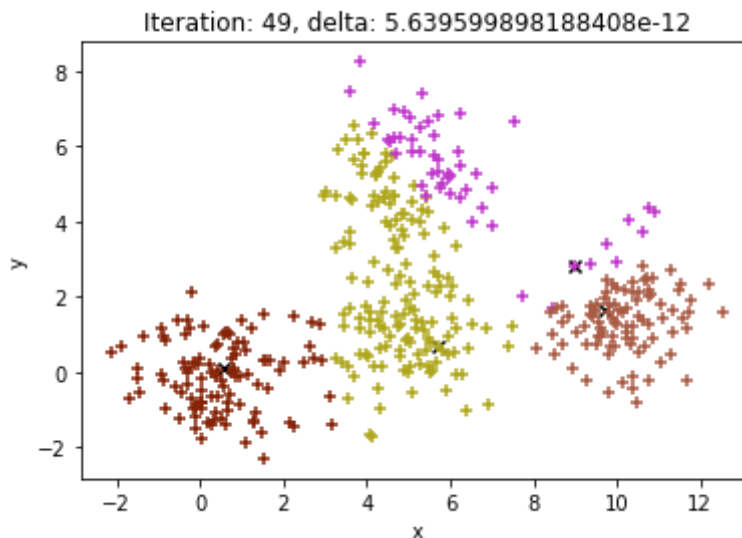
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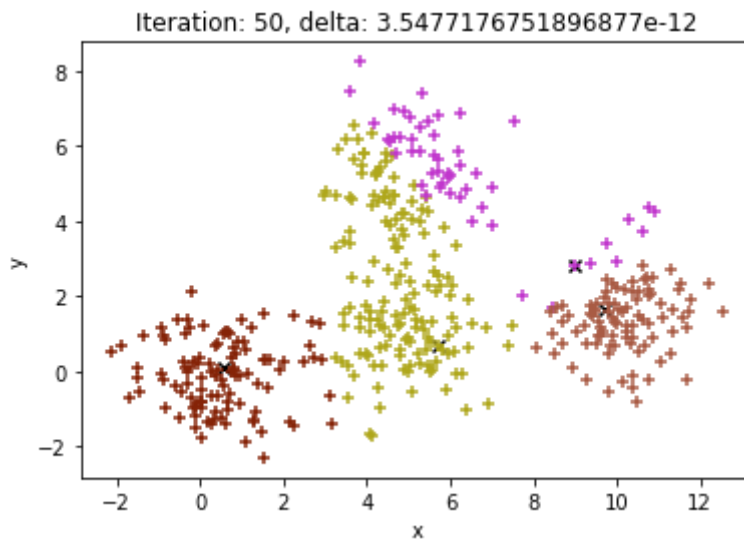
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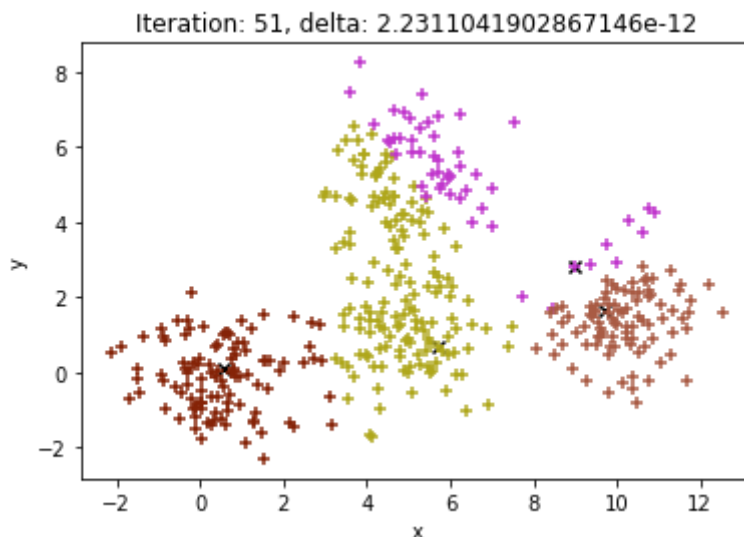
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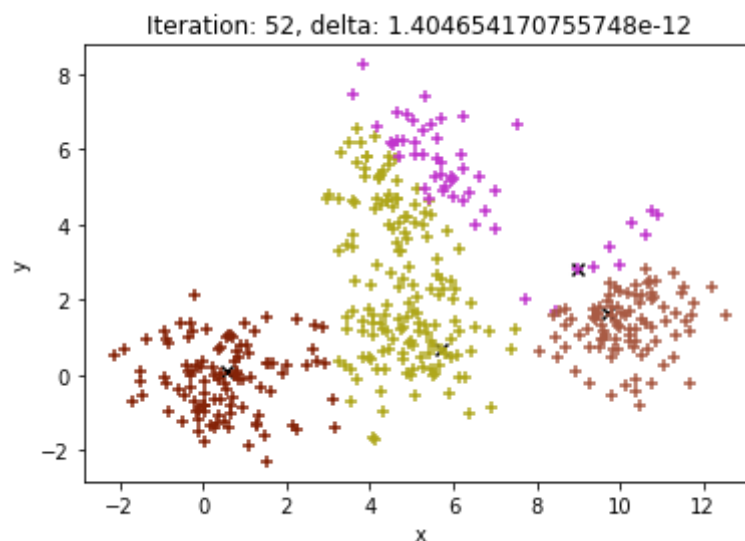
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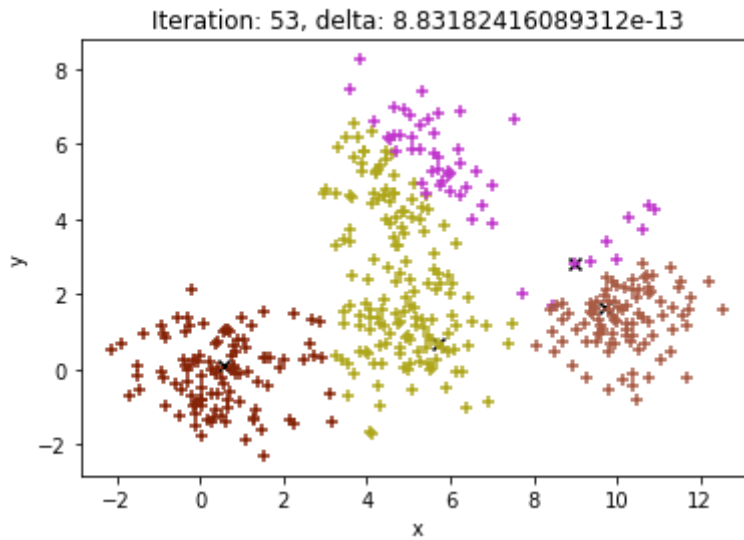
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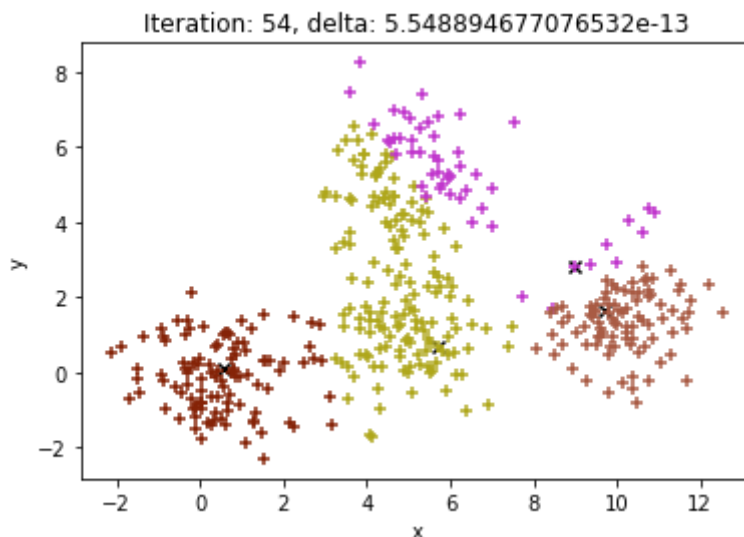
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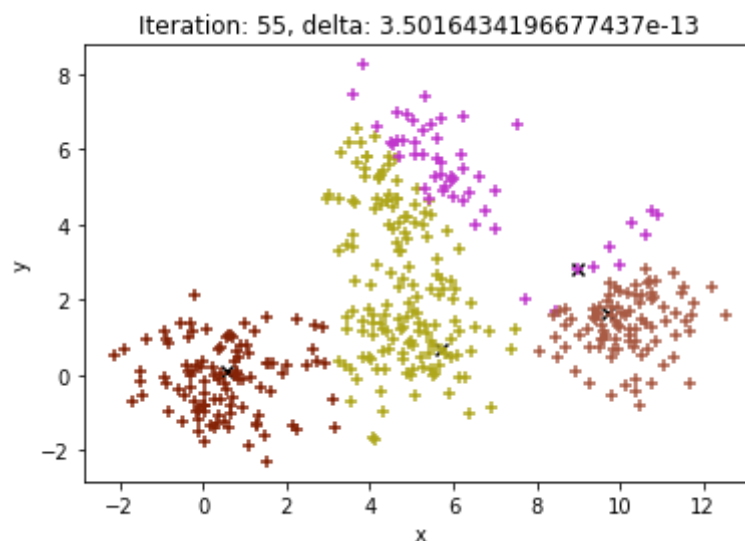
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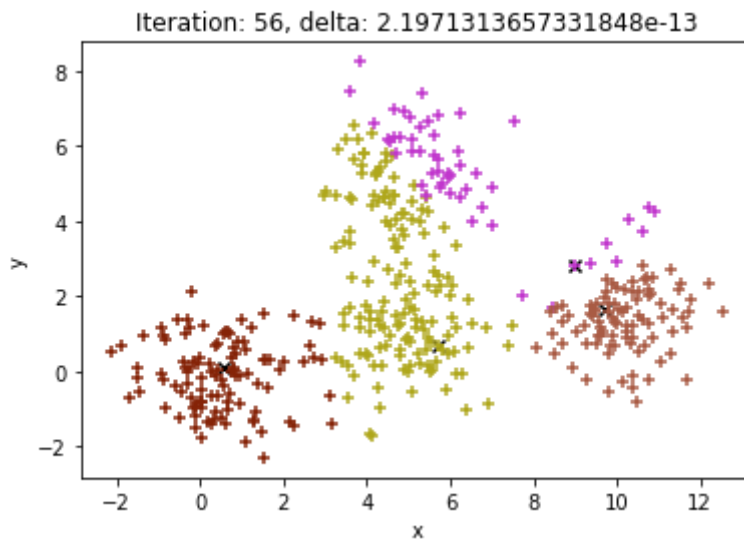
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 [0.5642809  0.09522234]]
```



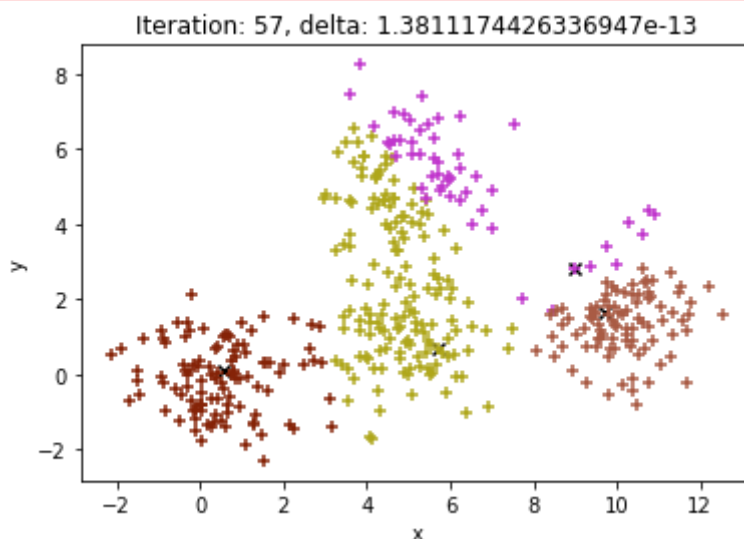
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[[5.72035875 0.65426631]
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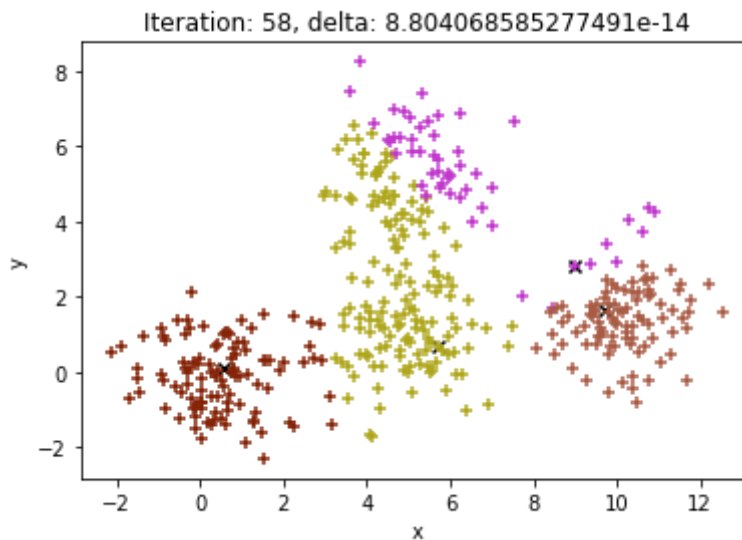
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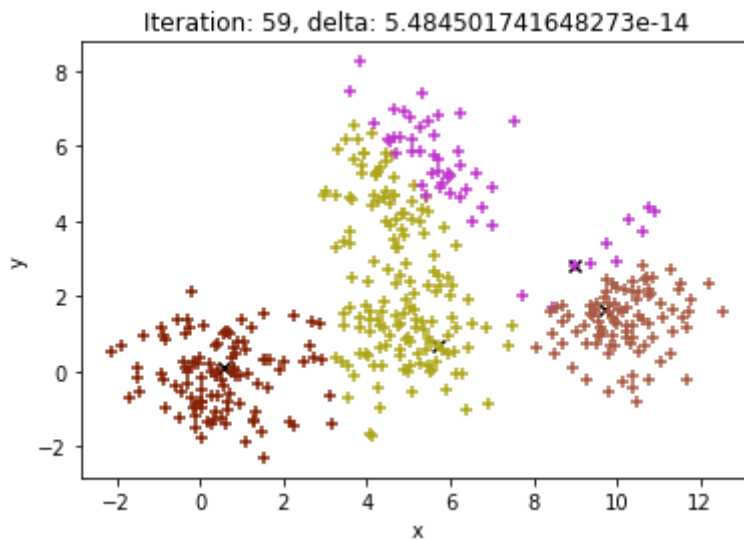
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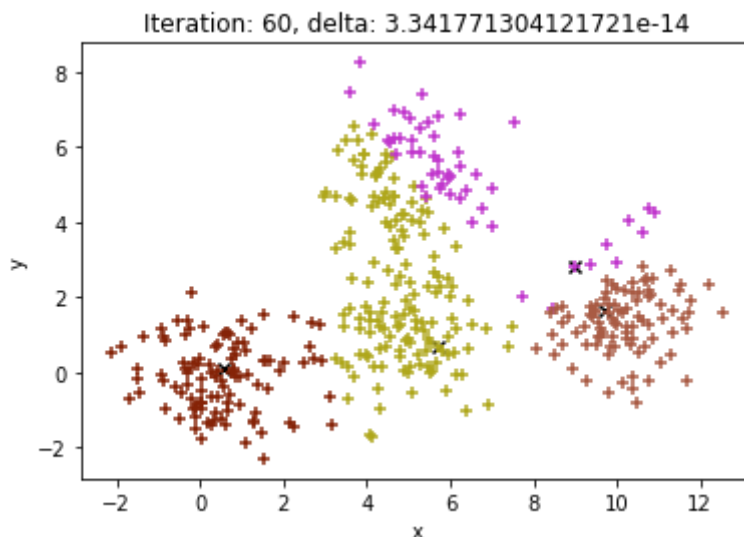
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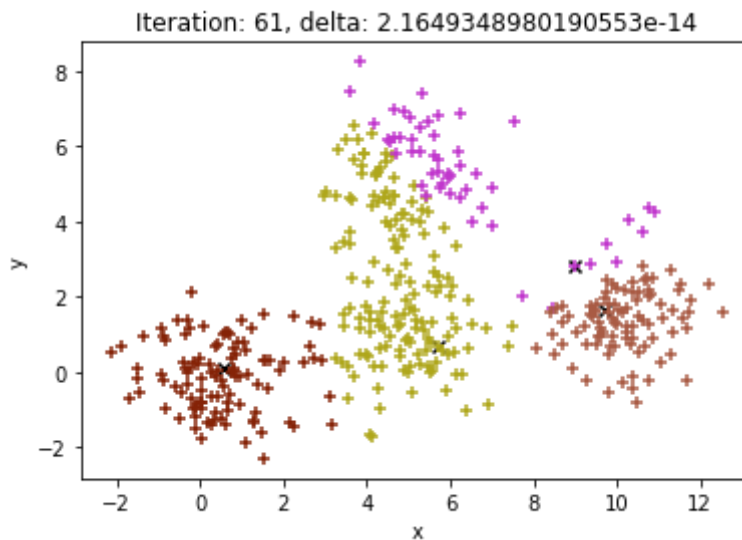


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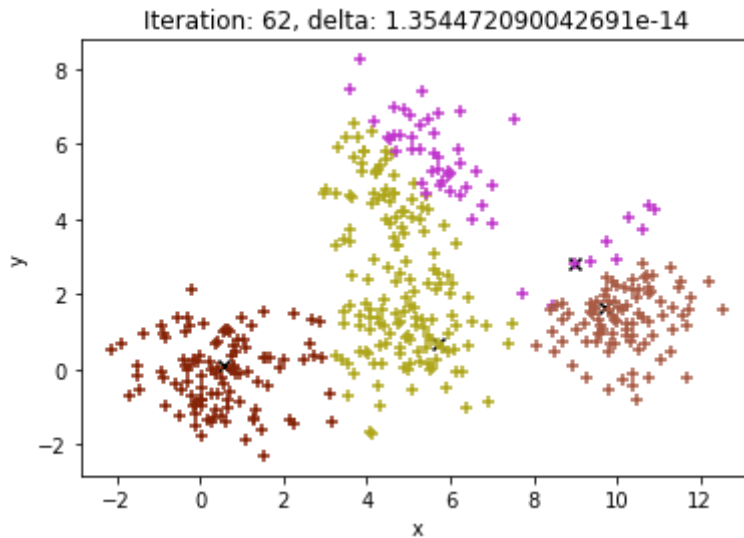
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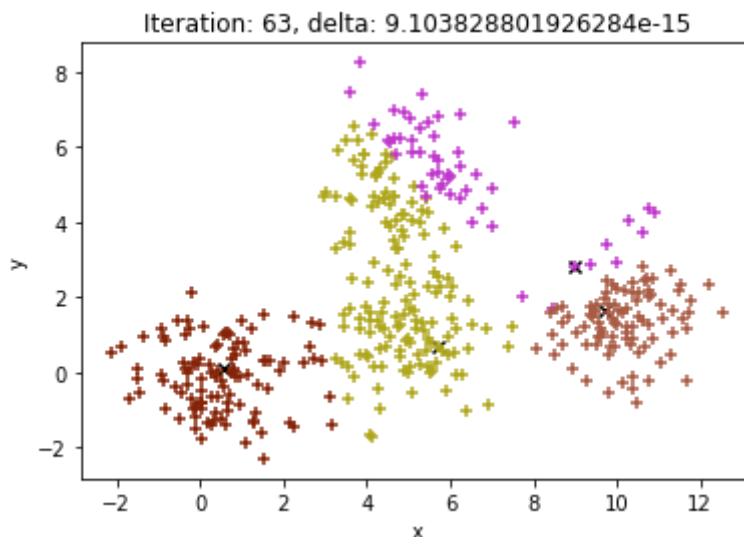
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[[5.72035875 0.65426631]
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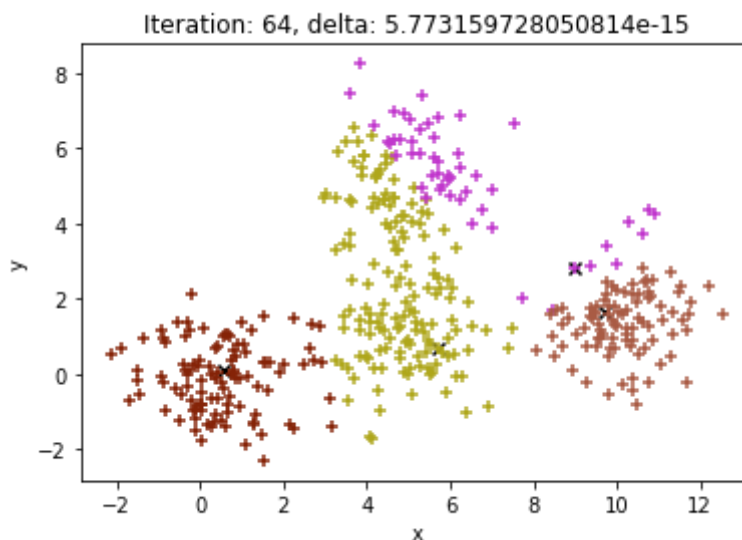
```
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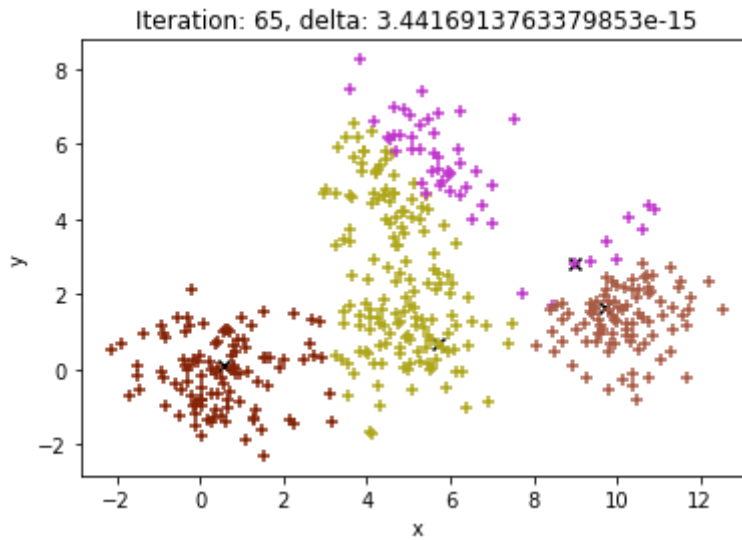
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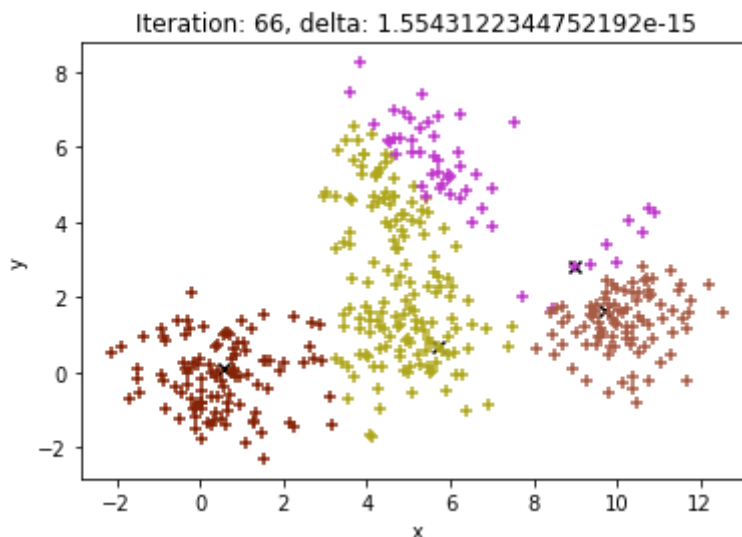
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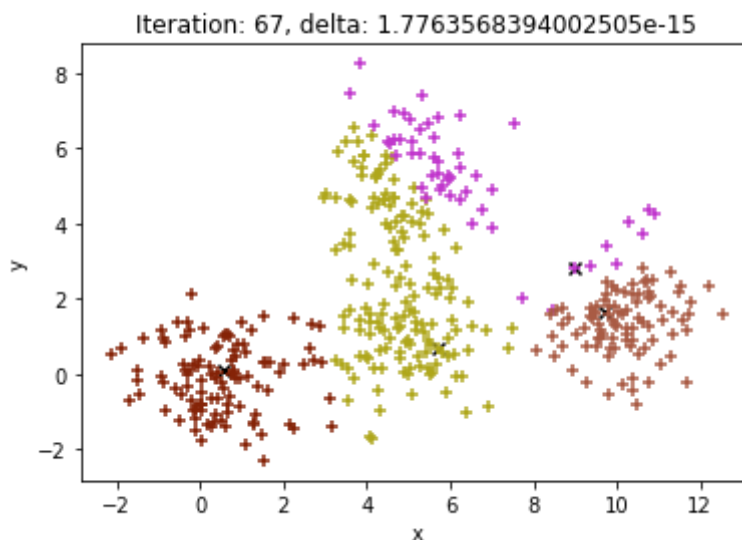
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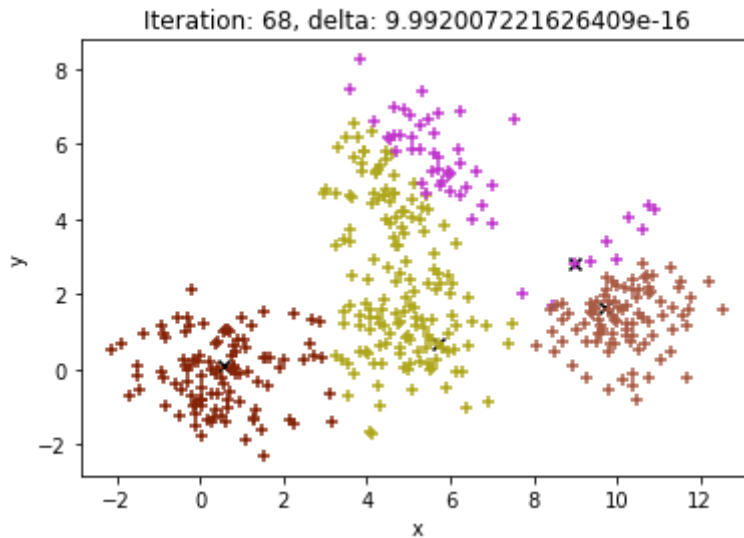
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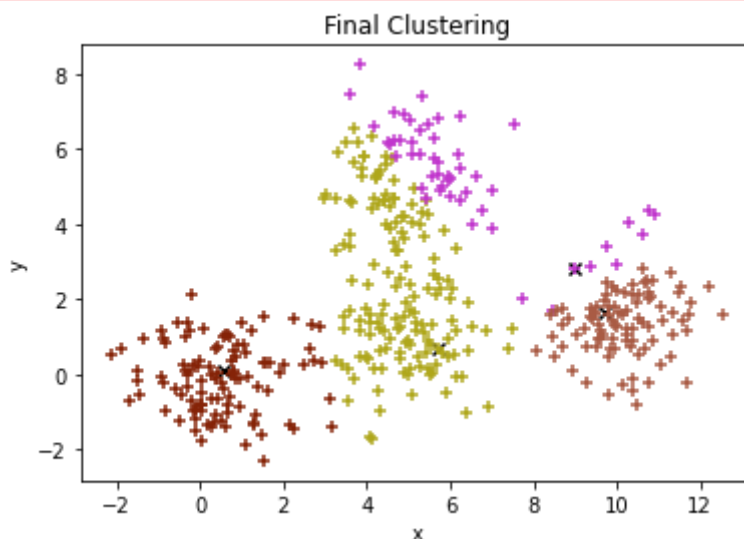


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## Hierarchical Clustering

Hierarchical clustering is an unsupervised clustering technique which groups together the unlabelled data of similar characteristics.

There are two types of hierarchical clustering:

- Agglomerative Clustering

- Divisive Clustering

### Agglomerative Clustering:

In this type of hierarchical clustering all data set are considered as individual cluster and at every iterations clusters with similar characteristics are merged to give bigger clusters. This is repeated until one single cluster is reached. It is also called bottom-top approach.

## Agglomerative Clustering:

Lets start with some dummy example :

$X = [x_1, x_2, \dots, x_5]$ , with

$$x_1 = \begin{bmatrix} 1 \\ 1 \end{bmatrix}, x_2 = \begin{bmatrix} 2 \\ 1 \end{bmatrix}, x_3 = \begin{bmatrix} 5 \\ 4 \end{bmatrix}, x_4 = \begin{bmatrix} 6 \\ 5 \end{bmatrix}, x_5 = \begin{bmatrix} 6.5 \\ 6 \end{bmatrix}$$

### Steps to perform Agglomerative Clustering:

1. Compute Distance matrix ( $N \times N$  matrix, where  $N$  number of vectors present in the dataset):  $D(a, b) = \|x_a - x_b\|_2$
2. Replace the diagonal elements with  $\infty$  and find the index of the minimum element present in the distance matrix (suppose we get the location  $(l, k)$ ).
3. Replace  $x_{\min(l,k)} = .5 \times [x_l + x_m]$  and delete  $x_{\max(l,m)}$  vector from  $X$  (i.e now  $(N = N - 1)$ ),

**repeat from step 1 again until all the vectors combined to a single cluster.**

```
In [ ]: def Euclidian_Dist(x,y):

    return np.linalg.norm(x-y) ## write your code here

def Dist_mat(X):
    ## write your code here
    mat_dist = np.zeros((X.shape[1],X.shape[1]))
    for i in range(X.shape[1]):
        for j in range(X.shape[1]):
            mat_dist[i][j] = round(Euclidian_Dist(X[:,i],X[:,j]),1)
    return mat_dist

def combine(X, cluster_comb):
    ## write your code here
    md = Dist_mat(X)
    max_val = np.inf
    md[(md==0)]=max_val
    print(md)
    arr_min = np.min(md, axis=0)
    #print(arr_min)
    index = np.argwhere(md == np.min(arr_min))
    index = index[0,:]
    #print(index)
    print('Vector of X to be combined: ', index+1)

    cluster_comb.append(index+1)
    #print(index[1])
    ret_x = X
```

```

ret_x = np.delete(ret_x,max(index),1)
ret_x[:,min(index)] = 0.5*(X[:,index[0]]+X[:,index[1]])
x_new = ret_x

return x_new

```

```

In [ ]: X=np.array([[1,1],[2,1],[5,4],[6,5],[6.5,6]])
X=X.transpose()

## write your code here
cluster_comb=[]
x_1 = X
print(X)
while x_1.shape!=(2,1):
    x_1 = combine(x_1, cluster_comb)
    print('\nMean of clusters after every iteration: \n\n',x_1)

print('\ncluster combination order: \n\n',cluster_comb)
print("Final X:", X)

## validate from inbuilt Dendrogram
import plotly.figure_factory as ff

lab=np.linspace(1,X.shape[1],X.shape[1])
fig = ff.create_dendrogram(X.T, labels=lab)
fig.update_layout(width=800, height=300)
fig.show()

```



```
[[1.  2.  5.  6.  6.5]
 [1.  1.  4.  5.  6. ]]
[[inf 1.  5.  6.4 7.4]
 [1.  inf 4.2 5.7 6.7]
 [5.  4.2 inf 1.4 2.5]
 [6.4 5.7 1.4 inf 1.1]
 [7.4 6.7 2.5 1.1 inf]]
Vector of X to be combined:  [1 2]
```

Mean of clusters after every iteration:

```
[[1.5 5.  6.  6.5]
 [1.  4.  5.  6. ]]
[[inf 4.6 6.  7.1]
 [4.6 inf 1.4 2.5]
 [6.  1.4 inf 1.1]
 [7.1 2.5 1.1 inf]]
Vector of X to be combined:  [3 4]
```

Mean of clusters after every iteration:

```
[[1.5  5.  6.25]
 [1.  4.  5.5  ]]
[[inf 4.6 6.5]
 [4.6 inf 2.  ]
 [6.5 2.  inf]]
Vector of X to be combined:  [2 3]
```

Mean of clusters after every iteration:

```
[[1.5  5.625]
 [1.  4.75  ]]
[[inf 5.6]
 [5.6 inf]]
Vector of X to be combined:  [1 2]
```

Mean of clusters after every iteration:

```
[[3.5625]
 [2.875  ]]
```

cluster combination order:

```
[array([1, 2], dtype=int64), array([3, 4], dtype=int64), array([2, 3], dtype=int64), array([1, 2], dtype=int64)]
Final X: [[1.  2.  5.  6.  6.5]
 [1.  1.  4.  5.  6.  ]]
```

## Clustering Algorithms on MNIST Digit dataset

Perform Kmeans and gmm clustering on MNIST dataset

1. Load MNIST data from the given images and labels
2. Consider any 2 classes

```
In [ ]: !pip install idx2numpy
```

Requirement already satisfied: idx2numpy in c:\users\shashank\.env\mldev\lib\site-packages (1.2.3)

Requirement already satisfied: numpy in c:\users\shashank\.env\mldev\lib\site-packages (from idx2numpy) (1.22.4)

Requirement already satisfied: six in c:\users\shashank\.env\mldev\lib\site-packages (from idx2numpy) (1.16.0)

```
In [ ]: import idx2numpy
        from keras.utils import np_utils
        img_path = "t10k-images-idx3-ubyte" ## write your code here
        label_path = "t10k-labels-idx1-ubyte" ## write your code here

        Images = idx2numpy.convert_from_file(img_path)
        labels = idx2numpy.convert_from_file(label_path)

        ## write your code here

        l1 = labels==2
        l2 = labels==9
        X = Images[np.logical_or(l1, l2)]
        K = 2

        print(X.shape)
        print(labels.shape)
        print(X[0])
        plt.imshow(X[0])
        plt.show()
        plt.imshow(X[5])
        plt.show()

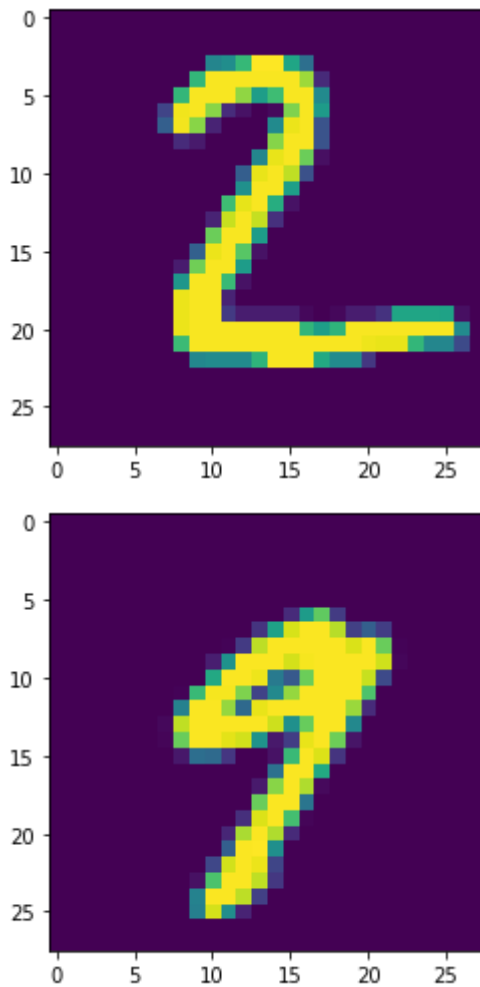
        X = X.reshape((X.shape[0], 28*28))
        mean_vectors = X[:K, :]
        mean_vectors
```

(2041, 28, 28)  
(10000,)

```

[[ 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
   0 0 0 0 0 0 0 0 0 0 0]
 [ 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
   0 0 0 0 0 0 0 0 0 0 0]
 [ 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
   0 0 0 0 0 0 0 0 0 0 0]
 [ 0 0 0 0 0 0 0 0 0 0 116 125 171 255 255 150 93 0
   0 0 0 0 0 0 0 0 0 0 0]
 [ 0 0 0 0 0 0 0 0 0 169 253 253 253 253 253 253 218 30
   0 0 0 0 0 0 0 0 0 0 0]
 [ 0 0 0 0 0 0 0 0 169 253 253 253 213 142 176 253 253 122
   0 0 0 0 0 0 0 0 0 0 0]
 [ 0 0 0 0 0 0 0 52 250 253 210 32 12 0 6 206 253 140
   0 0 0 0 0 0 0 0 0 0 0]
 [ 0 0 0 0 0 0 0 77 251 210 25 0 0 0 122 248 253 65
   0 0 0 0 0 0 0 0 0 0 0]
 [ 0 0 0 0 0 0 0 0 31 18 0 0 0 0 209 253 253 65
   0 0 0 0 0 0 0 0 0 0 0]
 [ 0 0 0 0 0 0 0 0 0 0 0 0 0 117 247 253 198 10
   0 0 0 0 0 0 0 0 0 0 0]
 [ 0 0 0 0 0 0 0 0 0 0 0 0 0 76 247 253 231 63 0
   0 0 0 0 0 0 0 0 0 0 0]
 [ 0 0 0 0 0 0 0 0 0 0 0 0 0 128 253 253 144 0 0
   0 0 0 0 0 0 0 0 0 0 0]
 [ 0 0 0 0 0 0 0 0 0 0 0 176 246 253 159 12 0 0
   0 0 0 0 0 0 0 0 0 0 0]
 [ 0 0 0 0 0 0 0 0 0 0 25 234 253 233 35 0 0 0
   0 0 0 0 0 0 0 0 0 0 0]
 [ 0 0 0 0 0 0 0 0 0 0 198 253 253 141 0 0 0 0
   0 0 0 0 0 0 0 0 0 0 0]
 [ 0 0 0 0 0 0 0 0 0 78 248 253 189 12 0 0 0 0
   0 0 0 0 0 0 0 0 0 0 0]
 [ 0 0 0 0 0 0 0 0 19 200 253 253 141 0 0 0 0 0
   0 0 0 0 0 0 0 0 0 0 0]
 [ 0 0 0 0 0 0 0 0 134 253 253 173 12 0 0 0 0 0
   0 0 0 0 0 0 0 0 0 0 0]
 [ 0 0 0 0 0 0 0 0 248 253 253 25 0 0 0 0 0 0
   0 0 0 0 0 0 0 0 0 0 0]
 [ 0 0 0 0 0 0 0 0 248 253 253 43 20 20 20 20 5 0
   5 20 20 37 150 150 150 147 10 0]
 [ 0 0 0 0 0 0 0 0 248 253 253 253 253 253 253 253 168 143
   166 253 253 253 253 253 253 253 123 0]
 [ 0 0 0 0 0 0 0 0 174 253 253 253 253 253 253 253 253 253
   253 253 249 247 247 169 117 117 57 0]
 [ 0 0 0 0 0 0 0 0 118 123 123 123 166 253 253 253 155
   123 123 41 0 0 0 0 0 0 0]
 [ 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
   0 0 0 0 0 0 0 0 0 0 0]
 [ 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
   0 0 0 0 0 0 0 0 0 0 0]
 [ 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
   0 0 0 0 0 0 0 0 0 0 0]
 [ 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
   0 0 0 0 0 0 0 0 0 0 0]
 [ 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
   0 0 0 0 0 0 0 0 0 0 0]]

```



Out[ ]: array([[0, 0, 0, ..., 0, 0, 0],  
[0, 0, 0, ..., 0, 0, 0]], dtype=uint8)

Use the K-means clustering algorithm from the last lab to form the clusters

```
In [ ]: ## Write your code here
tol = 1e-5

delta = float('inf')
prev_error = float('inf')

errors = []
iter = 0

while delta > tol:
    assigned = [[] for i in range(K)]
    for i in range(X.shape[0]):
        min_index = np.argmin(np.linalg.norm(X[i] - mean_vectors, axis=1))
        assigned[min_index].append(i)

    assigned_clusters = []
    for i in range(K): assigned_clusters.append(X[assigned[i]])

    mean_vectors = np.array([cluster.mean(axis=0) for cluster in assigned_clusters])

    sum_error = 0

    for i in range(K): sum_error += np.sum(np.linalg.norm(assigned_clusters[i] - mean_

    sum_error
    delta = abs(prev_error - sum_error/X.shape[0])
    prev_error = sum_error/X.shape[0]
```

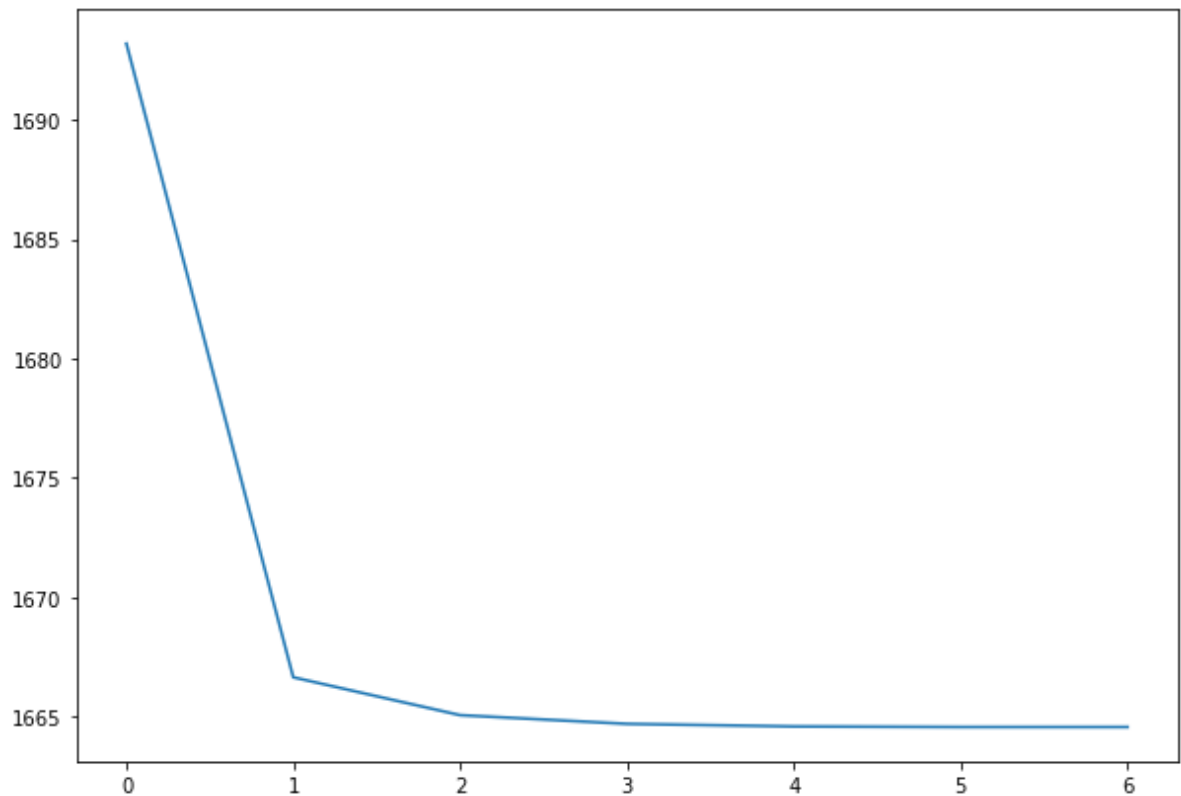
```

prev_error
errors.append(prev_error)
iter+=1

plt.figure(figsize=(10, 7))
plt.plot(range(len(errors)), errors)

```

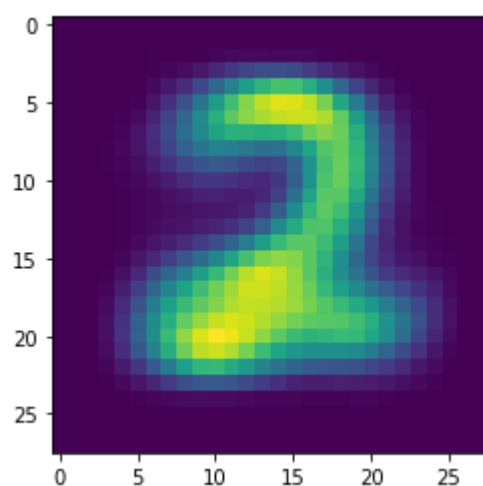
Out[ ]: [

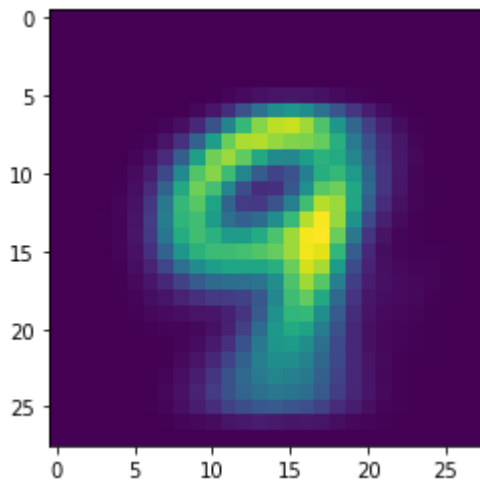


```

In [ ]: gen1 = mean_vectors[0].reshape((28, 28))
gen2 = mean_vectors[1].reshape((28, 28))
plt.imshow(gen1)
plt.show()
plt.imshow(gen2)
plt.show()

```





Use the GMM clustering algorithm from the last lab to form the clusters

```
In [ ]: ## Write your code here
def initialization(data,K):

    dim = data.shape[1]
    indices = np.random.randint(0, len(data)-1, K)
    mean_vectors = data[indices, :]
    cov_matrix = np.zeros((dim, dim, K))
    for k in range(K):
        cov_matrix[:, :, k] = np.identity(dim)*np.max(data)
    w = np.array([1/K for i in range(K)])

    theta = [mean_vectors, cov_matrix, w]

    return theta

from scipy.stats import multivariate_normal

def E_Step_GMM(data,K,theta):

    # write your code here
    mean_vectors = theta[0]
    cov_matrix = theta[1]
    w = theta[2]

    responsibility = np.zeros((len(data), K))
    for i in range(len(data)):
        for k in range(K):
            p_ik = multivariate_normal.pdf(data[i], mean=mean_vectors[k], cov=cov_ma
            numerator_ik = w[k] * p_ik

            denominator_ik = 0

            for k2 in range(K):
                p_ik_temp = multivariate_normal.pdf(data[i], mean=mean_vectors[k2],
                numerator_ik_temp = w[k2] * p_ik_temp
                denominator_ik += numerator_ik_temp

            responsibility[i][k] = numerator_ik/(denominator_ik+1e-20)

    return responsibility

def M_Step_GMM(data,responsibility):
    N = len(data)
    dim = data.shape[1]
    K = responsibility.shape[1]
```

```

N_k = np.sum(responsibility, axis=0)
N_k = np.reshape(N_k, (K, 1))
w = N_k/N

num_k = np.transpose(responsibility) @ data
mean_vectors = np.divide(num_k, N_k)

cov_matrix = np.zeros((dim, dim, K))
for k in range(K):
    for i in range(N):
        diff = np.reshape((data[i]-mean_vectors[k]), (dim, 1))
        cov_matrix[:, :, k] += responsibility[i][k] * (diff @ np.transpose(diff))
    cov_matrix[:, :, k] /= N_k[k]

theta = [mean_vectors, cov_matrix, w]

log_likelihood = 0

for k in range(K):
    inner = 0
    for i in range(N):
        inner += w[k] * multivariate_normal.pdf(data[i], mean=mean_vectors[k], cov=cov_matrix[:, :, k])
    log_likelihood += np.log(inner)

return theta, log_likelihood

log_l=[]
Itr=50
eps=10**(-14) # for threshold

print(X.shape, K)
theta=initialization(X,K)

for n in range(Itr):

    responsibility=E_Step_GMM(X,K,theta)

    cluster_label=np.argmax(responsibility,axis=1) #Label Points

    theta,log_likhd=M_Step_GMM(data,responsibility)

    log_l.append(log_likhd)

    Cents=theta[0]

    if n>2:
        if abs(log_l[n]-log_l[n-1])<eps:
            break

```

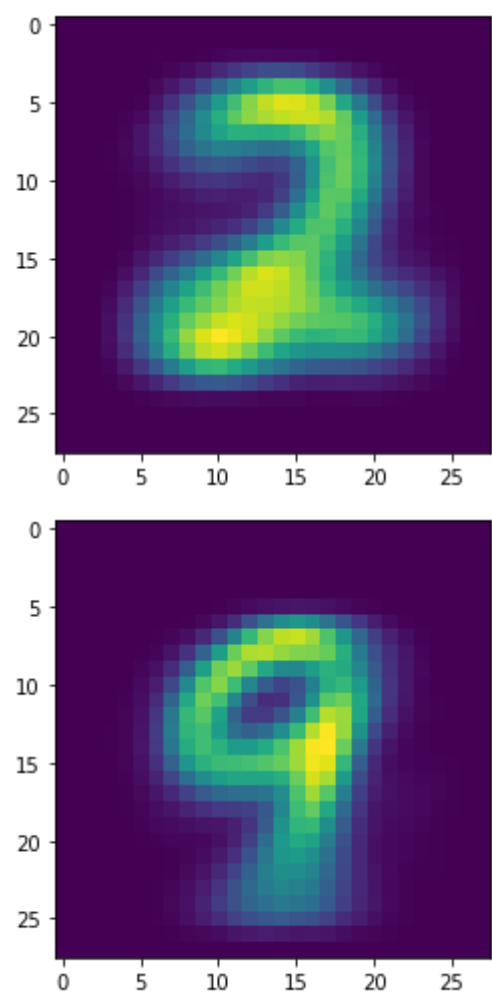
(2041, 784) 2

```

In [ ]: gen1 = theta[0][0].reshape((28, 28))
        gen2 = theta[0][1].reshape((28, 28))
        plt.imshow(gen1)
        plt.show()
        plt.imshow(gen2)
        plt.show()

```





In [ ]: