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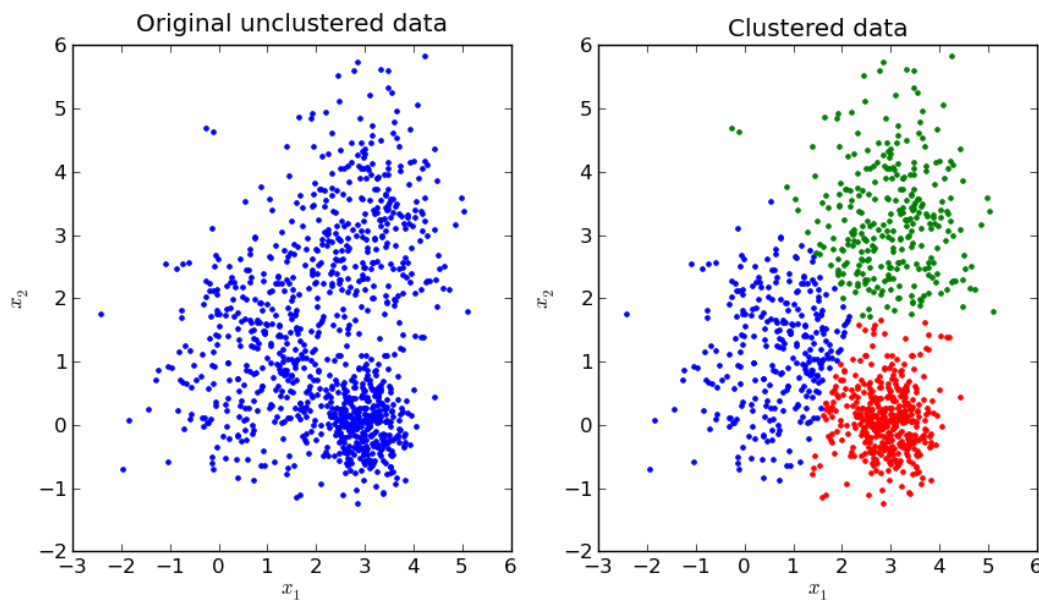
# K-Means Clustering in Python

*Posted by Mubaris NK on October 1, 2017*

Clustering is a type of **Unsupervised learning**. This is very often used when you don't have labeled data. **K-Means Clustering** is one of the popular clustering algorithm. The goal of this algorithm is to find groups(clusters) in the given data. In this post we will implement K-Means algorithm using Python from scratch.

## K-Means Clustering

K-Means is a very simple algorithm which clusters the data into  $K$  number of clusters. The following image from PyPR (<http://pypr.sourceforge.net/kmeans.html#k-means-example>) is an example of K-Means Clustering.



## Use Cases

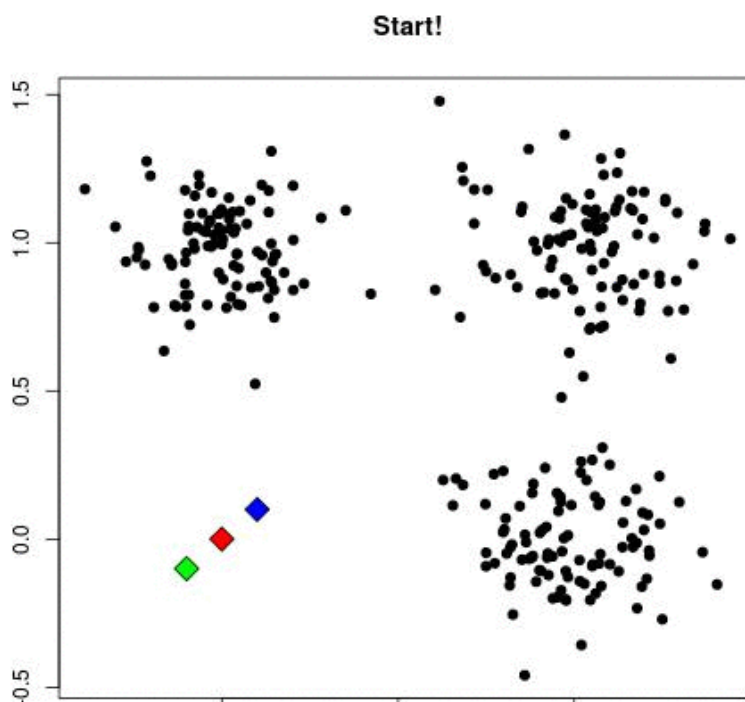
K-Means is widely used for many applications.

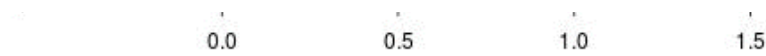
- Image Segmentation
- Clustering Gene Segmentation Data
- News Article Clustering
- Clustering Languages
- Species Clustering
- Anomaly Detection

## Algorithm

Our algorithm works as follows, assuming we have inputs  $x_1, x_2, x_3, \dots, x_n$  and value of **K**

- **Step 1** - Pick K random points as cluster centers called centroids.
- **Step 2** - Assign each  $x_i$  to nearest cluster by calculating its distance to each centroid.
- **Step 3** - Find new cluster center by taking the average of the assigned points.
- **Step 4** - Repeat Step 2 and 3 until none of the cluster assignments change.





The above animation is an example of running K-Means Clustering on a two dimensional data.

## Step 1

We randomly pick **K** cluster centers(centroids). Let's assume these are  $c_1, c_2, \dots, c_k$ , and we can say that;

$$C = c_1, c_2, \dots, c_k$$

$C$  is the set of all centroids.

## Step 2

In this step we assign each input value to closest center. This is done by calculating Euclidean(L2) distance between the point and the each centroid.

$$\arg \min_{c_i \in C} \text{dist}(c_i, x)^2$$

Where  $\text{dist}(\cdot)$  is the Euclidean distance.

## Step 3

In this step, we find the new centroid by taking the average of all the points assigned to that cluster.

$$c_i = \frac{1}{|S_i|} \sum_{x_i \in S_i} x_i$$

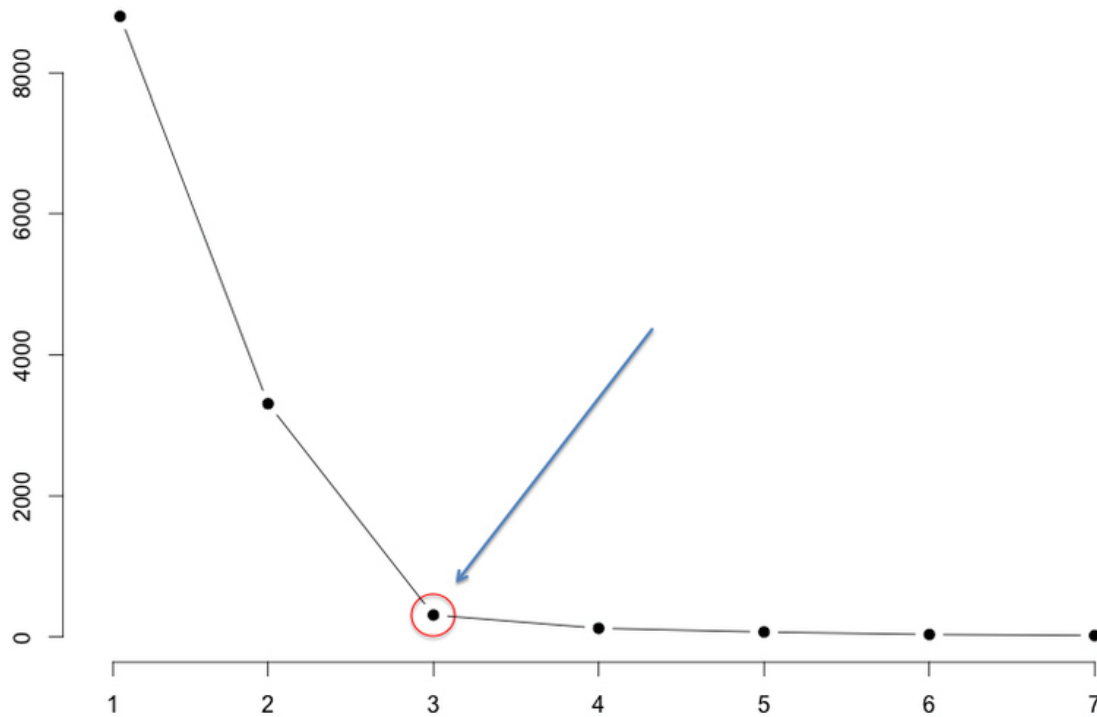
$S_i$  is the set of all points assigned to the  $i^{\text{th}}$  cluster.

## Step 4

In this step, we repeat step 2 and 3 until none of the cluster assignments change. That means until our clusters remain stable, we repeat the algorithm.

## Choosing the Value of K

We often know the value of K. In that case we use the value of K. Else we use the **Elbow Method**.



We run the algorithm for different values of **K**(say  $K = 10$  to  $1$ ) and plot the **K** values against SSE(Sum of Squared Errors). And select the value of **K** for the elbow point as shown in the figure.

## Implementation using Python

The dataset we are gonna use has 3000 entries with 3 clusters. So we already know the value of **K**.

Checkout this Github Repo (<https://github.com/mubaris/friendly-fortnight>) for full code and dataset.

We will start by importing the dataset.

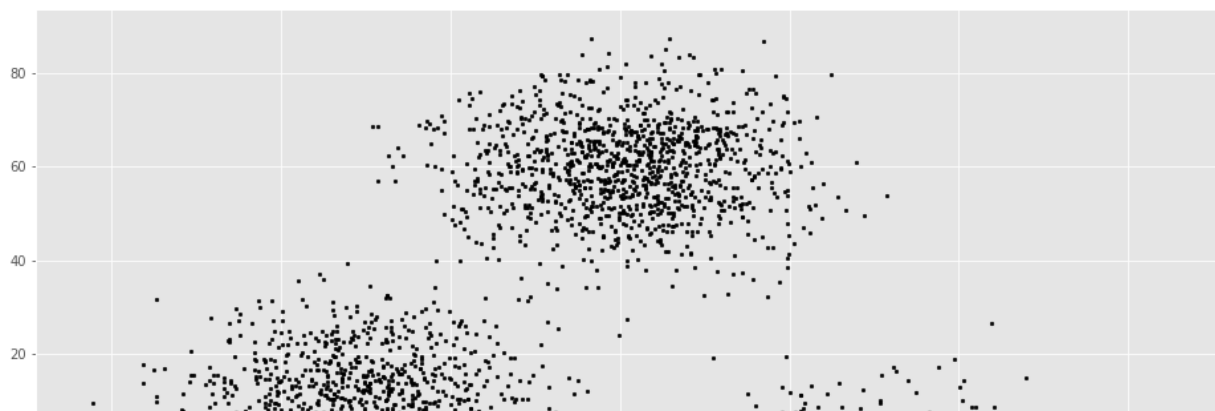
```
%matplotlib inline
from copy import deepcopy
import numpy as np
import pandas as pd
from matplotlib import pyplot as plt
plt.rcParams['figure.figsize'] = (16, 9)
plt.style.use('ggplot')
```

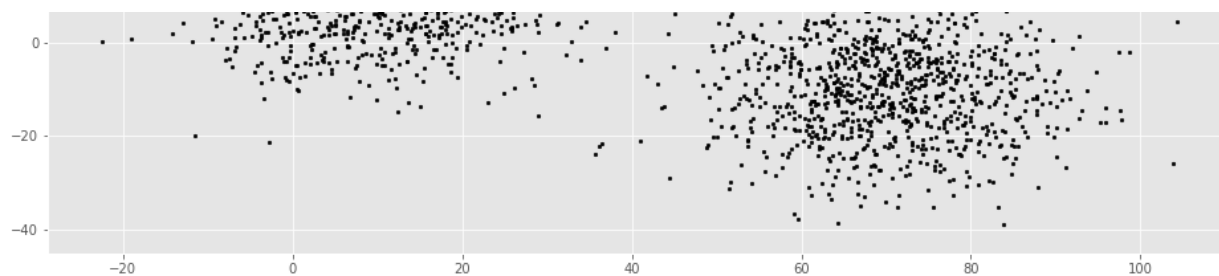
```
# Importing the dataset
data = pd.read_csv('xclara.csv')
print(data.shape)
data.head()
```

```
(3000, 2)
```

	V1	V2
0	2.072345	-3.241693
1	17.936710	15.784810
2	1.083576	7.319176
3	11.120670	14.406780
4	23.711550	2.557729

```
# Getting the values and plotting it
f1 = data['V1'].values
f2 = data['V2'].values
X = np.array(list(zip(f1, f2)))
plt.scatter(f1, f2, c='black', s=7)
```



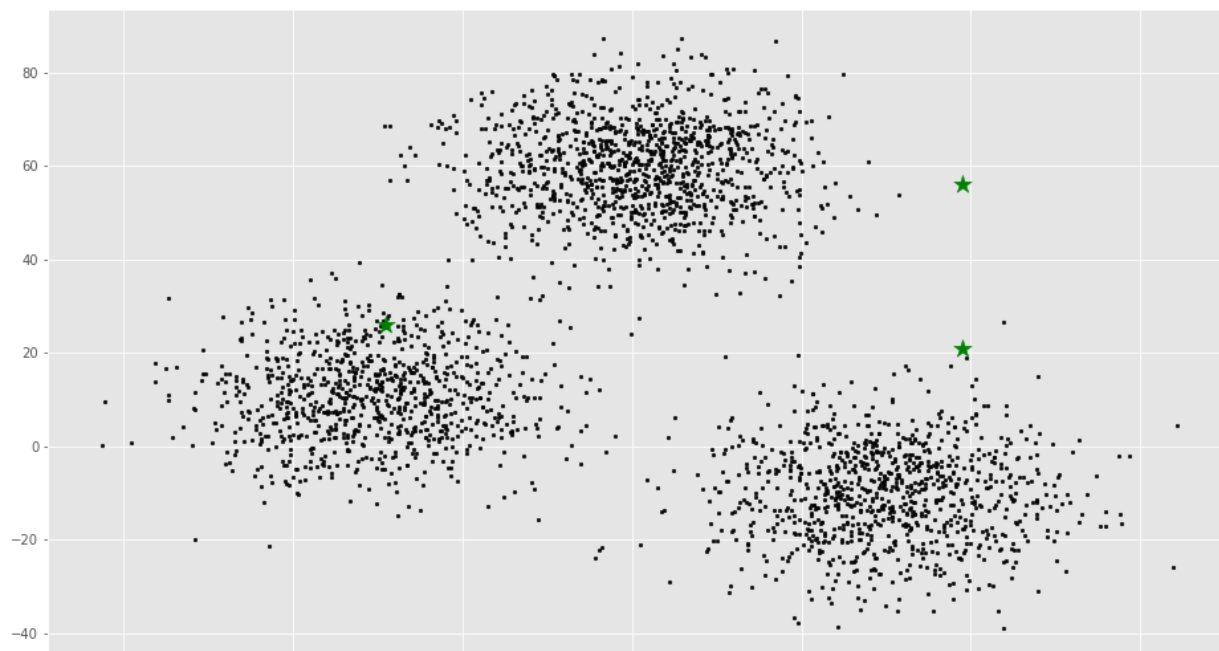


```
# Euclidean Distance Caculator
def dist(a, b, ax=1):
    return np.linalg.norm(a - b, axis=ax)
```

```
# Number of clusters
k = 3
# X coordinates of random centroids
C_x = np.random.randint(0, np.max(X)-20, size=k)
# Y coordinates of random centroids
C_y = np.random.randint(0, np.max(X)-20, size=k)
C = np.array(list(zip(C_x, C_y)), dtype=np.float32)
print(C)
```

```
[[ 11.  26.]
 [ 79.  56.]
 [ 79.  21.]]
```

```
# Plotting along with the Centroids
plt.scatter(f1, f2, c='#050505', s=7)
plt.scatter(C_x, C_y, marker='*', s=200, c='g')
```



```

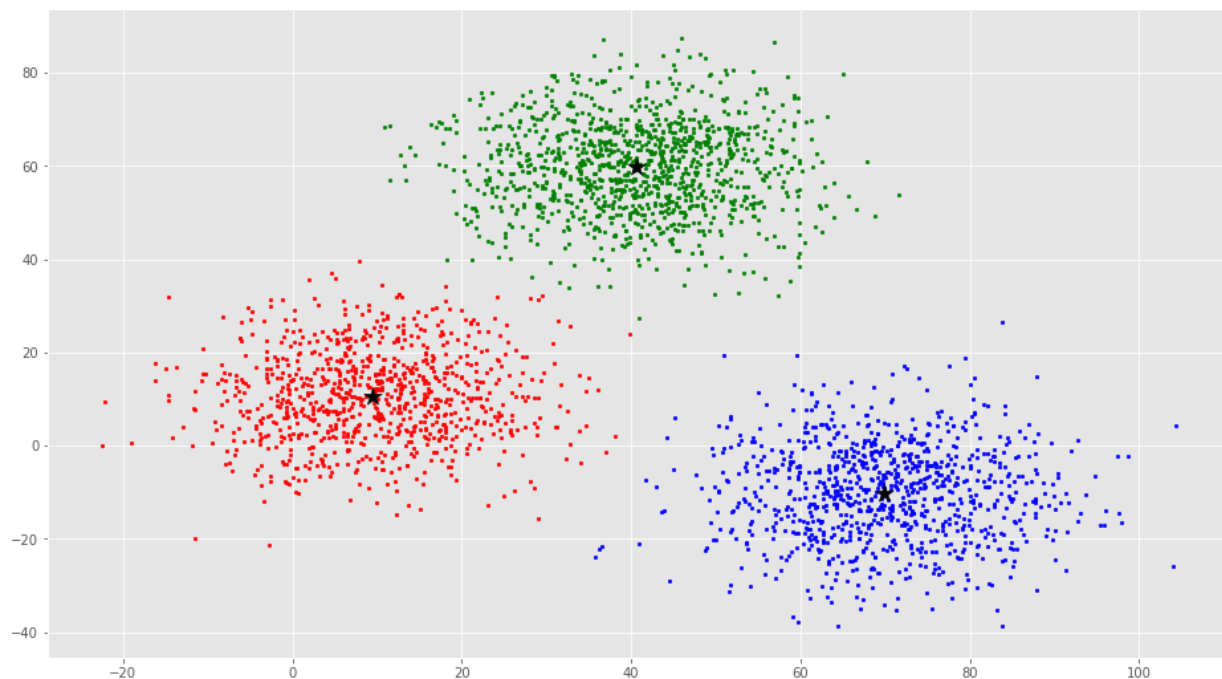
# To store the value of centroids when it updates
C_old = np.zeros(C.shape)
# Cluster Lables(0, 1, 2)
clusters = np.zeros(len(X))
# Error func. - Distance between new centroids and old centroids
error = dist(C, C_old, None)
# Loop will run till the error becomes zero
while error != 0:
    # Assigning each value to its closest cluster
    for i in range(len(X)):
        distances = dist(X[i], C)
        cluster = np.argmin(distances)
        clusters[i] = cluster
    # Storing the old centroid values
    C_old = deepcopy(C)
    # Finding the new centroids by taking the average value
    for i in range(k):
        points = [X[j] for j in range(len(X)) if clusters[j] == i]
        C[i] = np.mean(points, axis=0)
    error = dist(C, C_old, None)

```

```

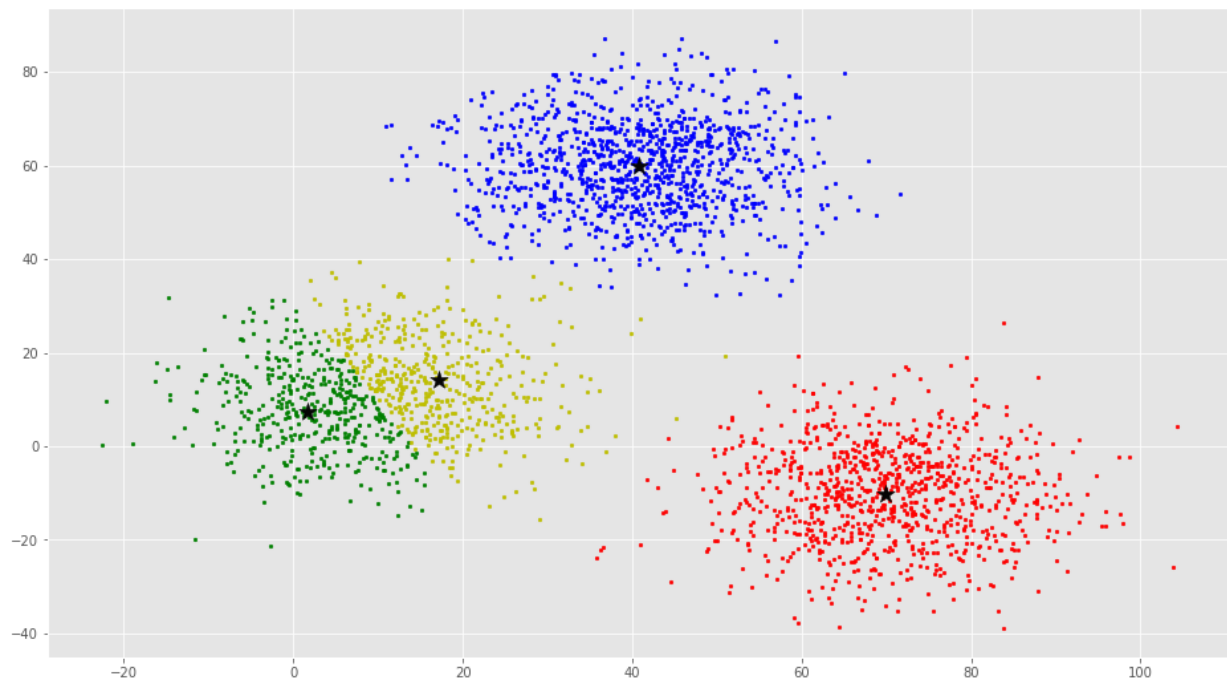
colors = ['r', 'g', 'b', 'y', 'c', 'm']
fig, ax = plt.subplots()
for i in range(k):
    points = np.array([X[j] for j in range(len(X)) if clusters[j] == i])
    ax.scatter(points[:, 0], points[:, 1], s=7, c=colors[i])
ax.scatter(C[:, 0], C[:, 1], marker='*', s=200, c='#050505')

```

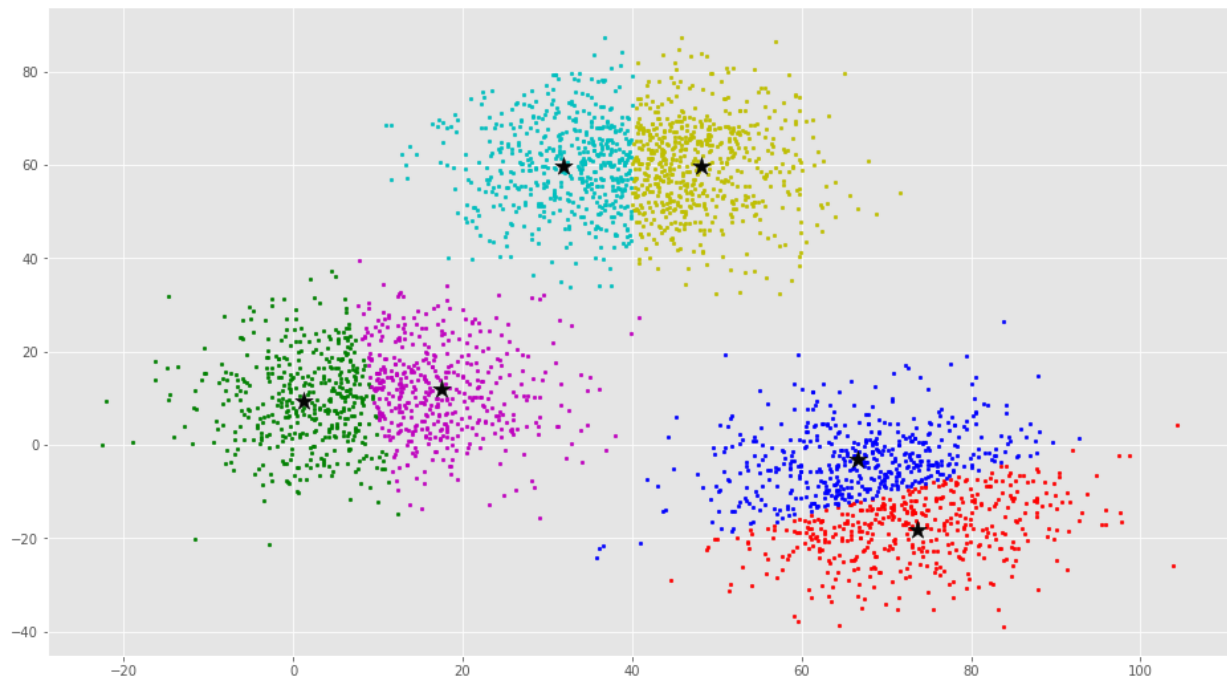
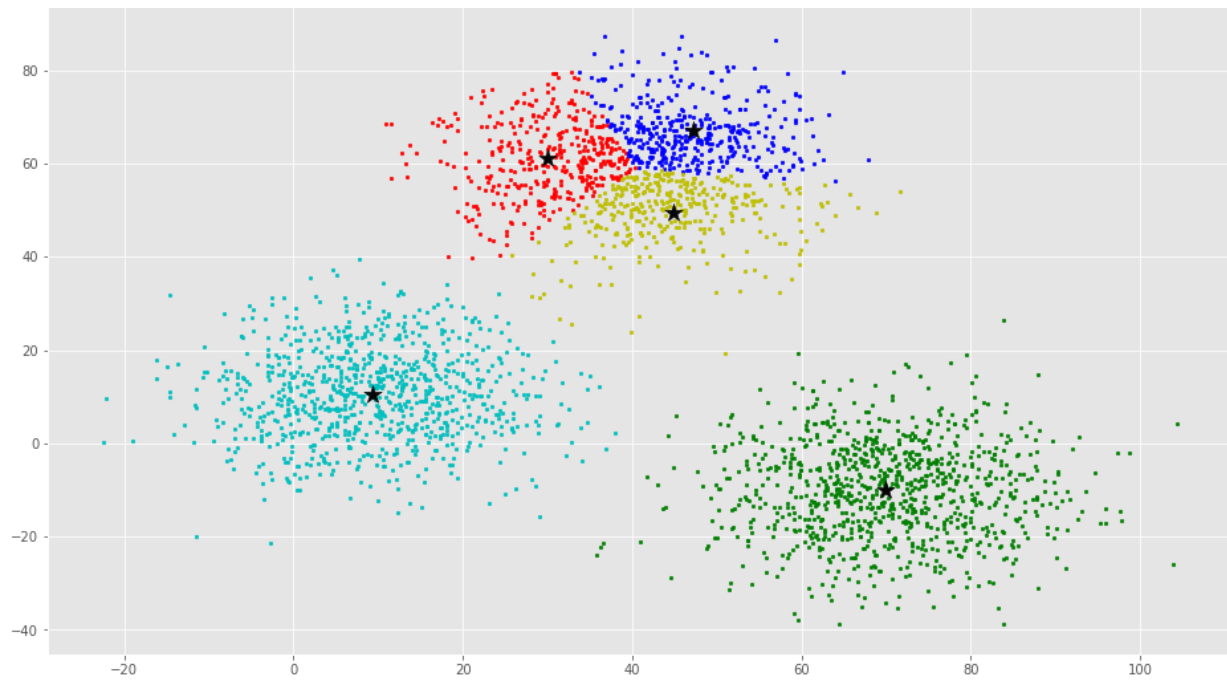


From this visualization it is clear that there are 3 clusters with black stars as their centroid.

If you run K-Means with wrong values of K, you will get completely misleading clusters. For example, if you run K-Means on this with values 2, 4, 5 and 6, you will get the following clusters.







Now we will see how to implement K-Means Clustering using **scikit-learn**

## The scikit-learn approach

### Example 1

We will use the same dataset in this example.

```
from sklearn.cluster import KMeans

# Number of clusters
kmeans = KMeans(n_clusters=3)
# Fitting the input data
kmeans = kmeans.fit(X)
# Getting the cluster labels
labels = kmeans.predict(X)
# Centroid values
centroids = kmeans.cluster_centers_
```

```
# Comparing with scikit-learn centroids
print(C) # From Scratch
print(centroids) # From sci-kit learn
```

```
[[ 9.47804546 10.68605232]
 [ 40.68362808 59.71589279]
 [ 69.92418671 -10.1196413 ]]
[[ 9.4780459 10.686052 ]
 [ 69.92418447 -10.11964119]
 [ 40.68362784 59.71589274]]
```

You can see that the centroid values are equal, but in different order.

## Example 2

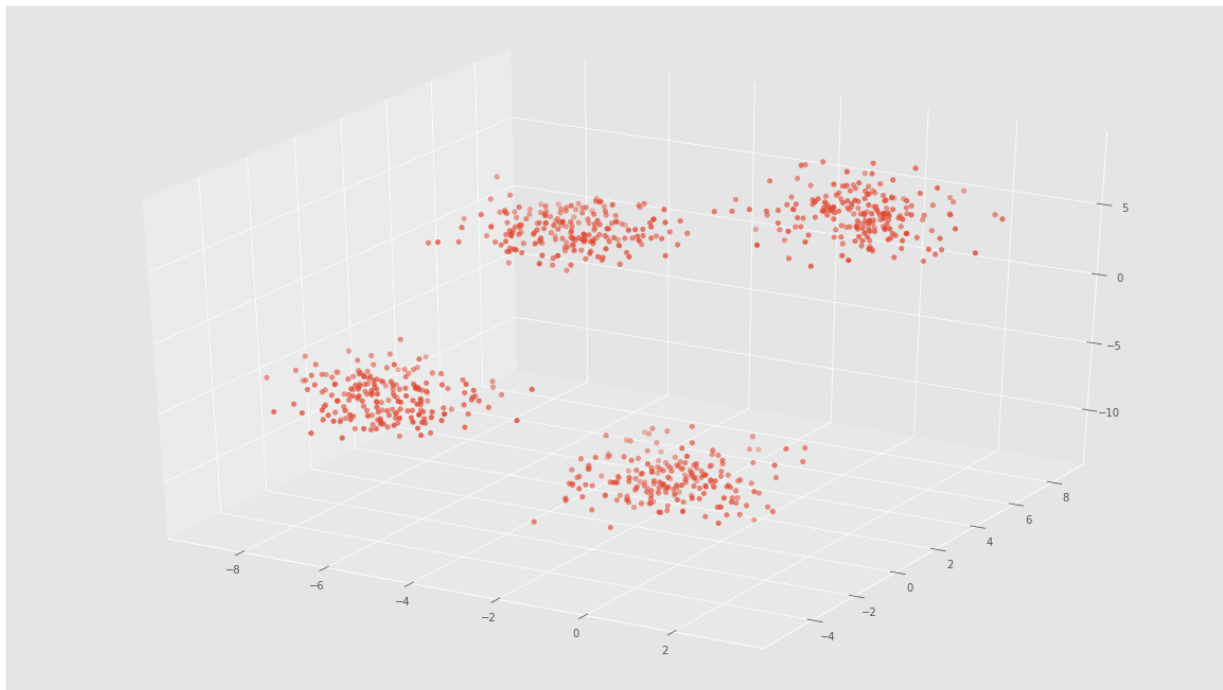
We will generate a new dataset using `make_blobs` function.

```
import numpy as np
import matplotlib.pyplot as plt
from mpl_toolkits.mplot3d import Axes3D
from sklearn.cluster import KMeans
from sklearn.datasets import make_blobs

plt.rcParams['figure.figsize'] = (16, 9)

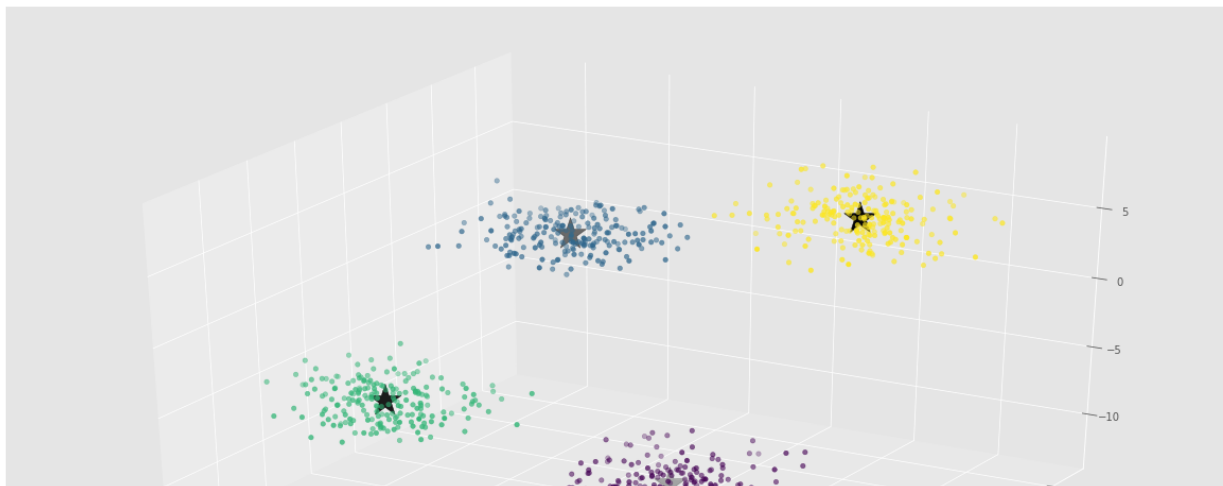
# Creating a sample dataset with 4 clusters
X, y = make_blobs(n_samples=800, n_features=3, centers=4)
```

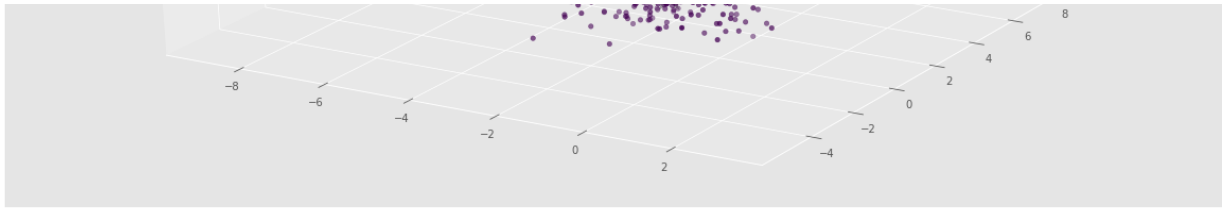
```
fig = plt.figure()
ax = Axes3D(fig)
ax.scatter(X[:, 0], X[:, 1], X[:, 2])
```



```
# Initializing KMeans
kmeans = KMeans(n_clusters=4)
# Fitting with inputs
kmeans = kmeans.fit(X)
# Predicting the clusters
labels = kmeans.predict(X)
# Getting the cluster centers
C = kmeans.cluster_centers_
```

```
fig = plt.figure()
ax = Axes3D(fig)
ax.scatter(X[:, 0], X[:, 1], X[:, 2], c=y)
ax.scatter(C[:, 0], C[:, 1], C[:, 2], marker='*', c='#050505', s=1000)
```





In the above image, you can see 4 clusters and their centroids as stars. scikit-learn approach is very simple and concise.

## More Resources

- K-Means Clustering Video (<https://www.youtube.com/watch?v=9991JIKnFmk>) by Siraj Raval
- K-Means Clustering Lecture Notes (<http://cs229.stanford.edu/notes/cs229-notes7a.pdf>) by Andrew Ng
- K-Means Clustering Slides (<http://people.csail.mit.edu/dsontag/courses/ml13/slides/lecture14.pdf>) by David Sontag (New York University)
- Programming Collective Intelligence Chapter 3 (<http://amzn.to/2xORaMc>)
- The Elements of Statistical Learning Chapter 14 (<http://amzn.to/2x9T5ZF>)
- Pattern Recognition and Machine Learning Chapter 9 (<http://amzn.to/2x9u3Ka>)

Checkout this Github Repo (<https://github.com/mubaris/friendly-fortnight>) for full code and dataset.

## Conclusion

Even though it works very well, K-Means clustering has its own issues. That include:

- If you run K-means on uniform data, you will get clusters.
- Sensitive to scale due to its reliance on Euclidean distance.
- Even on perfect data sets, it can get stuck in a local minimum

Have a look at this StackOverflow Answer (<https://stats.stackexchange.com/a/133841>) for detailed explanation.

Let me know if you found any errors and checkout this post on Hacker News (<https://news.ycombinator.com/item?id=15383216>)

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Name **Pablo Ruiz** • 23 days ago

Hi Mubaris, really great post!

Just one comment, when you call `dis(X[i], C)` you are comparing an array of shape(2,1) with an array of (3,2); which of course don't match. What am I missing? Shouldn't you create distances as an empty list and then iterate over the 3 centers and append the resulting distances?

Thanks in advance and keep it up!

Regards,  
Pablo



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