Skills Network

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K Means Clustering with Python

Estimated time needed: **45** minutes

How do brands always know which new products should recommend to me? Can they read my mind? Well, sort of. By (legally) gathering information about you and your purchasing habits, corporations are able to group you with other customers that have similar characteristics. K Means clustering is one such algorithm that can categorize similar people! Then, companies can determine this population's potential preferences and personalize your experience with the brand, which ranges from product recommendations to email marketing content.

In this notebook, you will learn the fundamentals of how to accomplish grouping with K Means and use it for segmenting mall customers and images.

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Objectives

After completing this lab you will be able to:

- Explain the theory behind K Means Clustering
- Implement K Means Clustering to perform exploratory data analysis
- Perform Image segmentation using K Means

Setup

For this lab, we will be using the following libraries:

- `pandas` (https://pandas.pydata.org/?utm_medium=Exinfluencer&utm_source=Exinfluencer&utm_content=000026UJ&utm_term=10006555&utm_id=NA-SkillsNetwork-Channel-SkillsNetworkCoursesIBMML0187ENSkillsNetwork31430127-2021-01-01) for managing the data.
- `numpy` (https://numpy.org/?utm_medium=Exinfluencer&utm_source=Exinfluencer&utm_content=000026UJ&utm_term=10006555&utm_id=NA-SkillsNetwork-Channel-SkillsNetworkCoursesIBMML0187ENSkillsNetwork31430127-2021-01-01) for mathematical operations.
- `sklearn` (https://scikit-learn.org/stable/?utm_medium=Exinfluencer&utm_source=Exinfluencer&utm_content=000026UJ&utm_term=10006555&utm_id=NA-SkillsNetwork-Channel-SkillsNetworkCoursesIBMML0187ENSkillsNetwork31430127-2021-01-01) for machine learning and machine-learning-pipeline related functions.
- `matplotlib` (https://matplotlib.org/?utm_medium=Exinfluencer&utm_source=Exinfluencer&utm_content=000026UJ&utm_term=10006555&utm_id=NA-SkillsNetwork-Channel-SkillsNetworkCoursesIBMML0187ENSkillsNetwork31430127-2021-01-01) for additional plotting tools.

Installing Required Libraries

The following required libraries are pre-installed in the Skills Network Labs environment. However, if you run this notebook commands in a different Jupyter environment (e.g. Watson Studio or Ananconda), you will need to install these libraries by removing the `#` sign before `!mamba` in the corresponding code cell below.

In [1]:
```
# All Libraries required for this lab are listed below. The libraries pre-installed on Skills Network Labs are comment
# !mamba install -qy pandas==1.3.4 numpy==1.21.4 matplotlib==3.5.0 scikit-learn==0.20.1
# Note: If your environment doesn't support "!mamba install", use "!pip install"
```

Importing Required Libraries

In [11]:
```
def warn(*args, **kwargs):
    pass
import warnings
warnings.warn = warn
warnings.filterwarnings('ignore')

import numpy as np
import pandas as pd
from sklearn.cluster import KMeans
from matplotlib import pyplot as plt
%matplotlib inline
```

Introduction

K Means Clustering is an unsupervised machine learning algorithm that organizes data into distinct groups based on certain similarities. The principle underlying the algorithm is simple to understand and is a great introduction to the potential of unsupervised learning algorithms for exploratory data analysis. In this lab, we will brush up on the basic theory underlying the algorithm and then go ahead and apply it ourselves to a real problem.

About K Means

Pros	Cons
Easy to implement	Must manually chose K
Always converges to local minimum	Not guaranteed to find global minimum
Scales well to large datasets	May not perform well on data of varying density

How does K Means Clustering work?

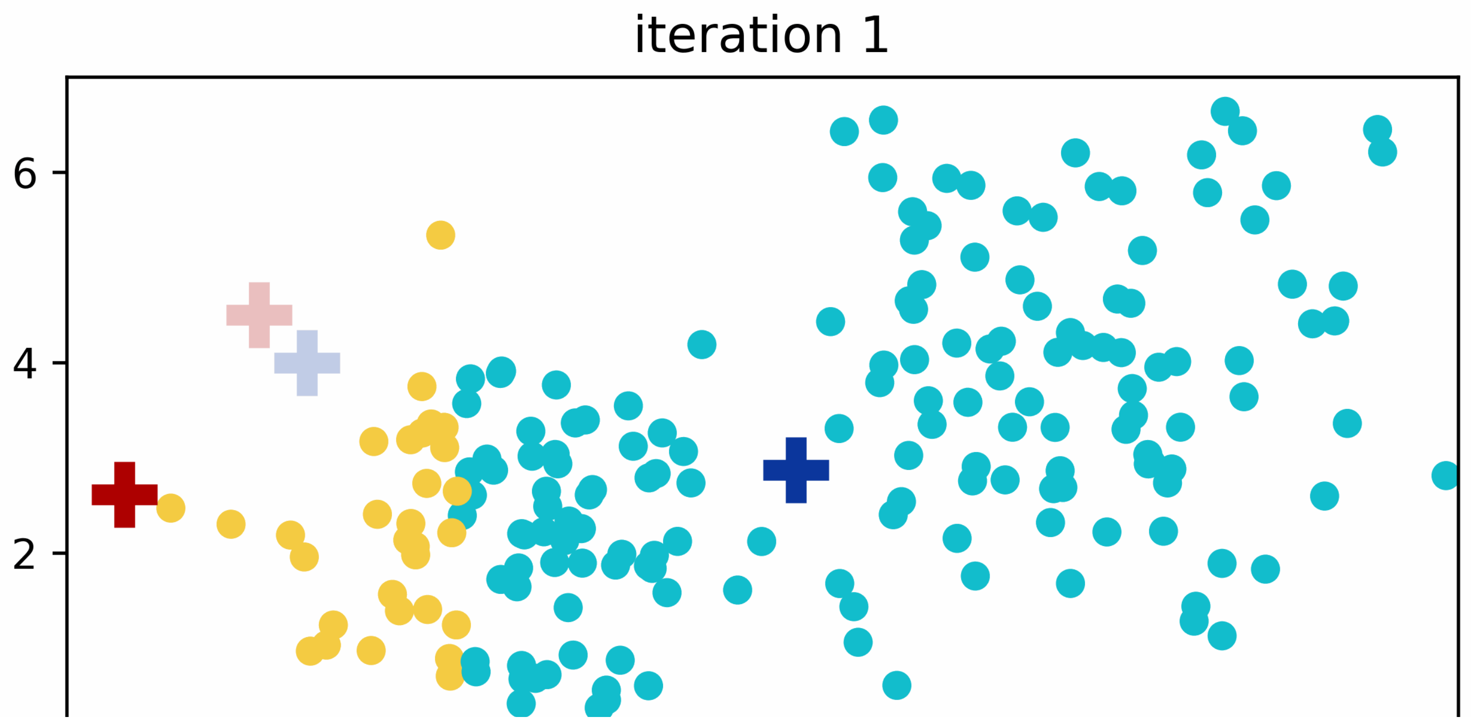
The KMeans algorithm is quite simple and can be broken down into the following steps:

1. We specify the hyperparameter `k`, which refers to the number of clusters we want our data to be clustered into.
2. Then `k` centroids, or cluster-means, are initialized at random.
3. Finally, the optimal centroid locations are found. This is done by the following algorithmic loop:
    A. **Assignment step:** Assign each data point to the nearest centroid (calculated as the squared distance from the data point to centroid).
    B. **Update step:** Recompute each centroid as the mean of the data points assigned to that cluster in the previous step.
4. We repeat the above step until the centroid locations remain unchanged. This tells us the algorithm has converged on a local optima and gives us the final cluster assignments for that run.

Example 1: Visual intuition

Take a look at the following animation for some physical intuition of what's going on during each iteration.

It shows several iterations of K Means Clustering (steps 3 & 4 in previous section) applied to a sample dataset with `k = 2` clusters.



Example 2: Segmenting Customer Data

While the theory and implementation of these algorithms are fascinating in their own right, as data scientists we're driven by the insights we can uncover and the stories we can tell with data.

Now more than ever, companies are making data driven business decisions, in part thanks to the massive increase of data available, as well as the availability of computational power to process and make sense of the data.

Customer segmentation is a process where customers are grouped together based on some common characteristics. For example, customers can be divided based on age, gender, income, marital status, and others. Segmenting customers in this way can have several applications for a business. For instance, common characteristics of the most profitable customers can be identified and a tailored marketing strategy can be implemented to target them.

Let's have a go at customer segmentation using the K Means Clustering algorithm.

Problem Statement

Suppose you are a data scientist at MegaMind Sporting Goods Ltd.

You've been tasked with segmenting customers into groups depending on their purchasing habits.

Once you have this information, your colleague John will be able to generate clothing recommendations tailored for each customer group.

About the dataset

We will explore a simple example of customer segmentation using the Mall Customers (https://github.com/SteffiPeTaffy/machineLearningAZ/blob/master/Machine%20Learning%20A-Z%20Template%20Folder/Part%204%20-%20Clustering/Section%2024%20-%20K-Means%20Clustering/Mall_Customers.csv) dataset. This is an artificial dataset that contains data on customers of a shopping mall. In particular, the following features are given about each customer.

- **CustomerID** - A unique identifying number for each customer
- **Gender**
- **Age**
- **Annual Income** - The annual income of the customer given in thousands of dollars
- **Spending Score** - A value given to the customer based on their spending habits, such as total spending and frequency. A higher value indicates a higher value customer for the mall

Loading the dataset

In [3]:
```
# Download the dataset and read it into a Pandas dataframe
df = pd.read_csv('https://cf-courses-data.s3.us.cloud-object-storage.appdomain.cloud/IBM-ML0187EN-SkillsNetwork/labs/m
```

Let's take a peek at our dataset to ensure it was loaded properly.

In [4]:
```
df.head()
```

Out[4]:

CustomerID	Gender	Age	Annual Income (k$)	Spending Score (1-100)
1	Male	19	15	39
2	Male	21	15	81
3	Female	20	16	6
4	Female	23	16	77
5	Female	31	17	40

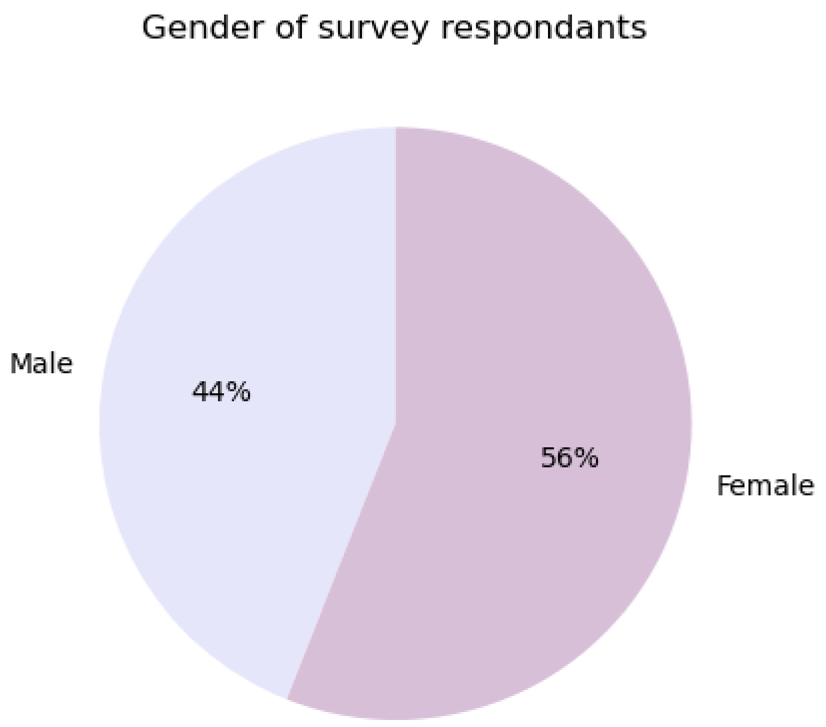
Getting familiar with the data

First, let's take a look at the data we have to gain a better general understanding of it before we attempt any clustering.

Let's start by looking at the distributions of some of the features.

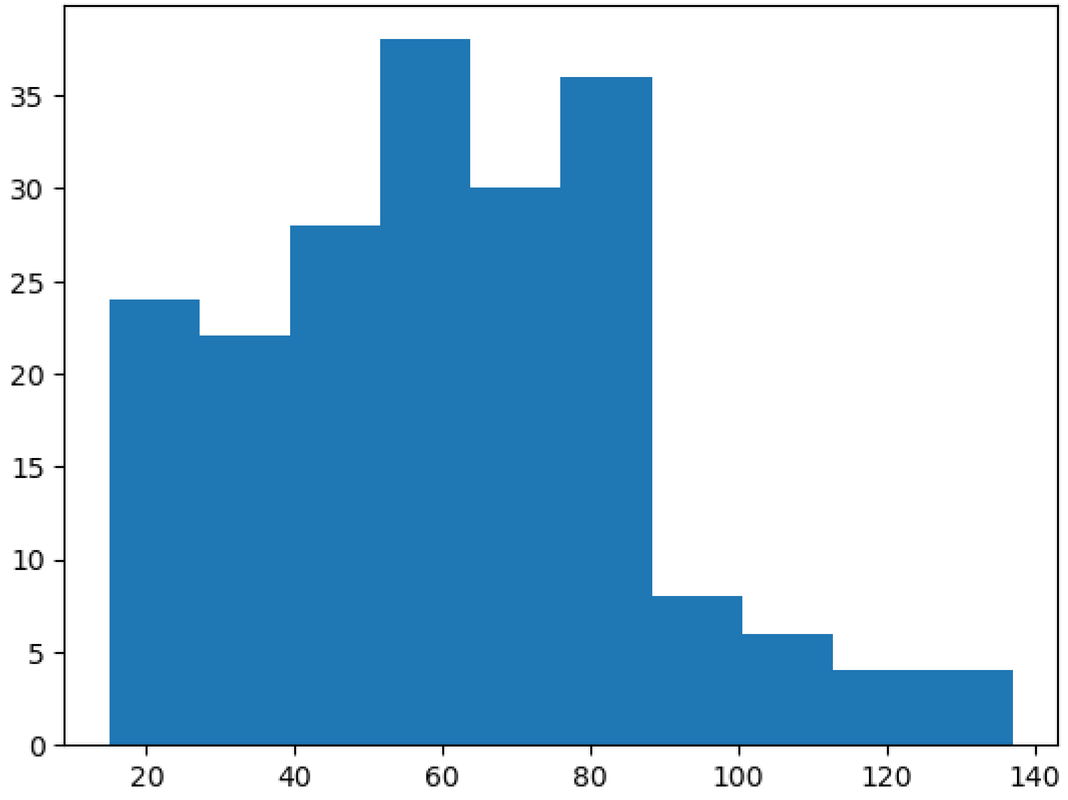
We can start by analyzing the ratio of male to female customers that were surveyed.

In [5]:
```
num_male = df[df['Gender'] == 'Male'].shape[0]
num_female = df[df['Gender'] == 'Female'].shape[0]
plt.pie(
    [num_male, num_female],
    labels=['Male', 'Female'],
    startangle=90,
    autopct='%1.f%%',
    colors=['lavender', 'thistle'])
plt.title('Gender of survey respondants')
plt.show()
```



We see that we have slightly more female respondents in our survey. Next, let's plot histograms of the age and annual incomes of the customers.

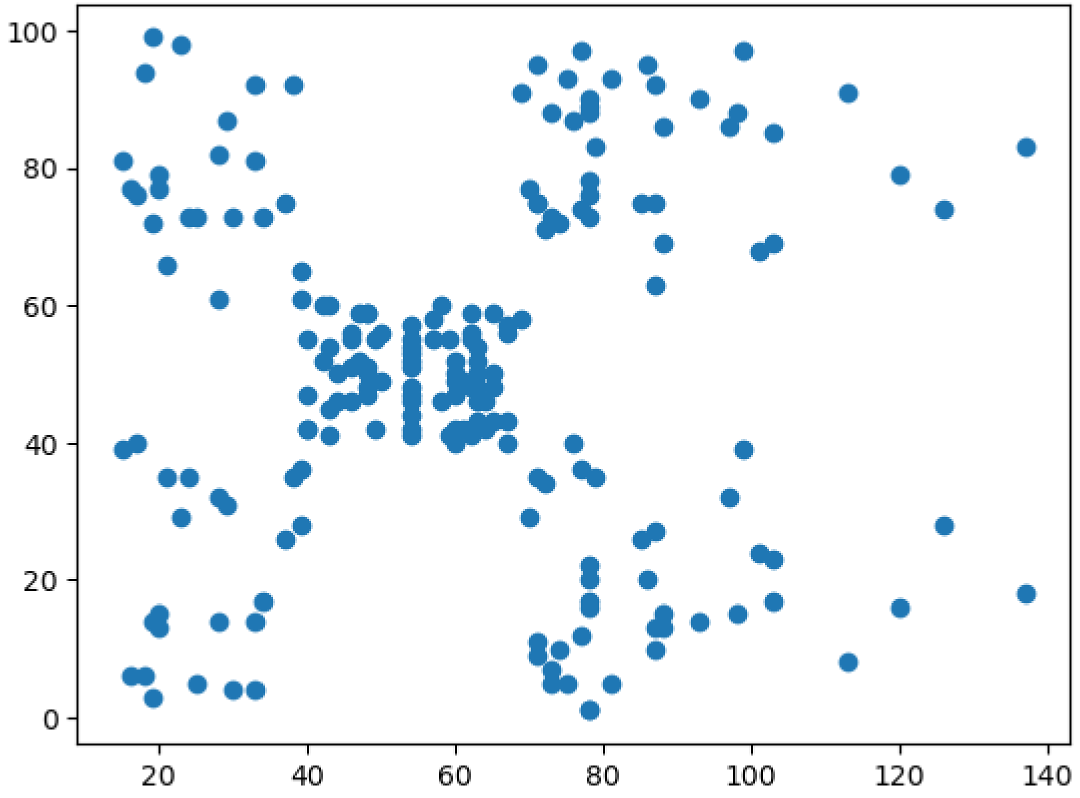
In [6]:
```
plt.hist(df['Annual Income (k$)'], bins=10)
plt.show()
```



Our distribution appears slightly skewed to the right. Not as many people are making over $100k per year.

Let's take a look at people's annual income vs. spending score:

In [7]:
```
X = df[['Annual Income (k$)', 'Spending Score (1-100)']]
plt.scatter(X['Annual Income (k$)'], X['Spending Score (1-100)'])
plt.show()
```



This looks promising, we can see our customers seem to fall into ~5 categories:

1. **Low** income, **high** spending.
2. **High** income, **low** spending.
3. **Low** income, **low** spending.
4. **High** income, **low** spending.
5. **Medium** income, **medium** spending.

If we manage to segment our existing customers into these 5 categories, we will obtain exactly the information John requires:

Clustering the data using K Means

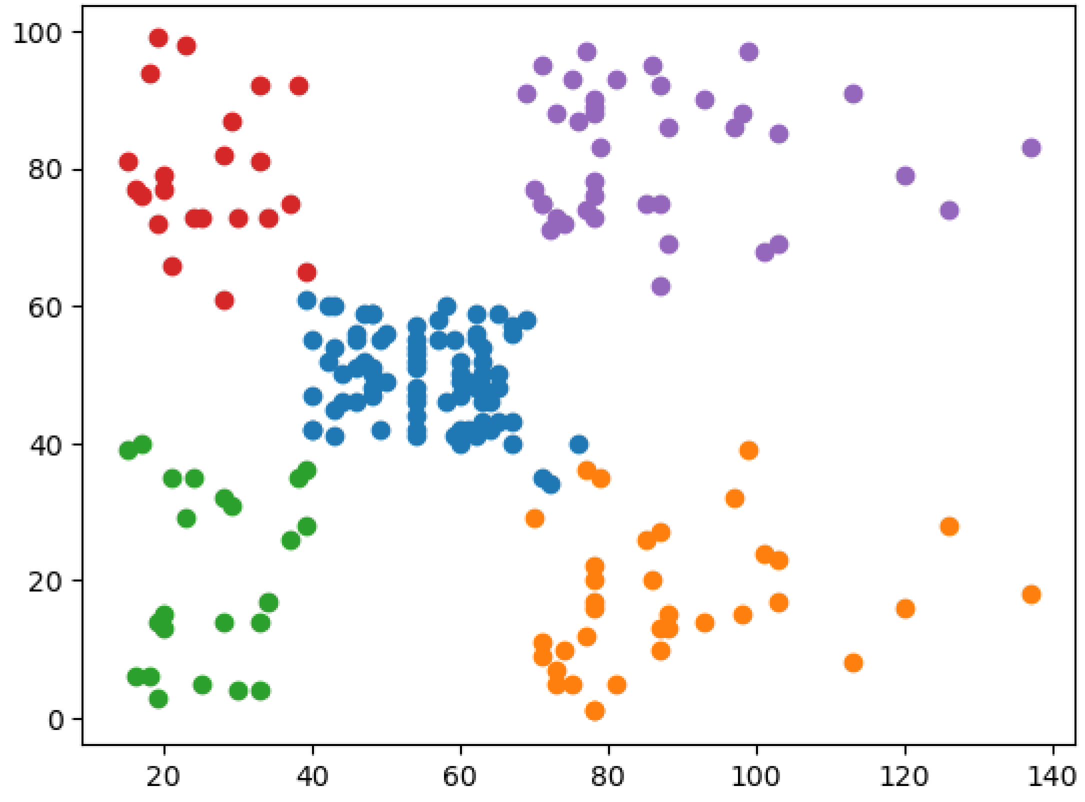
Let's start clustering our data!

To do so, we simply load the `sklearn.cluster.KMeans` object - with our desired number of clusters `k = 5` :

In [8]:
```
km = KMeans(n_clusters=5, random_state=42)
km.fit(X)
```

Out[8]:
```
▾                KMeans
KMeans(n_clusters=5, random_state=42)
```

In [9]:
```
for label in np.unique(km.labels_):
    X_ = X[label == km.labels_]
    plt.scatter(X_['Annual Income (k$)'], X_['Spending Score (1-100)'], label=label)
plt.show()
```



Awesome! Our KMeans algorithm was able to correctly group our data into the 5 categories that we initially noticed

Example 3: Image Segmentation

Image segmentation is the process of locating objects and boundaries in an image.

Various clustering can be used for this task.

How is this done?:

1. We cluster pixels using their brightness (grayscale) or RGB values (color).
2. We replace each pixel with the average brightness or RGB value of pixels in their cluster.

Let's look at an example using KMeans:

Loading the data

Let's start by loading the data into a `numpy.array` and taking a look at the image:

In [49]:
```
img_path = img_path = 'C:/Users/Hp/Downloads/cameraman.png'
img = plt.imread(img_path)
print(f'The image is {img.shape[0]}px by {img.shape[1]}px')
plt.axis('off')
plt.imshow(img)
plt.show()
```

```
The image is 490px by 487px
```

Segmenting the image using 2 clusters

In this example, we will segment our image into `k = 2` color-clusters:

In [36]:
```
k = 2

X = img.reshape(-1, 1)
km = KMeans(n_clusters=k, random_state=42)
```

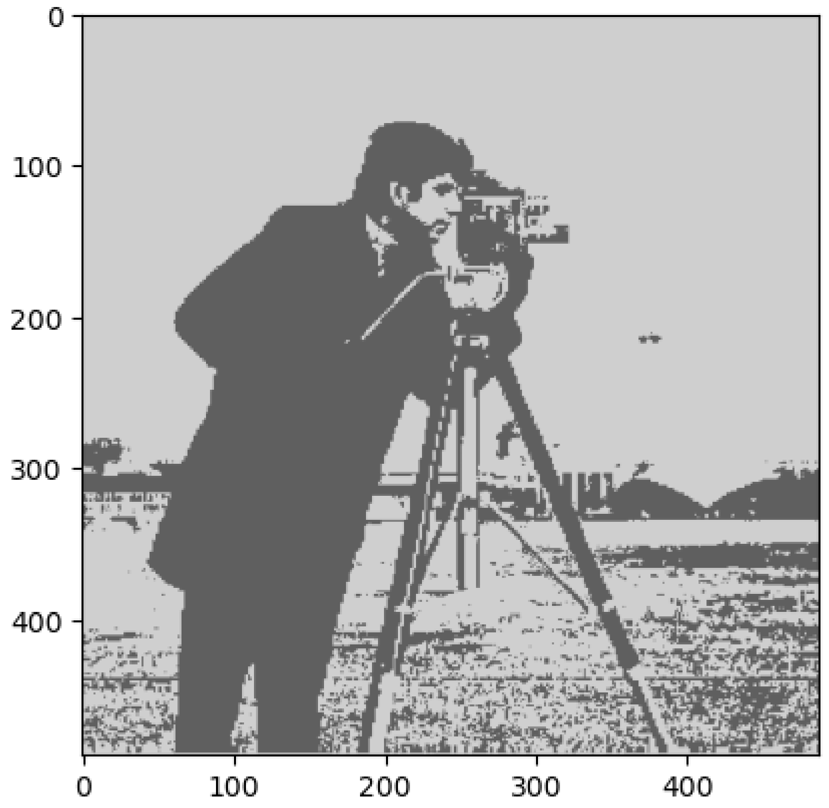
In [37]:
```
km.fit(X)
```

Out[37]:
```
▾                    KMeans

KMeans(n_clusters=2, random_state=42)
```

Let's see our segmented image; once we replace each pixel with the mean of the cluster it belongs to:

In [38]:
```
seg = np.zeros(X.shape)
for i in range(k):
    seg[km.labels_ == i] = km.cluster_centers_[i]
seg = seg.reshape(img.shape)
plt.imshow(seg)
```

Out[38]:
```
<matplotlib.image.AxesImage at 0x240de4efa60>
```



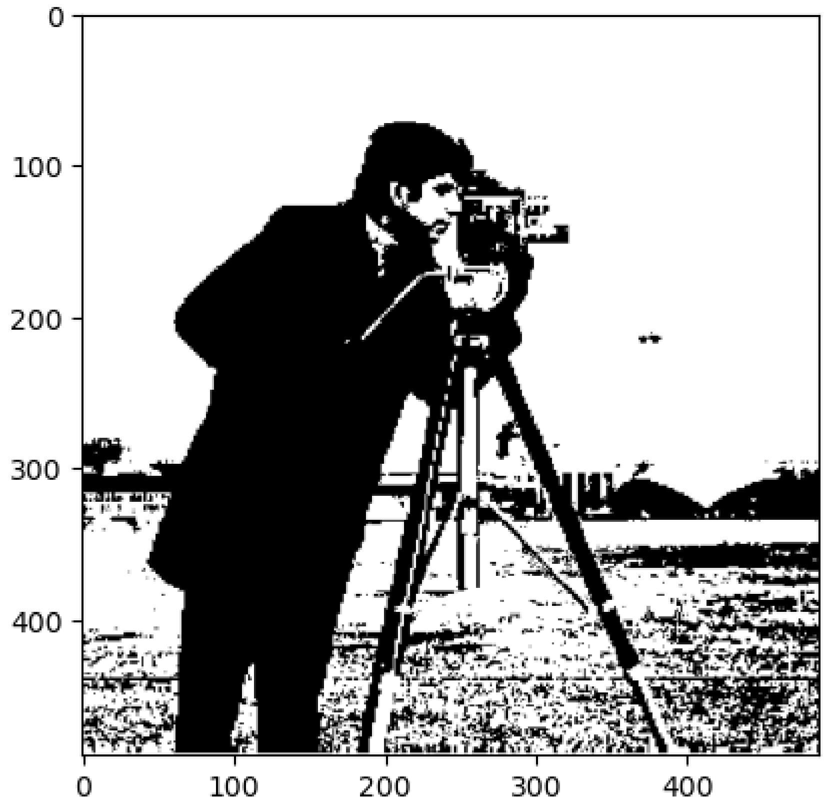
Awesome! Even as humans, we can still easily recognize our image after segmentation with `k = 2` colors.

Converting to black and white

Alternatively, we may view the image in black and white:

In [39]:
```
seg = np.zeros(X.shape)
for i in range(k):
    seg[km.labels_ == i] = 255 if km.cluster_centers_[i] > 0.5 else 0
seg = seg.reshape(img.shape).astype(np.uint8)
plt.imshow(seg)
```

Out[39]:
```
<matplotlib.image.AxesImage at 0x240df839d20>
```



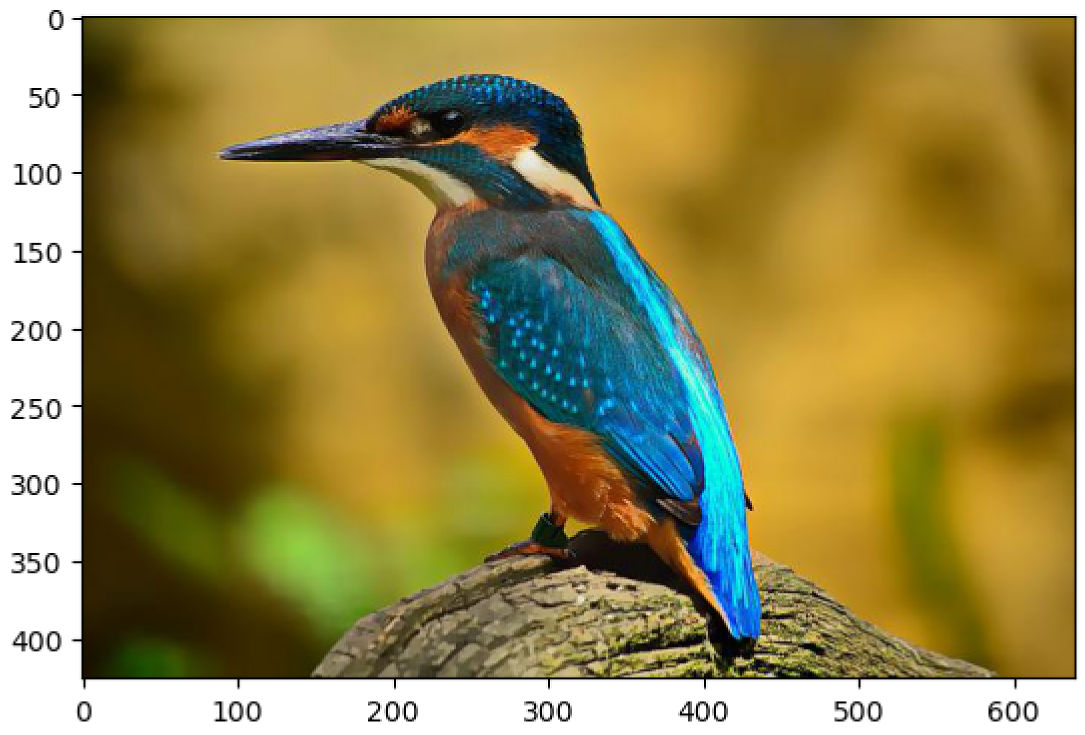
Exercises

In this section, we will segment another image; this time in full-color with various values for k.

Please run the following cell to load the data for the exercises:

In [40]:
```
img = plt.imread('C:Users/Hp/Downloads/kingfisher.jpeg', format='jpeg')
plt.imshow(img)
```

Out[40]:
```
<matplotlib.image.AxesImage at 0x240df8a1db0>
```



Exercise 1 - Fitting KMeans With k=2

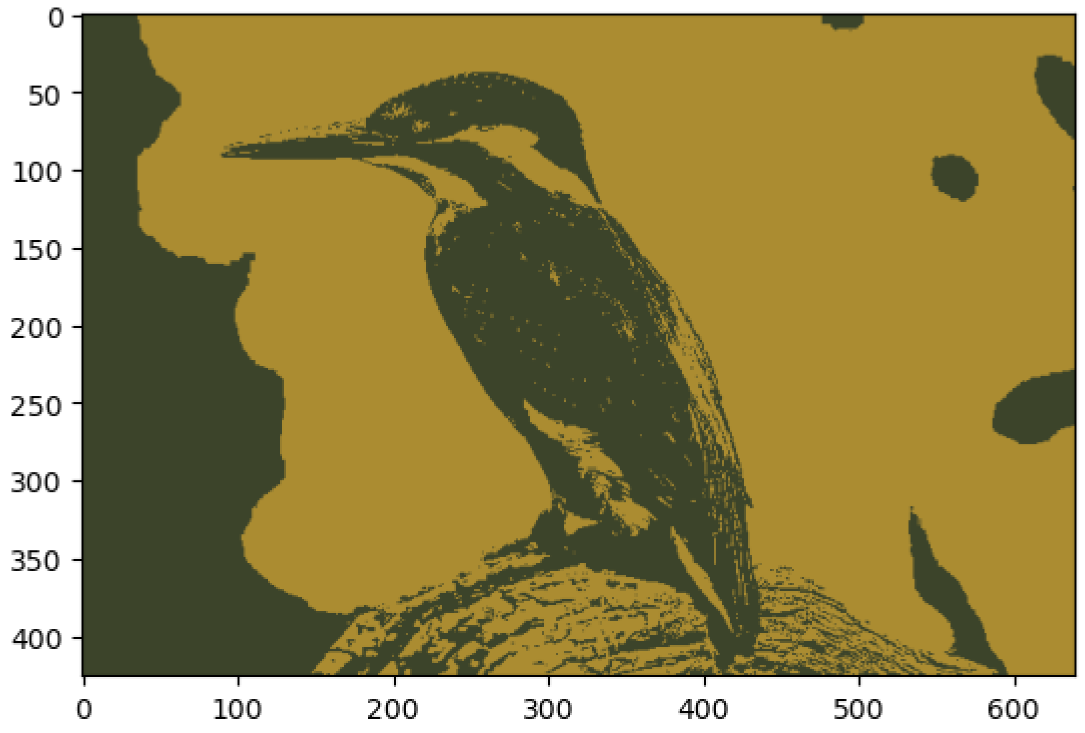
In [41]:
```
# Enter your solution here
k = 2

X = img.reshape(-1, 3) # Remember, since image is RGB
km = KMeans(n_clusters=k, random_state=42)
km.fit(X)
```

Out[41]:
```
▾                 KMeans
KMeans(n_clusters=2, random_state=42)
```

Exercise 2 - Viewing Segmented Image

In [42]:
```
# Enter your solution here
seg = np.zeros(X.shape)
for i in range(k):
    seg[km.labels_ == i] = km.cluster_centers_[i]
seg = seg.reshape(img.shape).astype(np.uint8)
plt.imshow(seg)
```

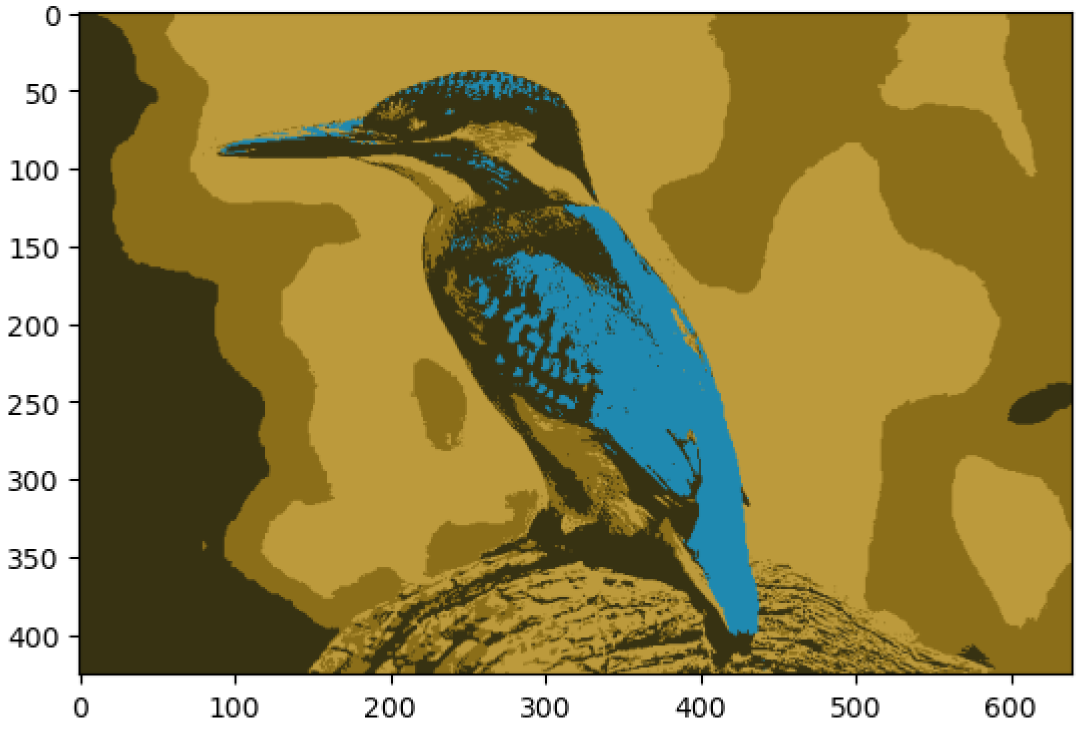
Out[42]:
```
<matplotlib.image.AxesImage at 0x240df93d7e0>
```



Exercise 3 - Fitting KMeans With k=4 and Viewing Segmented Image

In [43]:
```
# Enter your solution here
k = 4

X = img.reshape(-1, 3) # Remember, since image is RGB
km = KMeans(n_clusters=k, random_state=42)
km.fit(X)

seg = np.zeros(X.shape)
for i in range(k):
    seg[km.labels_ == i] = km.cluster_centers_[i]
seg = seg.reshape(img.shape).astype(np.uint8)
plt.imshow(seg)
```

Out[43]:
```
<matplotlib.image.AxesImage at 0x240df93d030>
```



Congratulations! You've completed the exercises. Later, you will learn about another clustering algorithm, GMM, which performs even better on image segmentation.

Thank you for completing this lab!

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Other Contributors

Change Log

Date (YYYY-MM-DD)	Version	Changed By	Change Description
2022-03-28	0.1	David Pasternak	Created Lab
2022-05-10	0.2	Sam Prokopchuk	Complete Draft of Lab