



OPEN CV WITH PYTHON

tutorialspoint
SIMPLY EASY LEARNING

www.tutorialspoint.com



<https://www.facebook.com/tutorialspointindia>



<https://twitter.com/tutorialspoint>

About the Tutorial

OpenCV stands for **Open Source Computer Vision** and is a library of functions which is useful in real time computer vision application programming. **OpenCV-Python** is a Python wrapper around C++ implementation of OpenCV library. It is a rapid prototyping tool for computer vision problems. This tutorial is designed to give fluency in OpenCV-Python and to explain how you can use it in your applications.

Audience

This tutorial is designed for the computer science students and professionals who wish to gain expertise in the field of computer vision applications. After completing this tutorial you will find yourself at a moderate level of expertise in using OpenCV-Python from where you can take yourself to next levels.

Prerequisites

We assume you have prior knowledge of Python and NumPy libraries. Moreover, it would be beneficial, if you are well acquainted with JAVA programming language. You can go through our tutorials on Python, JAVA and NumPy, if required, before beginning with this tutorial.

Copyright & Disclaimer

© Copyright 2021 by Tutorials Point (I) Pvt. Ltd.

All the content and graphics published in this e-book are the property of Tutorials Point (I) Pvt. Ltd. The user of this e-book is prohibited to reuse, retain, copy, distribute or republish any contents or a part of contents of this e-book in any manner without written consent of the publisher.

We strive to update the contents of our website and tutorials as timely and as precisely as possible, however, the contents may contain inaccuracies or errors. Tutorials Point (I) Pvt. Ltd. provides no guarantee regarding the accuracy, timeliness or completeness of our website or its contents including this tutorial. If you discover any errors on our website or in this tutorial, please notify us at contact@tutorialspoint.com

Table of Contents

About the Tutorial	i
Audience.....	i
Prerequisites.....	i
Copyright & Disclaimer	i
Table of Contents	ii
1. OpenCV-Python – Overview.....	1
2. OpenCV-Python — Environment Setup.....	2
3. OpenCV-Python — Reading an image	3
4. OpenCV-Python — Write an image	5
5. OpenCV-Python — Using Matplotlib	6
6. OpenCV-Python — Image Properties	8
7. OpenCV-Python — Bitwise Operations	10
8. OpenCV-Python — Draw Shapes and Text	14
Draw Shapes on Images	14
Draw Text	16
9. OpenCV-Python — Handling Mouse Events	18
10. OpenCV-Python — Add Trackbar	22
11. OpenCV-Python — Resize and Rotate an Image.....	24
Resize an Image	24
Rotate an image	25
12. OpenCV-Python — Image Threshold	27
13. OpenCV-Python — Image Filtering.....	33
14. OpenCV-Python — Edge Detection	36
15. OpenCV-Python — Histogram.....	38
Histogram using Matplotlib.....	38
16. OpenCV-Python — Color Spaces	40

17. OpenCV-Python — Morphological Transformations	43
Erosion	43
Dilation	43
18. OpenCV-Python — Image Contours	46
Find Contour	46
Draw Contour	46
19. OpenCV-Python — Template Matching	50
20. OpenCV-Python — Image Pyramids	53
21. OpenCV-Python — Image Addition	57
22. OpenCV-Python — Image Blending with Pyramids	60
23. OpenCV-Python — Fourier Transform.....	63
24. OpenCV-Python — Capture Video from Camera	65
25. OpenCV-Python — Play Video from File.....	67
26. OpenCV-Python — Extract Images from Video.....	69
27. OpenCV-Python — Video from Images	70
28. OpenCV-Python — Face Detection.....	71
29. OpenCV-Python — Meanshift and Camshift	73
Meanshift	73
Camshift.....	75
30. OpenCV-Python — Feature Detection.....	77
31. OpenCV-Python — Feature Matching	80
32. OpenCV-Python — Digit Recognition with KNN	82

1. OpenCV-Python – Overview

OpenCV stands for **Open Source Computer Vision** and is a library of functions which is useful in real time computer vision application programming. The term Computer vision is used for a subject of performing the analysis of digital images and videos using a computer program. Computer vision is an important constituent of modern disciplines such as artificial intelligence and machine learning.

Originally developed by Intel, OpenCV is a cross platform library written in C++ but also has a C Interface Wrappers for OpenCV which have been developed for many other programming languages such as Java and Python. In this tutorial, functionality of OpenCV's Python library will be described.

OpenCV-Python

OpenCV-Python is a Python wrapper around C++ implementation of OpenCV library. It makes use of NumPy library for numerical operations and is a rapid prototyping tool for computer vision problems.

OpenCV-Python is a cross-platform library, available for use on all Operating System (OS) platforms including, Windows, Linux, MacOS and Android. OpenCV also supports the Graphics Processing Unit (GPU) acceleration.

This tutorial is designed for the computer science students and professionals who wish to gain expertise in the field of computer vision applications. Prior knowledge of Python and NumPy library is essential to understand the functionality of OpenCV-Python.

2. OpenCV-Python — Environment Setup

In most of the cases, using pip should be sufficient to install OpenCV-Python on your computer.

The command which is used to install pip is as follows:

```
pip install opencv-python
```

Performing this installation in a new virtual environment is recommended. The current version of OpenCV-Python is 4.5.1.48 and it can be verified by following command:

```
>>> import cv2
>>> cv2.__version__
'4.5.1'
```

Since OpenCV-Python relies on NumPy, it is also installed automatically. Optionally, you may install Matplotlib for rendering certain graphical output.

On Fedora, you may install OpenCV-Python by the below mentioned command:

```
$ yum install numpy opencv*
```

OpenCV-Python can also be installed by building from its source available at <http://sourceforge.net/projects/opencvlibrary/>. Follow the installation instructions given for the same.

3. OpenCV-Python — Reading an image

The **CV2** package (name of OpenCV-Python library) provides the **imread()** function to read an image.

The command to read an image is as follows:

```
img=cv2.imread(filename, flags)
```

The flags parameters are the enumeration of following constants:

- cv2.IMREAD_COLOR (1): Loads a color image.
- cv2.IMREAD_GRAYSCALE (0): Loads image in grayscale mode
- cv2.IMREAD_UNCHANGED (-1): Loads image as such including alpha channel

The function will return an image object, which can be rendered using **imshow()** function. The command for using imshow() function is given below:

```
cv2.imshow(window-name, image)
```

The image is displayed in a named window. A new window is created with the AUTOSIZE flag set. The **WaitKey()** is a keyboard binding function. Its argument is the time in milliseconds.

The function waits for specified milliseconds and keeps the window on display till a key is pressed. Finally, we can destroy all the windows thus created.

The program to display the OpenCV logo is as follows:

```
import numpy as np
import cv2
# Load a color image in grayscale
img = cv2.imread('OpenCV_Logo.png',1)
cv2.imshow('image',img)
cv2.waitKey(0)
cv2.destroyAllWindows()
```

The above program displays the OpenCV logo as follows:



4. OpenCV-Python — Write an image

CV2 package has **imwrite()** function that saves an image object to a specified file.

The command to save an image with the help of imwrite() function is as follows:

```
cv2.imwrite(filename, img)
```

The image format is automatically decided by OpenCV from the file extension. OpenCV supports *.bmp, *.dib, *.jpeg, *.jpg, *.png, *.webp, *.sr, *.tiff, *.tif etc. image file types.

Following program loads OpenCV logo image and saves its greyscale version when 's' key is pressed:

```
import numpy as np
import cv2
# Load an color image in grayscale
img = cv2.imread('OpenCV_Logo.png',0)
cv2.imshow('image',img)
key=cv2.waitKey(0)
if key==ord('s'):
    cv2.imwrite("opencv_logo_GS.png", img)
cv2.destroyAllWindows()
```

Output

When you execute the above program, you should see the following output:



5. OpenCV-Python — Using Matplotlib

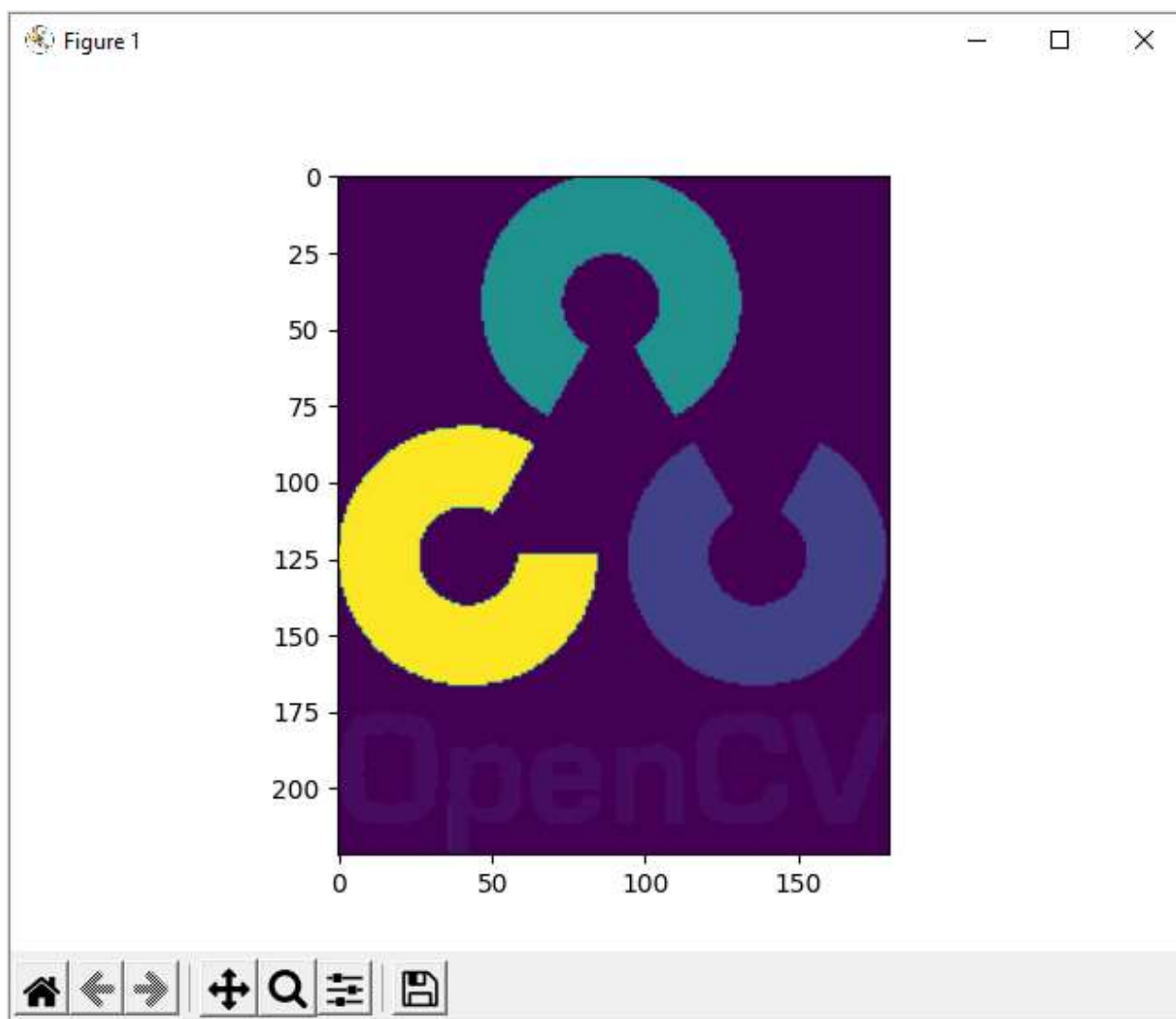
Python's Matplotlib is a powerful plotting library with a huge collection of plotting functions for the variety of plot types. It also has **imshow()** function to render an image. It gives additional facilities such as zooming, saving etc.

Ensure that Matplotlib is installed in the current working environment before running the following program.

```
import numpy as np
import cv2
import matplotlib.pyplot as plt
# Load an color image in grayscale
img = cv2.imread('OpenCV_Logo.png',0)
plt.imshow(img)
plt.show()
```

Output

The Matplotlib output will be displayed as follows:



6. OpenCV-Python — Image Properties

OpenCV reads the image data in a NumPy array. The **shape()** method of this ndarray object reveals image properties such as dimensions and channels.

The command to use the shape() method is as follows:

```
>>> img = cv.imread("OpenCV_Logo.png", 1)
>>> img.shape
(222, 180, 3)
```

In the above command:

- The first two items shape[0] and shape[1] represent width and height of the image.
- Shape[2] stands for a number of channels.
- 3 indicates that the image has Red Green Blue (RGB) channels.

Similarly, the size property returns the size of the image. The command for the size of an image is as follows:

```
>>> img.size
119880
```

Each element in the ndarray represents one image pixel.

We can access and manipulate any pixel's value, with the help of the command mentioned below.

```
>>> p=img[50,50]
>>> p
array([ 1,  1, 255], dtype=uint8)
```

Following code changes the color value of the first 100X100 pixels to black. The **imshow()** function can verify the result.

```
>>> for i in range(100):
    for j in range(100):
        img[i,j]=[0,0,0]
```

Output

When you execute the above code, you should see the following output:



The image channels can be split in individual planes by using the **split()** function. The channels can be merged by using **merge()** function.

The `split()` function returns a multi-channel array.

We can use the following command to split the image channels:

```
>>> img = cv.imread("OpenCV_Logo.png", 1)
>>> b,g,r = cv.split(img)
```

You can now perform manipulation on each plane.

Suppose we set all pixels in blue channel to 0, the code will be as follows:

```
>>> img[:, :, 0]=0
>>> cv.imshow("image", img)
```

The resultant image will be shown as below:



7. OpenCV-Python — Bitwise Operations

Bitwise operations are used in image manipulation and for extracting the essential parts in the image.

Following operators are implemented in OpenCV:

- bitwise_and
- bitwise_or
- bitwise_xor
- bitwise_not

Example 1

To demonstrate the use of these operators, two images with filled and empty circles are taken.

Following program demonstrates the use of bitwise operators in OpenCV-Python:

```
import cv2
import numpy as np

img1 = cv2.imread('a.png')
img2 = cv2.imread('b.png')

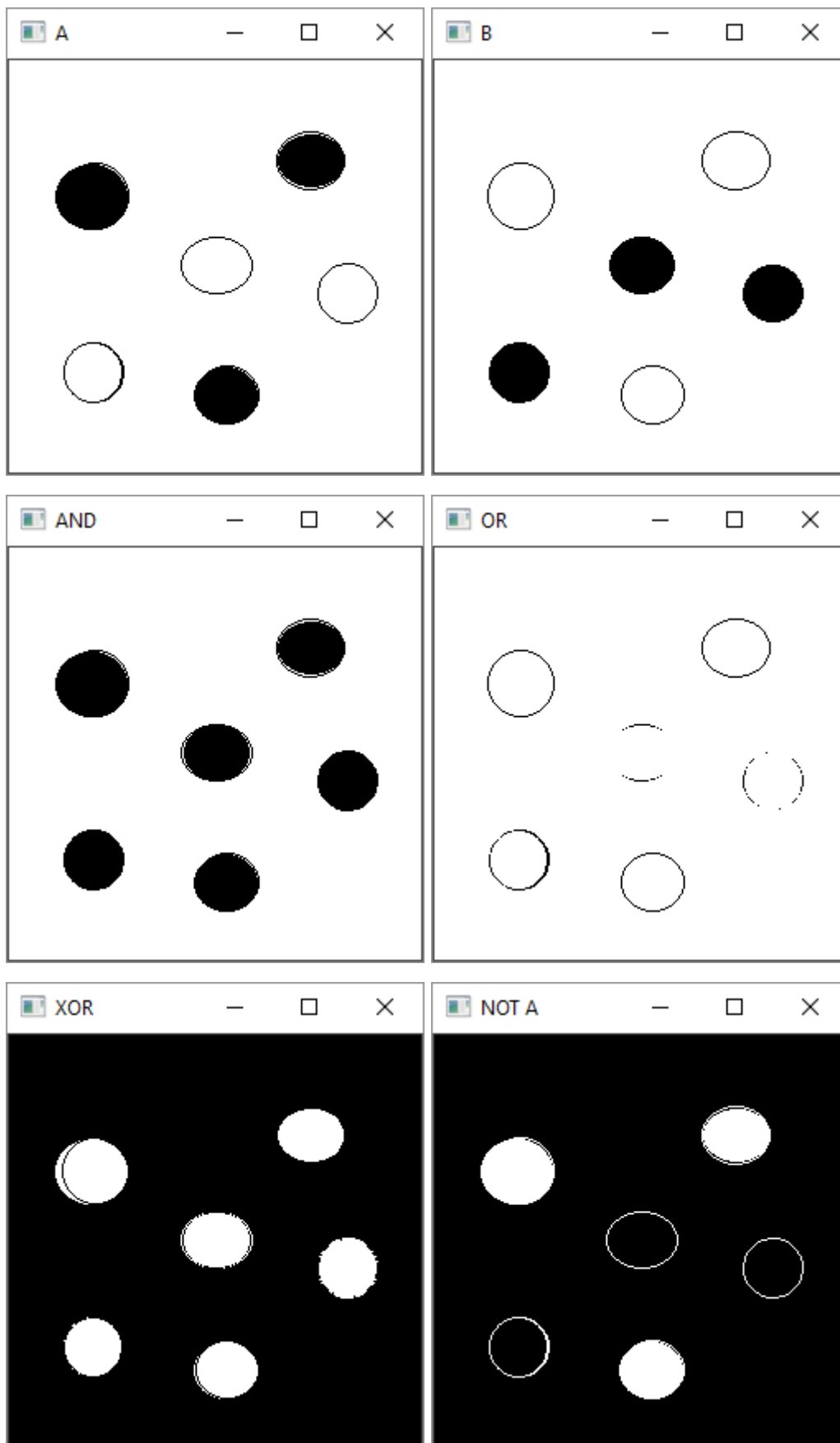
dest1 = cv2.bitwise_and(img2, img1, mask = None)
dest2 = cv2.bitwise_or(img2, img1, mask = None)
dest3 = cv2.bitwise_xor(img1, img2, mask = None)

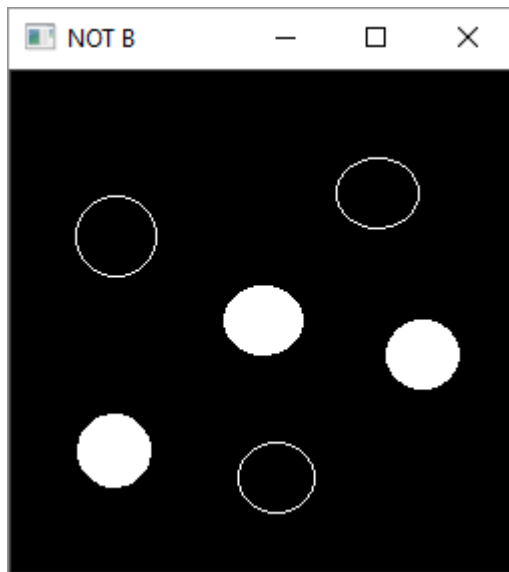
cv2.imshow('A', img1)
cv2.imshow('B', img2)
cv2.imshow('AND', dest1)
cv2.imshow('OR', dest2)
cv2.imshow('XOR', dest3)
cv2.imshow('NOT A', cv2.bitwise_not(img1))
cv2.imshow('NOT B', cv2.bitwise_not(img2))

if cv2.waitKey(0) & 0xff == 27:
    cv2.destroyAllWindows()
```

Output

On executing the above program, you will get the following result:





Example 2

In another example involving bitwise operations, the opencv logo is superimposed on another image. Here, we obtain a mask array calling **threshold()** function on the logo and perform AND operation between them.

Similarly, by NOT operation, we get an inverse mask. Also, we get AND with the background image.

Following is the program which determines the use of bitwise operations:

```
import cv2 as cv
import numpy as np

img1 = cv.imread('lena.jpg')
img2 = cv.imread('whitelogo.png')
rows,cols,channels = img2.shape
roi = img1[0:rows, 0:cols]
img2gray = cv.cvtColor(img2,cv.COLOR_BGR2GRAY)
ret, mask = cv.threshold(img2gray, 10, 255, cv.THRESH_BINARY)
mask_inv = cv.bitwise_not(mask)
# Now black-out the area of logo
img1_bg = cv.bitwise_and(roi,roi,mask = mask_inv)

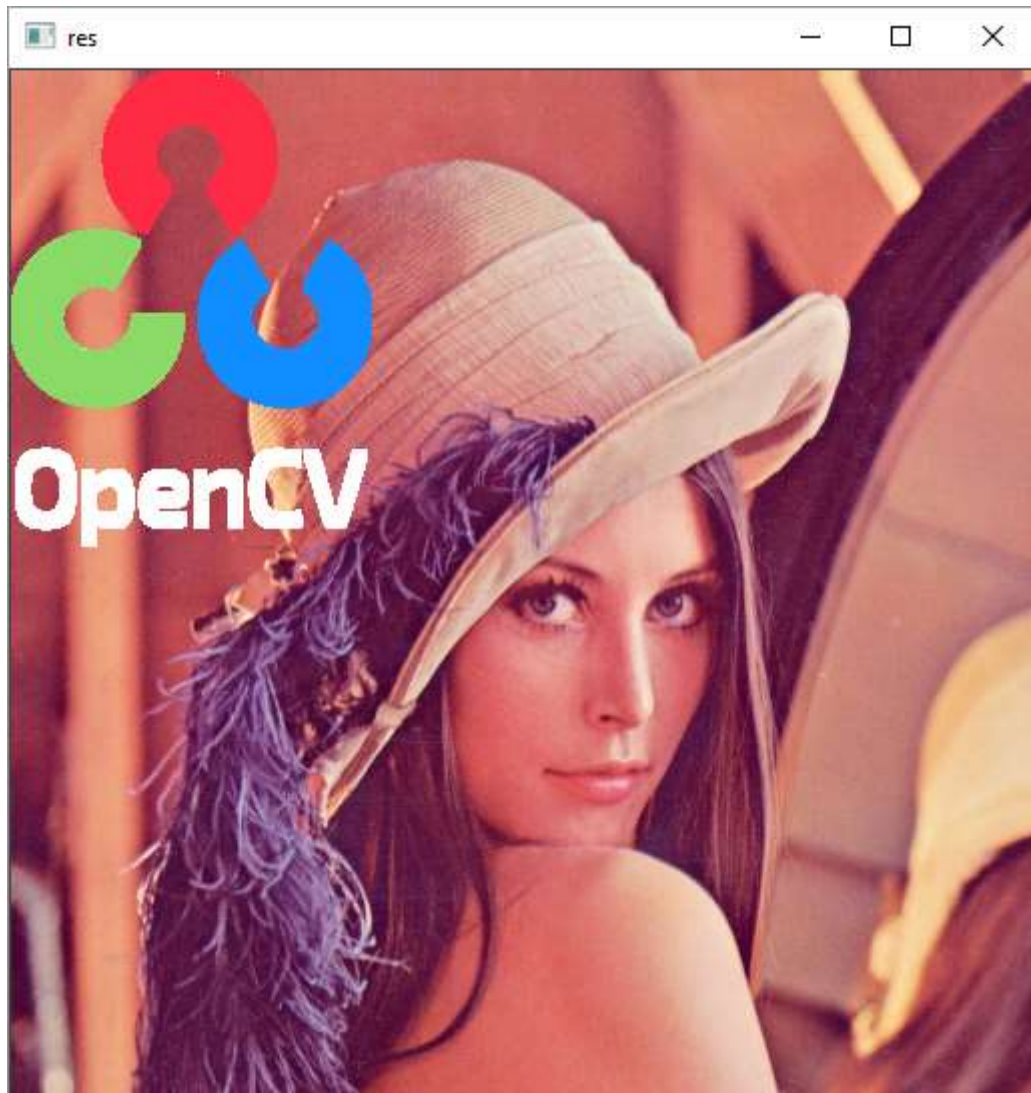
# Take only region of logo from logo image.
img2_fg = cv.bitwise_and(img2,img2,mask = mask)
# Put logo in ROI
dst = cv.add(img2_fg, img1_bg)
img1[0:rows, 0:cols ] = dst
```



```
cv.imshow(Result,img1)  
cv.waitKey(0)  
cv.destroyAllWindows()
```

Output

The masked images give following result:



8. OpenCV-Python — Draw Shapes and Text

In this chapter, we will learn how to draw shapes and text on images with the help of OpenCV-Python. Let us begin by understanding about drawing shapes on images.

Draw Shapes on Images

We need to understand the required functions in OpenCV-Python, which help us to draw the shapes on images.

Functions

The OpenCV-Python package (referred as cv2) contains the following functions to draw the respective shapes.

Function	Description	Command
cv2.line()	Draws a line segment connecting two points.	cv2.line(img, pt1, pt2, color, thickness)
cv2.circle()	Draws a circle of given radius at given point as center	cv2.circle(img, center, radius, color, thickness)
cv2.rectangle	Draws a rectangle with given points as top-left and bottom-right.	cv2.rectangle(img, pt1, pt2, color, thickness)
cv2.ellipse()	Draws a simple or thick elliptic arc or fills an ellipse sector.	cv2.ellipse(img, center, axes, angle, startAngle, endAngle, color, thickness)

Parameters

The common parameters to the above functions are as follows:

img	The image where you want to draw the shapes
color	Color of the shape. for BGR, pass it as a tuple. For grayscale, just pass the scalar value.
thickness	Thickness of the line or circle etc. If -1 is passed for closed figures like circles, it will fill the shape
lineType	Type of line, whether 8-connected, anti-aliased line etc.

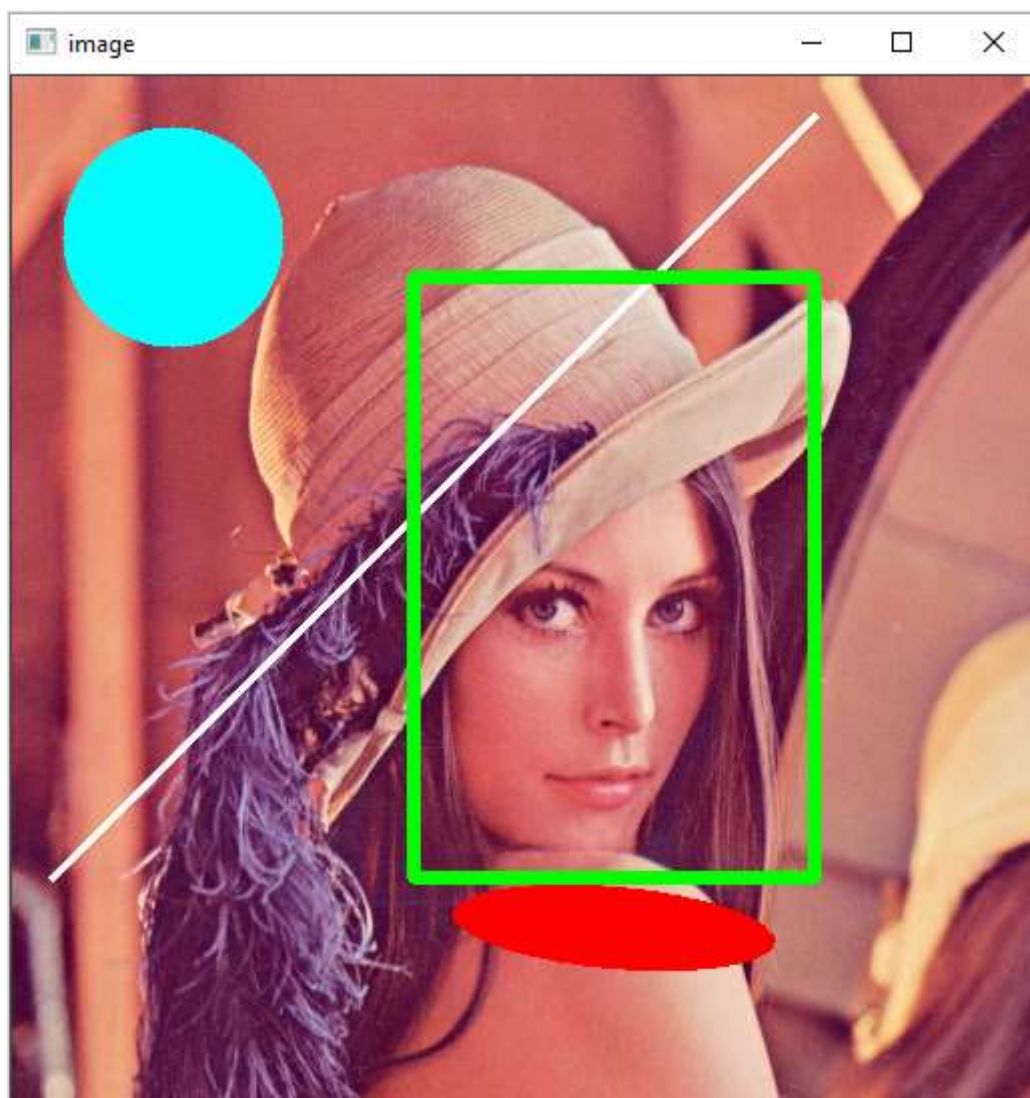
Example

Following example shows how the shapes are drawn on top of an image. The program for the same is given below:

```
import numpy as np
import cv2
img = cv2.imread('LENA.JPG',1)
cv2.line(img,(20,400),(400,20),(255,255,255),3)
cv2.rectangle(img,(200,100),(400,400),(0,255,0),5)
cv2.circle(img,(80,80), 55, (255,255,0), -1)
cv2.ellipse(img, (300,425), (80, 20), 5, 0, 360, (0,0,255), -1)
cv2.imshow('image',img)
cv2.waitKey(0)
cv2.destroyAllWindows()
```

Output

On executing the above program, you will get the following result:



Draw Text

The **cv2.putText()** function is provided to write a text on the image. The command for the same is as follows:

```
img, text, org, fontFace, fontScale, color, thickness)
```

Fonts

OpenCV supports the following fonts:

Font Name	Font Size
FONT_HERSHEY_SIMPLEX	0
FONT_HERSHEY_PLAIN	1
FONT_HERSHEY_DUPLEX	2
FONT_HERSHEY_COMPLEX	3
FONT_HERSHEY_TRIPLEX	4
FONT_HERSHEY_COMPLEX_SMALL	5
FONT_HERSHEY_SCRIPT_SIMPLEX	6
FONT_HERSHEY_SCRIPT_COMPLEX	7
FONT_ITALIC	16

Program

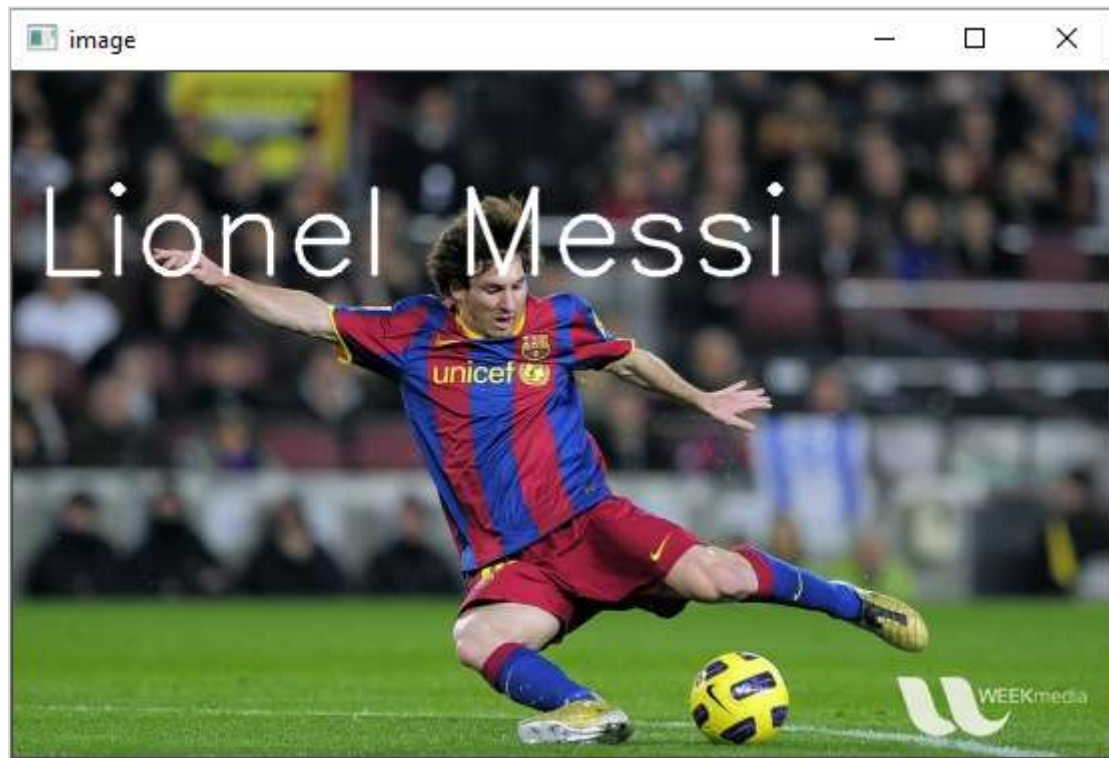
Following program adds a text caption to a photograph showing Lionel Messi, the famous footballer.

```
import numpy as np
import cv2
img = cv2.imread('messi.JPG',1)
txt="Lionel Messi"
font = cv2.FONT_HERSHEY_SIMPLEX
cv2.putText(img,txt,(10,100), font, 2,(255,255,255),2,cv2.LINE_AA)

cv2.imshow('image',img)
cv2.waitKey(0)
cv2.destroyAllWindows()
```

Output

Upon execution, you will receive the following output:



9. OpenCV-Python — Handling Mouse Events

OpenCV is capable of registering various mouse related events with a callback function. This is done to initiate a certain user defined action depending on the type of mouse event.

Mouse Events

The mouse events defined in OpenCV are explained in the following table:

Mouse event	Description
cv.EVENT_MOUSEMOVE	When the mouse pointer has moved over the window.
cv.EVENT_LBUTTONDOWN	Indicates that the left mouse button is pressed.
cv.EVENT_RBUTTONDOWN	Event of that the right mouse button is pressed.
cv.EVENT_MBUTTONDOWN	Indicates that the middle mouse button is pressed.
cv.EVENT_LBUTTONUP	When the left mouse button is released.
cv.EVENT_RBUTTONUP	When the right mouse button is released.
cv.EVENT_MBUTTONUP	Indicates that the middle mouse button is released.
cv.EVENT_LBUTTONDBLCLK	This event occurs when the left mouse button is double clicked.
cv.EVENT_RBUTTONDBLCLK	Indicates that the right mouse button is double clicked.
cv.EVENT_MBUTTONDBLCLK	Indicates that the middle mouse button is double clicked.
cv.EVENT_MOUSEWHEEL	Positive for forward and negative for backward scrolling

To fire a function on a mouse event, it has to be registered with the help of **setMouseCallback()** function. The command for the same is as follows:

```
cv2.setMouseCallback(window, callbak_function)
```

This function passes the type and location of the event to the callback function for further processing.

Program 1

Following code draws a circle whenever left button double click event occurs on the window showing an image as background:

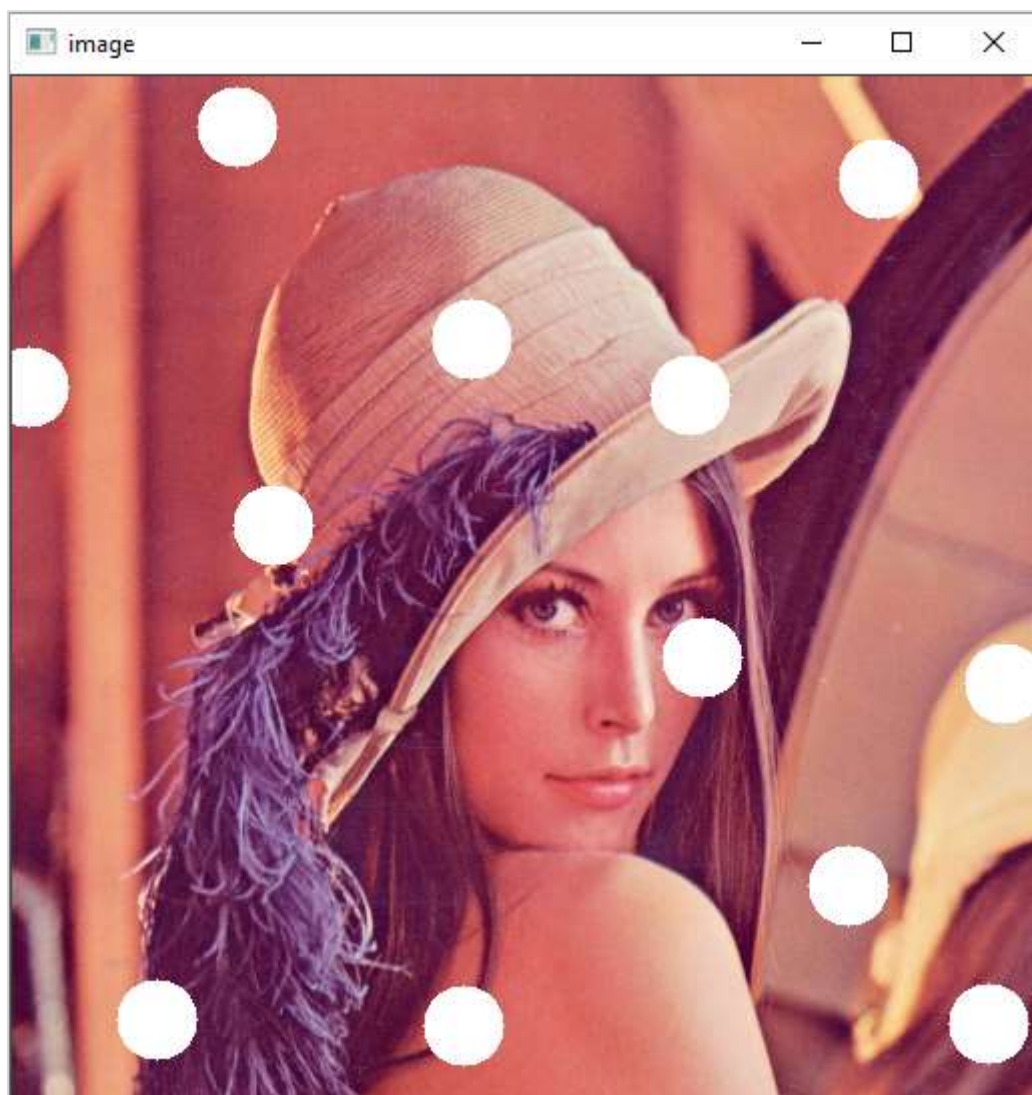
```
import numpy as np
import cv2 as cv
# mouse callback function
def drawfunction(event,x,y,flags,param):
```



```
if event == cv.EVENT_LBUTTONDBLCLK:
    cv.circle(img,(x,y),20,(255,255,255),-1)
img = cv.imread('lena.jpg')
cv.namedWindow('image')
cv.setMouseCallback('image',drawfunction)
while(1):
    cv.imshow('image',img)
    key=cv.waitKey(1)
    if key == 27:
        break
cv.destroyAllWindows()
```

Output

Run the above program and double click at random locations. The similar output will appear:



Program 2

Following program interactively draws either rectangle, line or circle depending on user input (1,2 or 3):

```
import numpy as np
import cv2 as cv
# mouse callback function

drawing=True
shape='r'

def draw_circle(event,x,y,flags,param):
    global x1,x2
    if event == cv.EVENT_LBUTTONDOWN:
        drawing = True
        x1,x2 = x,y
    elif event == cv.EVENT_LBUTTONUP:
        drawing = False
        if shape == 'r':
            cv.rectangle(img,(x1,x2),(x,y),(0,255,0),-1)
        if shape == 'l':
            cv.line(img,(x1,x2),(x,y),(255,255,255),3)
        if shape=='c':
            cv.circle(img,(x,y), 10, (255,255,0), -1)
img = cv.imread('lena.jpg')
cv.namedWindow('image')
cv.setMouseCallback('image',draw_circle)
while(1):
    cv.imshow('image',img)
    key=cv.waitKey(1)
    if key==ord('1'):
        shape='r'
    if key==ord('2'):
        shape='l'
    if key==ord('3'):
        shape='c'

    #print (shape)
```



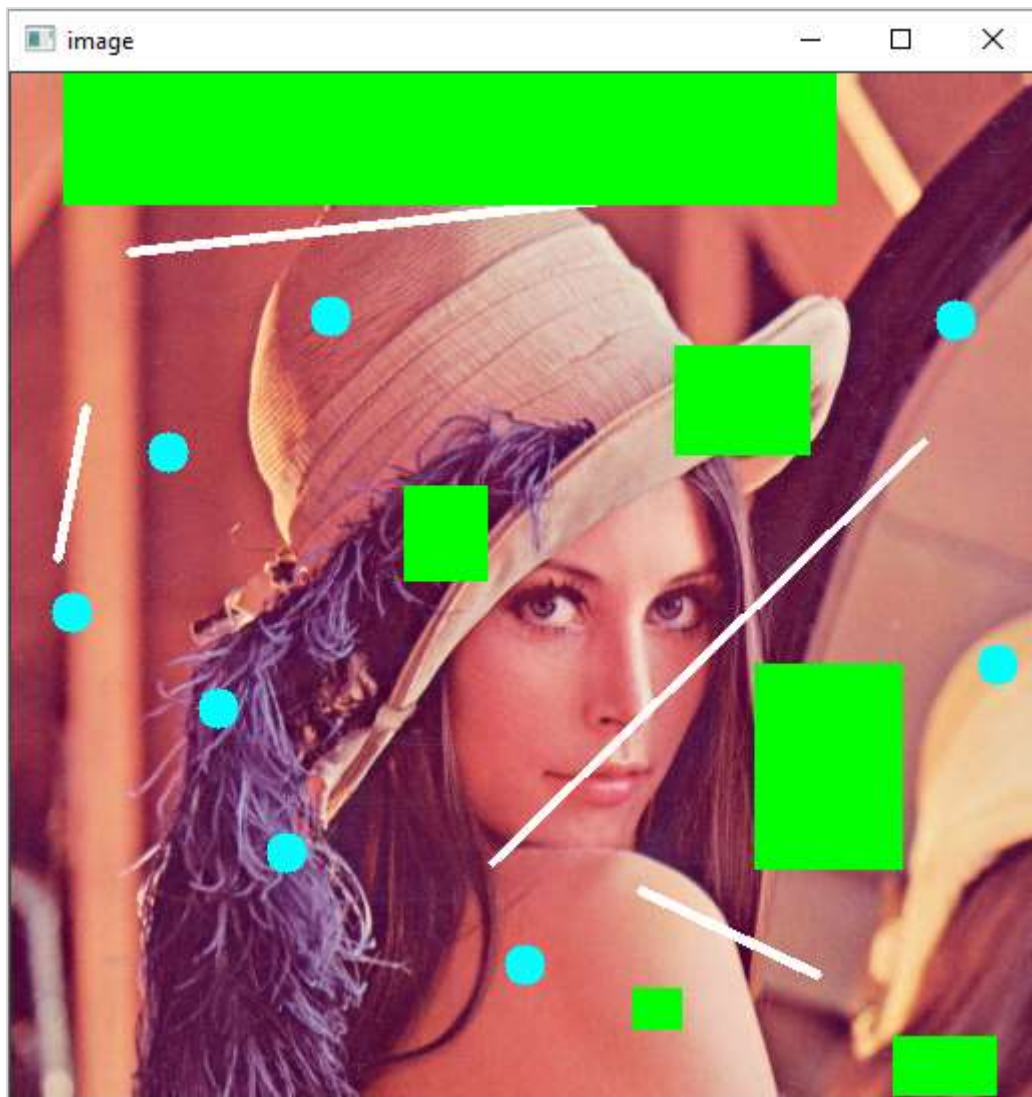
```
if key == 27:  
    break  
cv.destroyAllWindows()
```

On the window surface, a rectangle is drawn between the coordinates of the mouse left button down and up if '1' is pressed.

If user choice is 2, a line is drawn using coordinates as endpoints.

On choosing 3 for the circle, it is drawn at the coordinates of the mouse up event.

Following image will be the output after the successful execution of the above mentioned program:



10. OpenCV-Python — Add Trackbar

Trackbar in OpenCV is a slider control which helps in picking a value for the variable from a continuous range by manually sliding the tab over the bar. Position of the tab is synchronised with a value.

The `createTrackbar()` function creates a Trackbar object with the following command:

```
cv2.createTrackbar(trackbarname, winname, value, count, TrackbarCallback)
```

In the following example, three trackbars are provided for the user to set values of R, G and B from the grayscale range 0 to 255.

Using the track bar position values, a rectangle is drawn with the fill colour corresponding to RGB colour value.

Program

Following program is for adding a trackbar:

```
import numpy as np
import cv2 as cv
img = np.zeros((300,400,3), np.uint8)
cv.namedWindow('image')
def nothing(x):
    pass

# create trackbars for color change
cv.createTrackbar('R','image',0,255,nothing)
cv.createTrackbar('G','image',0,255,nothing)
cv.createTrackbar('B','image',0,255,nothing)

while(1):
    cv.imshow('image',img)
    k = cv.waitKey(1) & 0xFF
    if k == 27:
        break

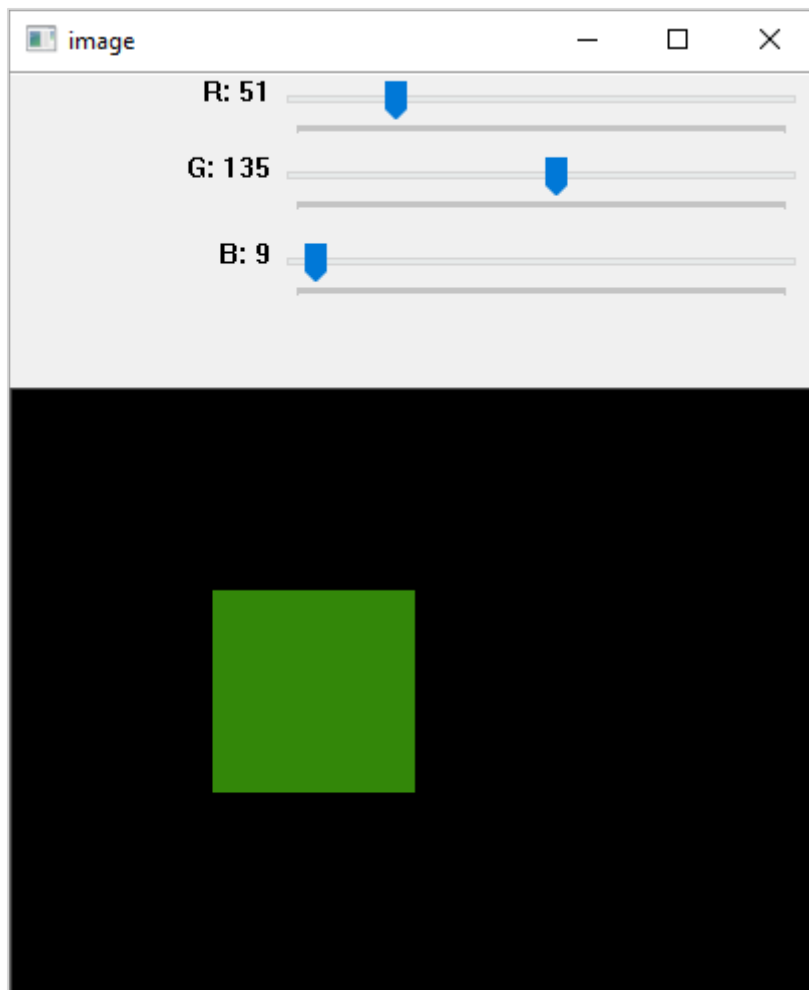
    # get current positions of four trackbars
    r = cv.getTrackbarPos('R','image')
    g = cv.getTrackbarPos('G','image')
```

```
b = cv.getTrackbarPos('B','image')

#s = cv.getTrackbarPos(switch,'image')
#img[:] = [b,g,r]
cv.rectangle(img, (100,100),(200,200), (b,g,r),-1)
cv.destroyAllWindows()
```

Output

On executing the above program, you will get the following result:



11. OpenCV-Python — Resize and Rotate an Image

In this chapter, we will learn how to resize and rotate an image with the help of OpenCV-Python.

Resize an Image

It is possible to scale up or down an image with the use of `cv2.resize()` function.

The **`resize()`** function is used as follows:

```
resize(src, dsize, dst, fx, fy, interpolation)
```

In general, interpolation is a process of estimating values between known data points.

When graphical data contains a gap, but data is available on either side of the gap or at a few specific points within the gap. Interpolation allows us to estimate the values within the gap.

In the above `resize()` function, interpolation flags determine the type of interpolation used for calculating size of destination image.

Types of Interpolation

The types of interpolation are as follows:

- **INTER_NEAREST** - A nearest-neighbor interpolation.
- **INTER_LINEAR** - A bilinear interpolation (used by default)
- **INTER_AREA** - Resampling using pixel area relation. It is a preferred method for image decimation but when the image is zoomed, it is similar to the **INTER_NEAREST** method.
- **INTER_CUBIC** - A bicubic interpolation over 4x4 pixel neighborhood
- **INTER_LANCZOS4** - A Lanczos interpolation over 8x8 pixel neighborhood

Preferable interpolation methods are `cv2.INTER_AREA` for shrinking and `cv2.INTER_CUBIC` (slow) & `cv2.INTER_LINEAR` for zooming.

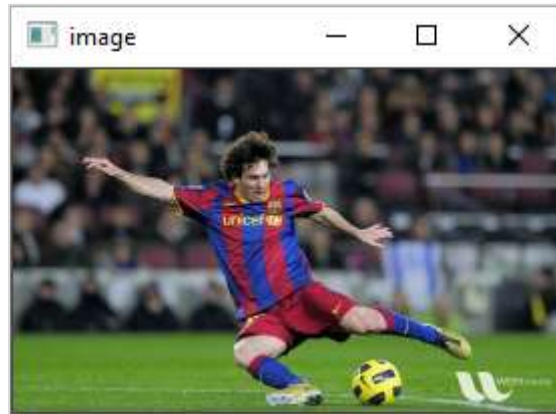
Following code resizes the 'messi.jpg' image to half its original height and width.

```
import numpy as np
import cv2
img = cv2.imread('messi.JPG',1)
height, width = img.shape[:2]
res = cv2.resize(img,(int(width/2), int(height/2)), interpolation =
cv2.INTER_AREA)
```

```
cv2.imshow('image',res)
cv2.waitKey(0)
cv2.destroyAllWindows()
```

Output

When you execute the above code, you should see the following output:



Rotate an image

OpenCV uses affine transformation functions for operations on images such as translation and rotation. The affine transformation is a transformation that can be expressed in the form of a matrix multiplication (linear transformation) followed by a vector addition (translation).

The cv2 module provides two functions **cv2.warpAffine** and **cv2.warpPerspective**, with which you can have all kinds of transformations. cv2.warpAffine takes a 2x3 transformation matrix while cv2.warpPerspective takes a 3x3 transformation matrix as input.

To find this transformation matrix for rotation, OpenCV provides a function, **cv2.getRotationMatrix2D**, which is as follows:

```
getRotationMatrix2D(center, angle, scale)
```

We then apply the **warpAffine** function to the matrix returned by getRotationMatrix2D() function to obtain rotated image.

Following program rotates the original image by 90 degrees without changing the dimensions:

```
import numpy as np
import cv2
img = cv2.imread('OpenCV_Logo.png',1)
h, w = img.shape[:2]
```

```
center = (w / 2, h / 2)
mat = cv2.getRotationMatrix2D(center, 90, 1)
rotimg = cv2.warpAffine(img, mat, (h, w))
cv2.imshow('original',img)
cv2.imshow('rotated', rotimg)
cv2.waitKey(0)
cv2.destroyAllWindows()
```

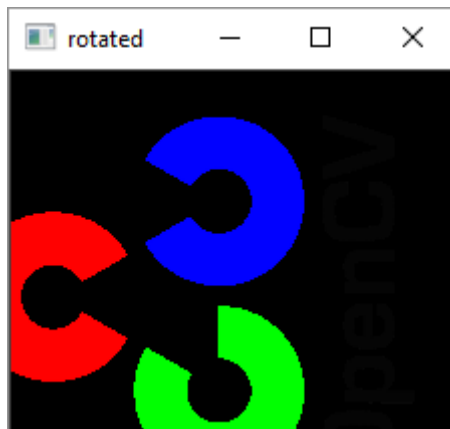
Output

You will receive the following output:

Original Image



Rotated Image



12. OpenCV-Python — Image Threshold

In digital image processing, the thresholding is a process of creating a binary image based on a threshold value of pixel intensity. Thresholding process separates the foreground pixels from background pixels.

OpenCV provides functions to perform **simple**, **adaptive** and **Otsu's** thresholding.

In simple thresholding, all pixels with value less than threshold are set to zero, rest to the maximum pixel value. This is the simplest form of thresholding.

The **cv2.threshold()** function has the following definition.

```
cv2.threshold((src, thresh, maxval, type, dst)
```

Parameters

The parameters for the image thresholding are as follows:

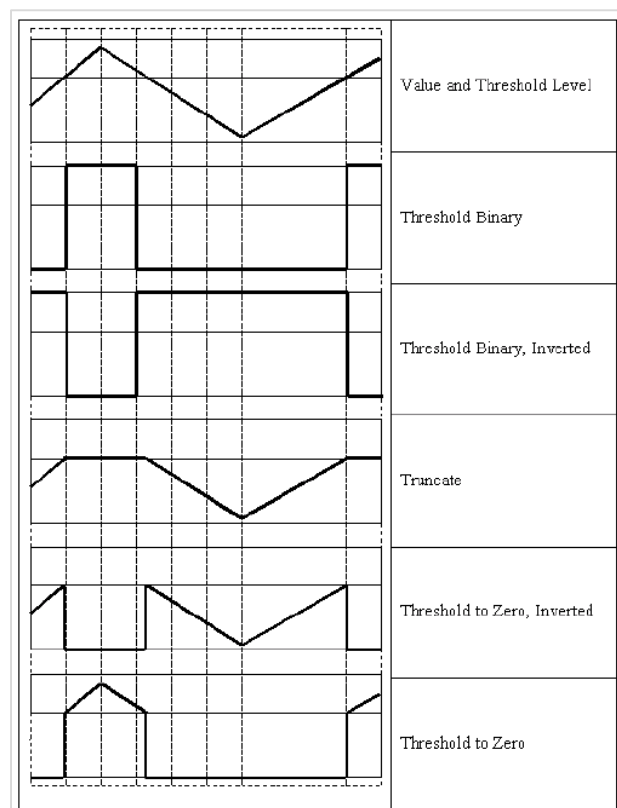
- Src: Input array.
- Dst: Output array of same size.
- Thresh: Threshold value.
- Maxval: Maximum value.
- Type: Thresholding type.

Types of Thresholding

Other types of thresholding are enumerated as below:

Type	Function
cv.THRESH_BINARY	$\text{dst}(x,y) = \text{maxval}$ if $\text{src}(x,y) > \text{thresh}$ 0 otherwise
cv.THRESH_BINARY_INV	$\text{dst}(x,y) = 0$ if $\text{src}(x,y) > \text{thresh}$ maxval otherwise
cv.THRESH_TRUNC	$\text{dst}(x,y) = \text{threshold}$ if $\text{src}(x,y) > \text{thresh}$ $\text{src}(x,y)$ otherwise
cv.THRESH_TOZERO	$\text{dst}(x,y) = \text{src}(x,y)$ if $\text{src}(x,y) > \text{thresh}$ 0 otherwise
cv.THRESH_TOZERO_INV	$\text{dst}(x,y) = 0$ if $\text{src}(x,y) > \text{thresh}$ $\text{src}(x,y)$ otherwise

These threshold types result in operation on input image according to following diagram:



The `threshold()` function returns threshold used and threshold image.

Following program produces a binary image from the original with a gradient of grey values from 255 to 0 by setting a threshold to 127.

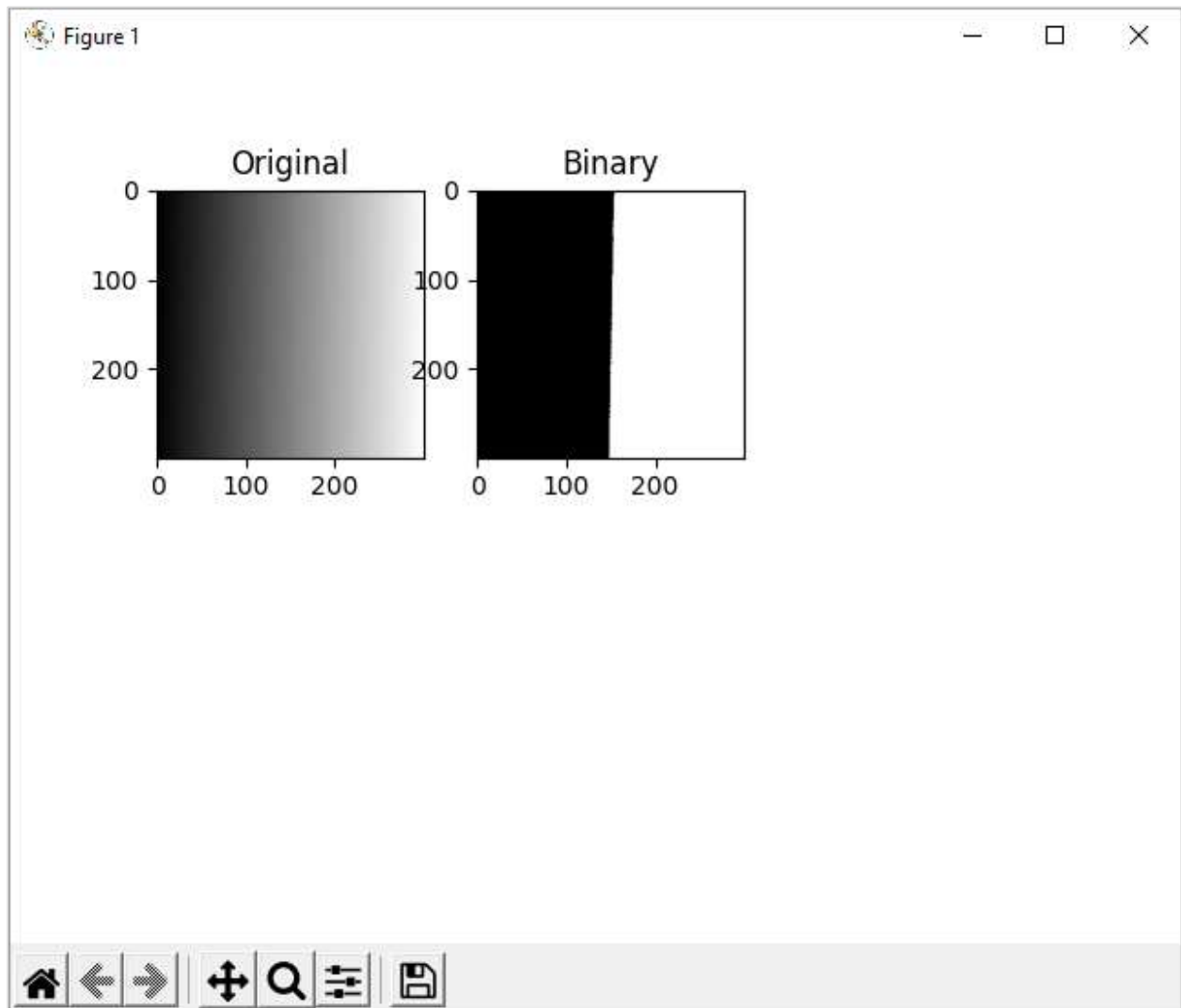
Original and resultant threshold binary images are plotted side by side using Matplotlib library.

```
import cv2 as cv
import numpy as np
from matplotlib import pyplot as plt
img = cv.imread('gradient.png',0)
ret,img1 = cv.threshold(img,127,255,cv.THRESH_BINARY)

plt.subplot(2,3,1),plt.imshow(img,'gray',vmin=0,vmax=255)
plt.title('Original')
plt.subplot(2,3,2),plt.imshow(img1,'gray',vmin=0,vmax=255)
plt.title('Binary')
plt.show()
```


Output

You will receive the following output:



The adaptive thresholding determines the threshold for a pixel based on a small region around it. So, different thresholds for different regions of the same image are obtained. This gives better results for images with varying illumination.

The **cv2.adaptiveThreshold()** method takes following input arguments:

```
cv.adaptiveThreshold(    src, maxValue, adaptiveMethod, thresholdType,
                        blockSize, C[, dst]    )
```

The adaptiveMethod has following enumerated values:

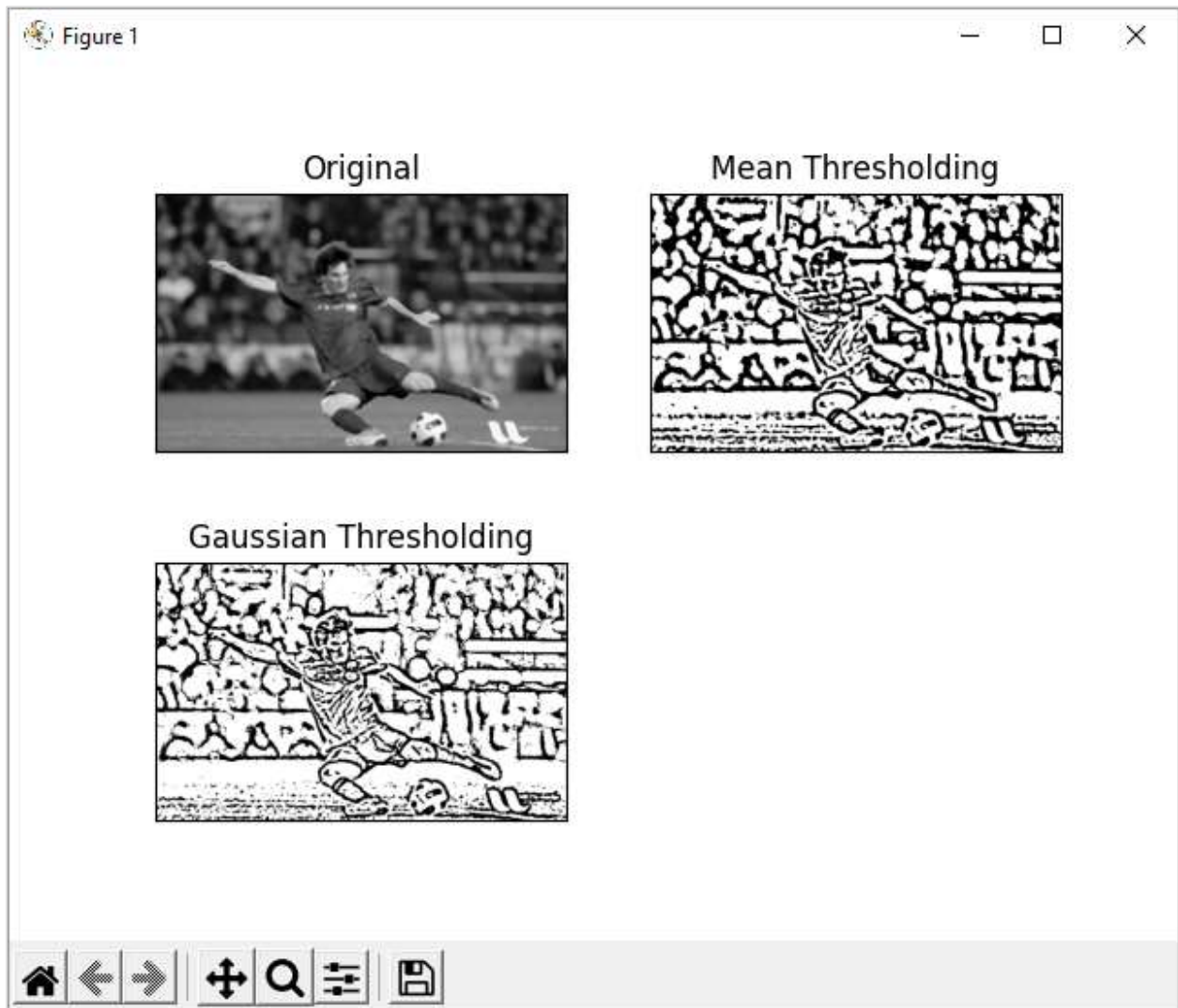
- **cv.ADAPTIVE_THRESH_MEAN_C:** The threshold value is the mean of the neighbourhood area minus the constant C.
- **cv.ADAPTIVE_THRESH_GAUSSIAN_C:** The threshold value is a Gaussian-weighted sum of the neighbourhood values minus the constant C.

In the example below, the original image (messi.jpg) is applied with mean and Gaussian adaptive thresholding.

```
import cv2 as cv
import numpy as np
from matplotlib import pyplot as plt
img = cv.imread('messi.jpg',0)
img = cv.medianBlur(img,5)
th1 = cv.adaptiveThreshold(img,255,cv.ADAPTIVE_THRESH_MEAN_C,\
                           cv.THRESH_BINARY,11,2)
th2 = cv.adaptiveThreshold(img,255,cv.ADAPTIVE_THRESH_GAUSSIAN_C,\
                           cv.THRESH_BINARY,11,2)
titles = ['Original', 'Mean Thresholding', 'Gaussian Thresholding']
images = [img, th1, th2]
for i in range(3):
    plt.subplot(2,2,i+1),plt.imshow(images[i], 'gray')
    plt.title(titles[i])
    plt.xticks([],plt.yticks([]))
plt.show()
```

Output

Original as well as adaptive threshold binary images are plotted by using matplotlib as shown below:



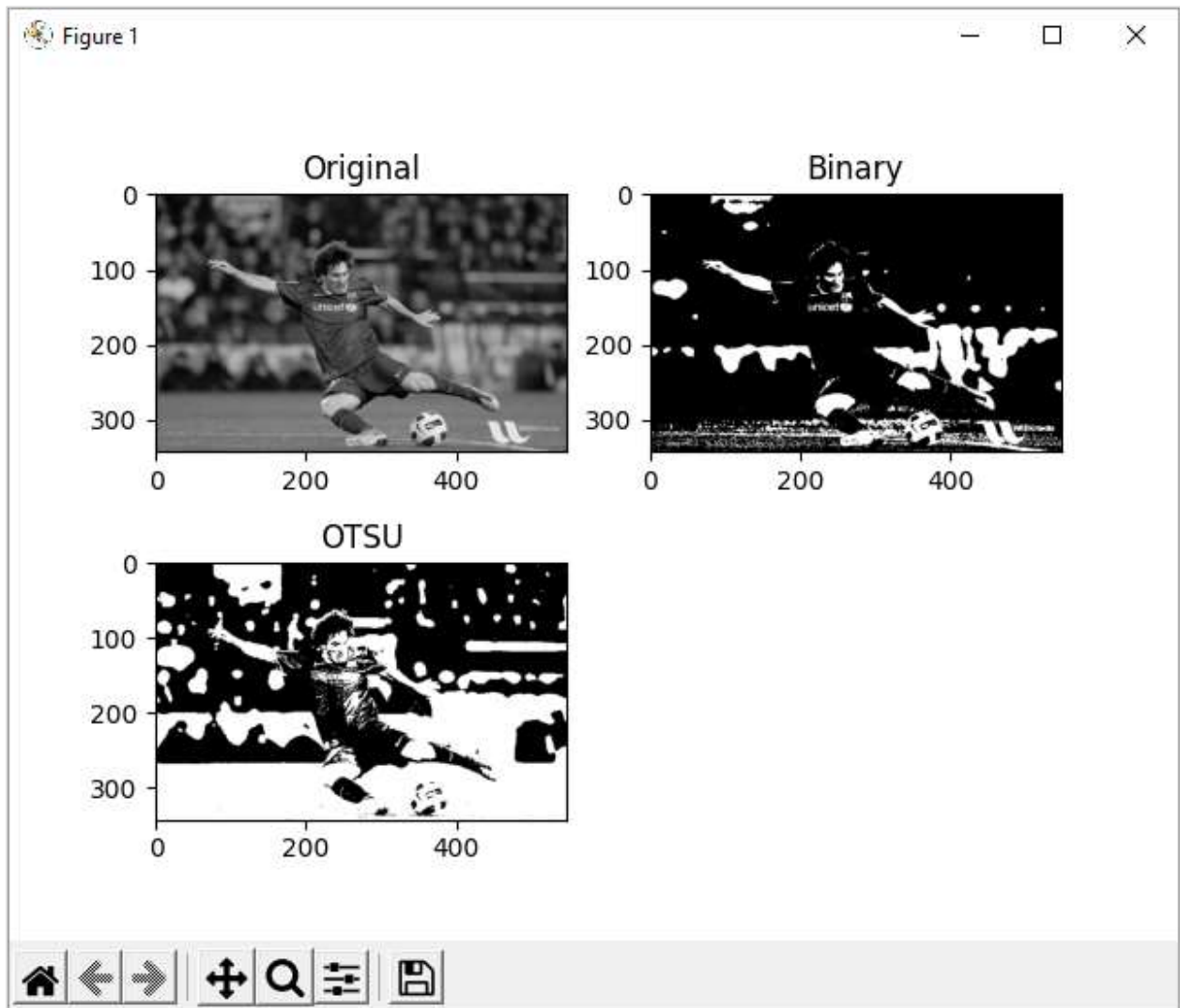
OTSU algorithm determines the threshold value automatically from the image histogram. We need to pass the `cv.THRESH_OTSU` flag in addition to the `THRESH-BINARY` flag.

```
import cv2 as cv
import numpy as np
from matplotlib import pyplot as plt
img = cv.imread('messi.jpg',0)
# global thresholding
ret1,img1 = cv.threshold(img,127,255,cv.THRESH_BINARY)
# Otsu's thresholding
ret2,img2 = cv.threshold(img,0,255,cv.THRESH_BINARY+cv.THRESH_OTSU)
plt.subplot(2,2,1),plt.imshow(img,'gray',vmin=0,vmax=255)
plt.title('Original')
plt.subplot(2,2,2),plt.imshow(img1,'gray')
plt.title('Binary')
```

```
plt.subplot(2,2,3),plt.imshow(img2,'gray')  
plt.title('OTSU')  
plt.show()
```

Output

The matplotlib's plot result is as follows:



13. OpenCV-Python — Image Filtering

An image is basically a matrix of pixels represented by binary values between 0 to 255 corresponding to gray values. A color image will be a three dimensional matrix with a number of channels corresponding to RGB.

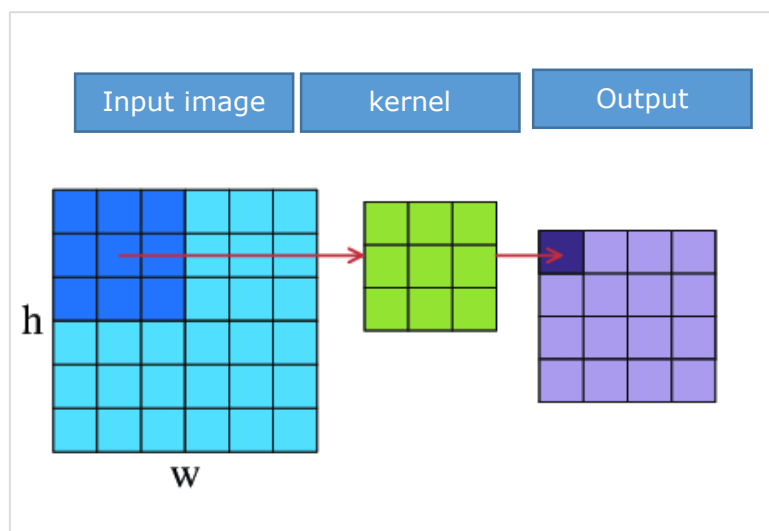
Image filtering is a process of averaging the pixel values so as to alter the shade, brightness, contrast etc. of the original image.

By applying a low pass filter, we can remove any noise in the image. High pass filters help in detecting the edges.

The OpenCV library provides **cv2.filter2D()** function. It performs convolution of the original image by a kernel of a square matrix of size 3X3 or 5X5 etc.

Convolution slides a kernel matrix across the image matrix horizontally and vertically. For each placement, add all pixels under the kernel, take the average of pixels under the kernel and replace the central pixel with the average value.

Perform this operation for all pixels to obtain the output image pixel matrix. Refer the diagram given below:



The `cv2.filter2D()` function requires input array, kernel matrix and output array parameters.

Following figure uses this function to obtain an averaged image as a result of 2D convolution. The program for the same is as follows:

```
import numpy as np
import cv2 as cv
from matplotlib import pyplot as plt
img = cv.imread('opencv_logo_gs.png')
```

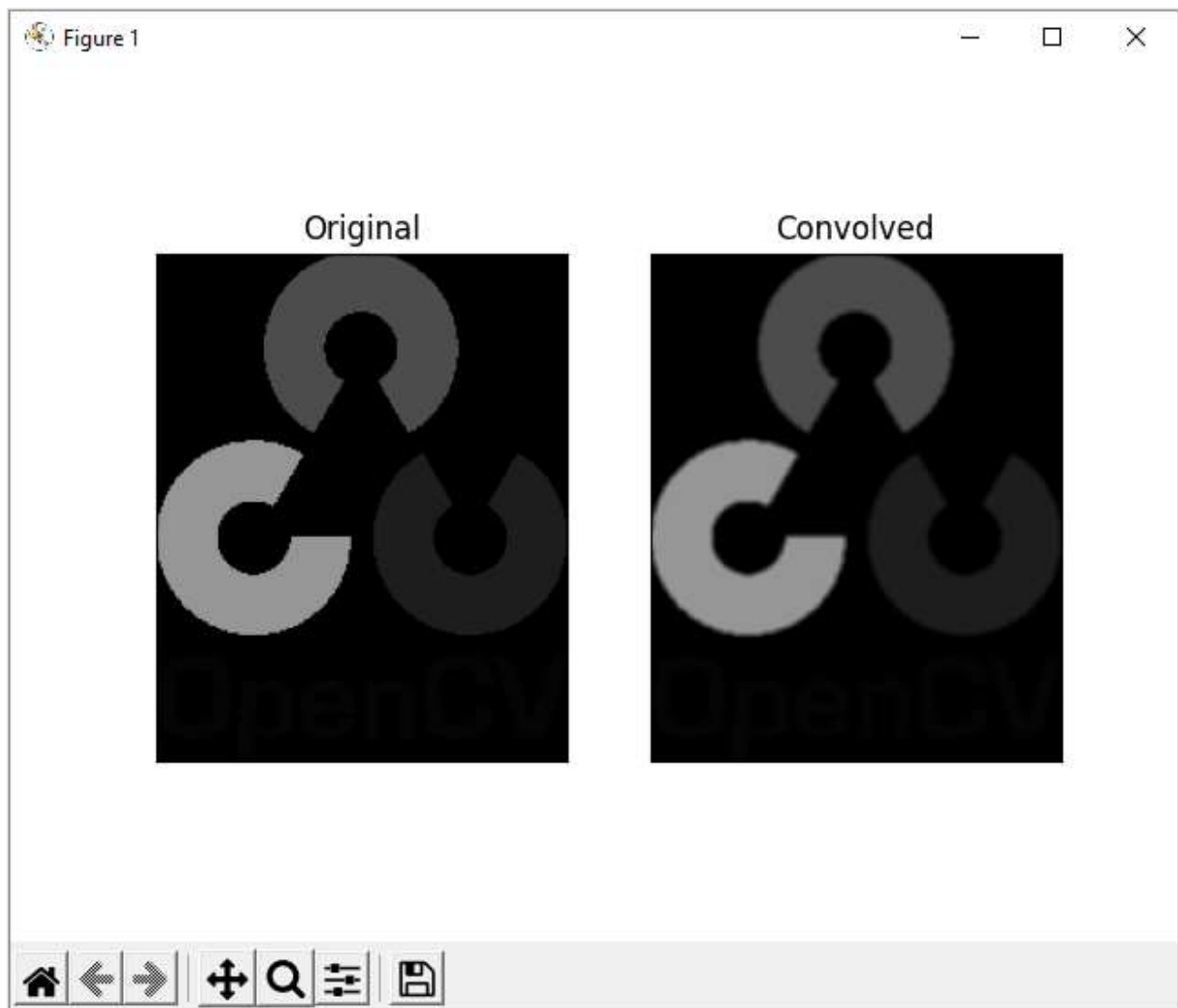
```

kernel = np.ones((3,3),np.float32)/9
dst = cv.filter2D(img,-1,kernel)
plt.subplot(121),plt.imshow(img),plt.title('Original')
plt.xticks([], plt.yticks([]))
plt.subplot(122),plt.imshow(dst),plt.title('Convolved')
plt.xticks([], plt.yticks([]))
plt.show()

```

Output

The above program displays following result:



Types of Filtering Function

Other types of filtering function in OpenCV includes:

- **BilateralFilter:** Reduces unwanted noise keeping edges intact.
- **BoxFilter:** This is an average blurring operation.

- **GaussianBlur:** Eliminates high frequency content such as noise and edges.
- **MedianBlur:** Instead of average, it takes the median of all pixels under the kernel and replaces the central value.

14. OpenCV-Python — Edge Detection

An edge here means the boundary of an object in the image. OpenCV has a **cv2.Canny()** function that identifies the edges of various objects in an image by implementing Canny's algorithm.

Canny edge detection algorithm was developed by John Canny. According to it, object's edges are determined by performing following steps:

First step is to reduce the noisy pixels in the image. This is done by applying 5X5 Gaussian Filter.

Second step involves finding the intensity gradient of the image. The smooth image of the first stage is filtered by applying the Sobel operator to obtain first order derivatives in horizontal and vertical directions (G_x and G_y).

The root mean square value gives edge gradient and tan inverse ratio of derivatives gives the direction of edge.

$$\text{Edge gradient } G = \sqrt{G_x^2 + G_y^2}$$

$$\text{Angle } \theta = \tan^{-1} (G_y/G_x)$$

After getting gradient magnitude and direction, a full scan of the image is done to remove any unwanted pixels which may not constitute the edge.

Next step is to perform hysteresis thresholding by using minval and maxval thresholds. Intensity gradients less than minval and maxval are non-edges so discarded. Those in between are treated as edge points or non-edges based on their connectivity.

All these steps are performed by OpenCV's **cv2.Canny()** function which needs the input image array and minval and maxval parameters.

Example

Here's the example of canny edge detection. The program for the same is as follows:

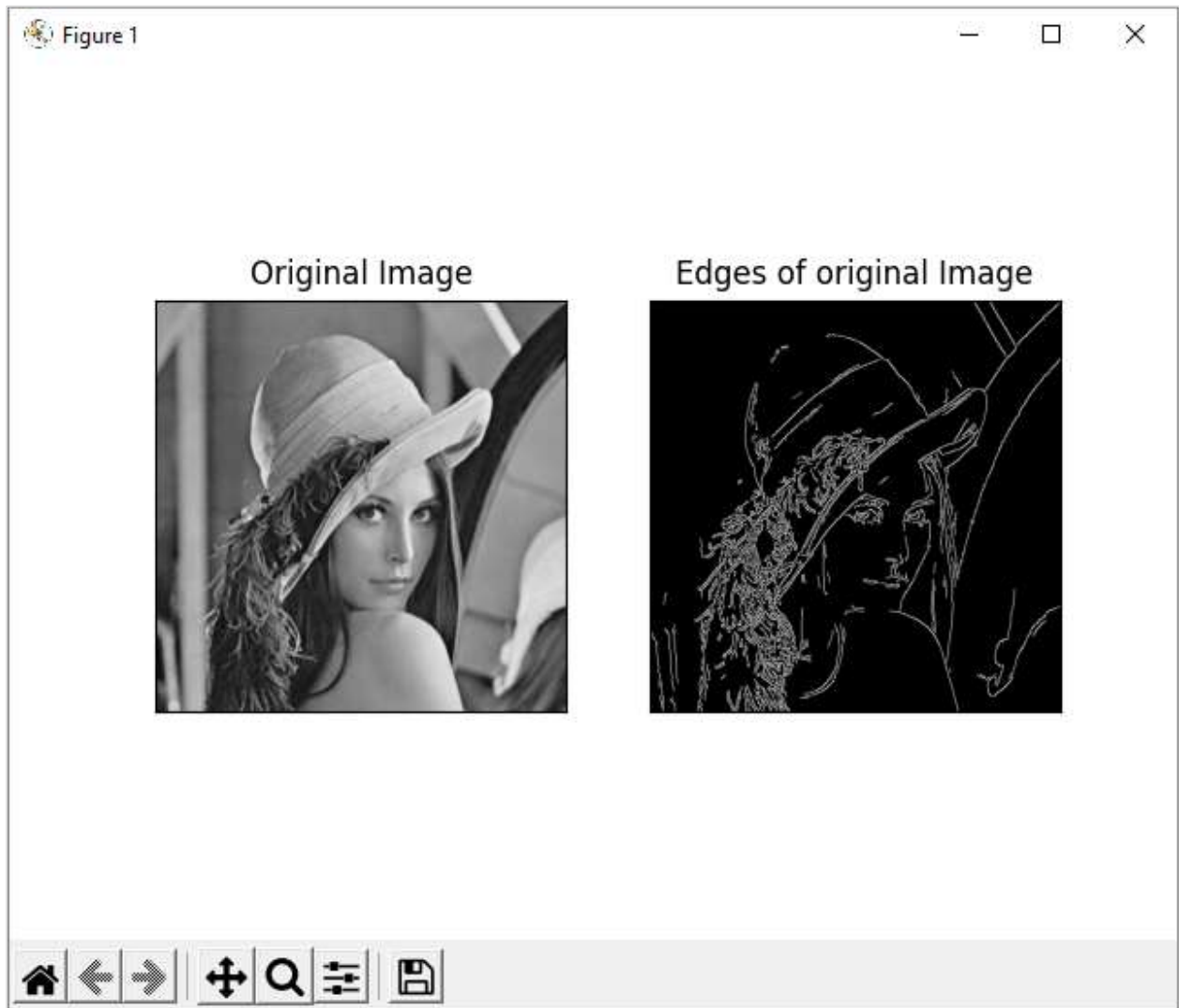
```
import numpy as np
import cv2 as cv
from matplotlib import pyplot as plt
img = cv.imread('lena.jpg', 0)
edges = cv.Canny(img,100,200)
plt.subplot(121),plt.imshow(img,cmap = 'gray')
plt.title('Original Image'), plt.xticks([]), plt.yticks([])
plt.subplot(122),plt.imshow(edges,cmap = 'gray')
```



```
plt.title('Edges of original Image'), plt.xticks([]), plt.yticks([])  
plt.show()
```

Result

The output is as follows:



15. OpenCV-Python — Histogram

Histogram shows the intensity distribution in an image. It plots the pixel values (0 to 255) on X axis and number of pixels on Y axis.

By using histogram, one can understand the contrast, brightness and intensity distribution of the specified image. The bins in a histogram represent incremental parts of the values on X axis.

In our case, it is the pixel value and the default bin size is one.

In OpenCV library, the function **cv2.calcHist()** function which computes the histogram from the input image. The command for the function is as follows:

```
cv.calcHist(images, channels, mask, histSize, ranges)
```

Parameters

The **cv2.calcHist()** function's parameters are as follows:

- **images:** It is the source image of type uint8 or float32, in square brackets, i.e., "[img]".
- **channels:** It is the index of the channel for which we calculate histogram. For a grayscale image, its value is [0]. For BGR images, you can pass [0], [1] or [2] to calculate the histogram of each channel.
- **mask:** Mask image is given as "None" for full image. For a particular region of image, you have to create a mask image for that and give it as a mask.
- **histSize:** This represents our BIN count.
- **ranges:** Normally, it is [0,256].

Histogram using Matplotlib

A histogram plot can be obtained either with the help of Matplotlib's **pyplot.plot()** function or by calling **Polylines()** function from OpenCV library.

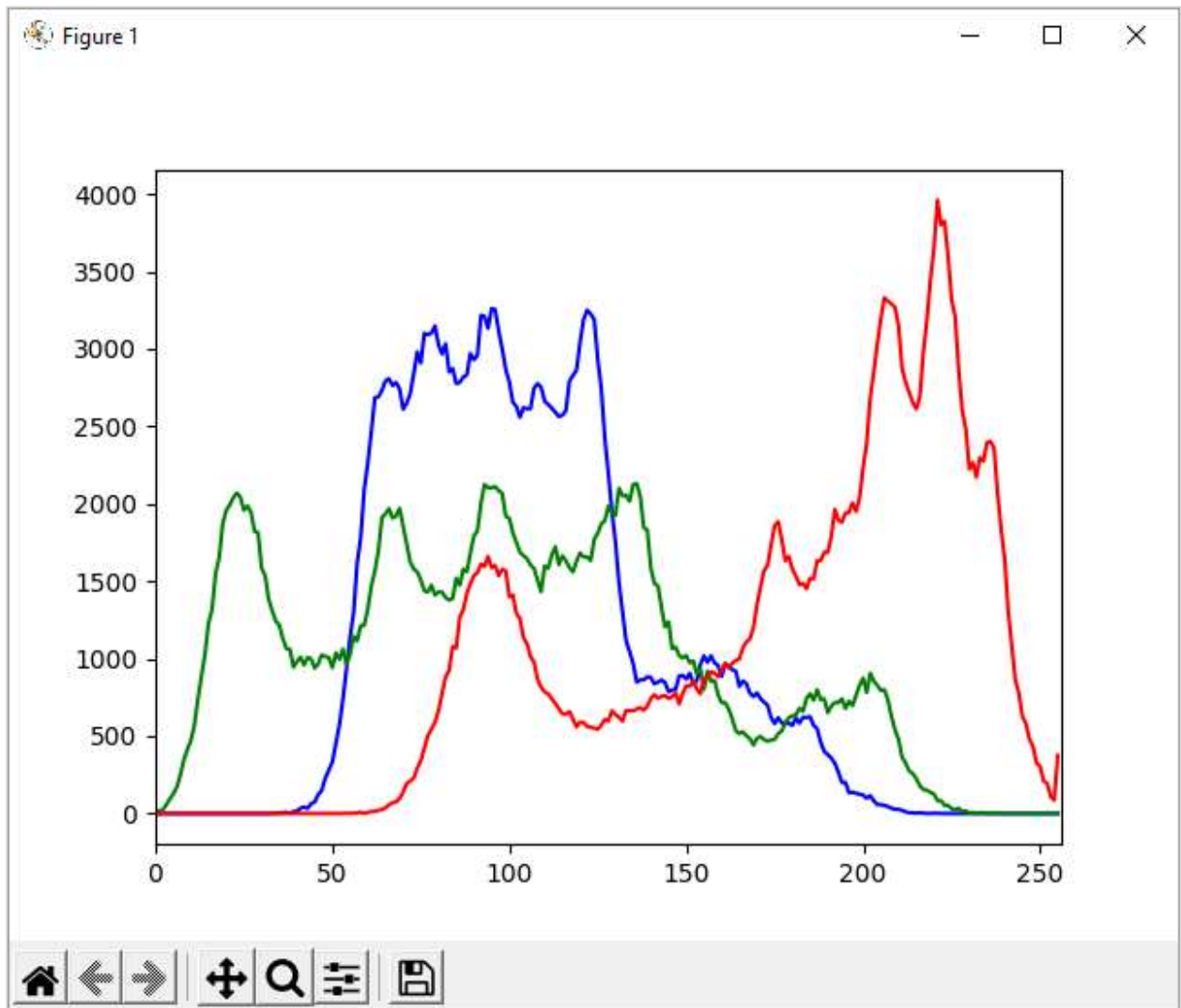
Following program computes histogram for each channel in the image (lena.jpg) and plots the intensity distribution for each channel:

```
import numpy as np
import cv2 as cv
from matplotlib import pyplot as plt
img = cv.imread('lena.jpg')
color = ('b','g','r')
for i,col in enumerate(color):
```

```
hist = cv.calcHist([img],[i],None,[256],[0,256])  
plt.plot(hist, color = col)  
plt.xlim([0,256])  
plt.show()
```

Output

When you execute the above program, you will get the following result:



16. OpenCV-Python — Color Spaces

A color space is a mathematical model describing how colours can be represented. It is described in a specific, measurable, and fixed range of possible colors and luminance values.

OpenCV supports following well known color spaces:

- **RGB Color space:** It is an additive color space. A color value is obtained by combination of red, green and blue colour values. Each is represented by a number ranging between 0 to 255.
- **HSV color space:** H, S and V stand for Hue, Saturation and Value. This is an alternative color model to RGB. This model is supposed to be closer to the way a human eye perceives any colour. Hue value is between 0 to 179, whereas S and V numbers are between 0 to 255.
- **CMYK color space:** In contrast to RGB, CMYK is a subtractive color model. The alphabets stand for Cyan, Magenta, Yellow and Black. White light minus red leaves cyan, green subtracted from white leaves magenta, and white minus blue returns yellow. All the values are represented on the scale of 0 to 100 %.
- **CIELAB color space:** The LAB color space has three components which are L for lightness, A color components ranging from Green to Magenta and B for components from Blue to Yellow.
- **YCrCb color space:** Here, Cr stands for R-Y and Cb stands for B-Y. This helps in separation of luminance from chrominance into different channels.

OpenCV supports conversion of image between color spaces with the help of **cv2.cvtColor()** function.

The command for the **cv2.cvtColor()** function is as follows:

```
cv.cvtColor(src, code, dst)
```

Conversion Codes

The conversion is governed by following predefined conversion codes.

Conversion Code	Function
cv.COLOR_BGR2BGRA	Add alpha channel to RGB or BGR image.
cv.COLOR_BGRA2BGR	Remove alpha channel from RGB or BGR image.
cv.COLOR_BGR2GRAY	Convert between RGB/BGR and grayscale.

cv.COLOR_BGR2YCrCb	Convert RGB/BGR to luma-chroma
cv.COLOR_BGR2HSV	Convert RGB/BGR to HSV
cv.COLOR_BGR2Lab	Convert RGB/BGR to CIE Lab
cv.COLOR_HSV2BGR	Backward conversions HSV to RGB/BGR

Program

Following program shows the conversion of original image with RGB color space to HSV and Gray schemes:

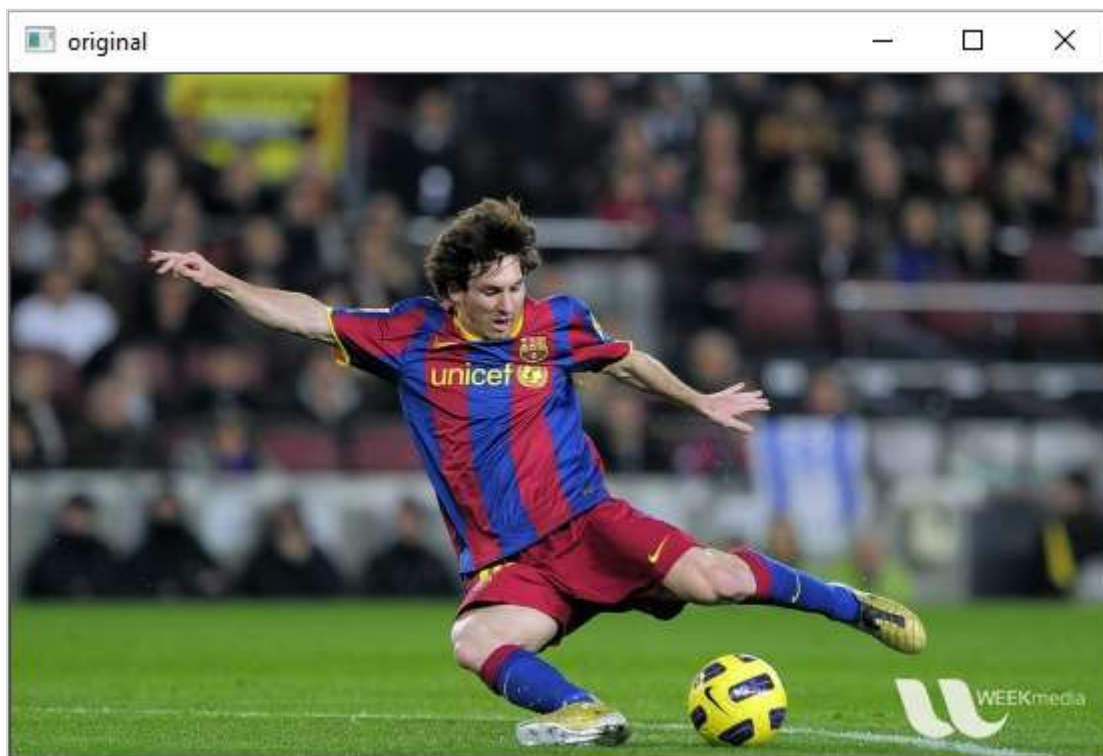
```
import cv2

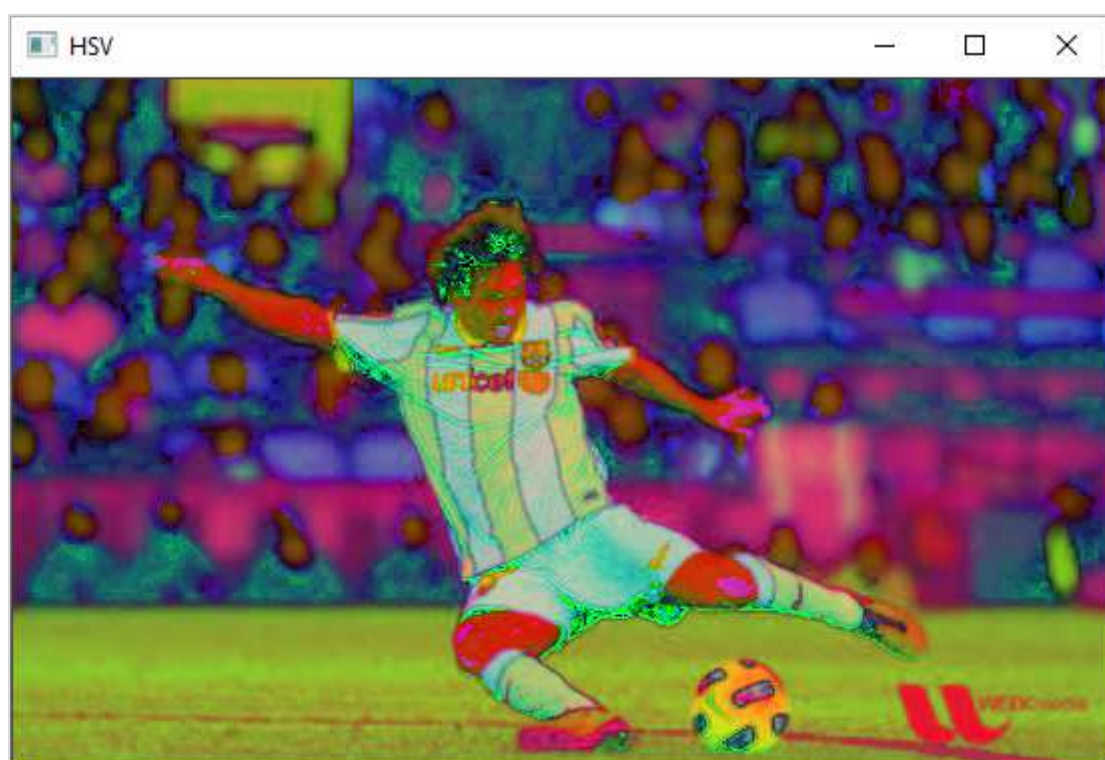
img = cv2.imread('messi.jpg')

img1 = cv2.cvtColor(img, cv2.COLOR_BGR2GRAY )
img2 = cv2.cvtColor(img, cv2.COLOR_BGR2HSV)
# Displaying the image
cv2.imshow('original', img)
cv2.imshow('Gray', img1)
cv2.imshow('HSV', img2)
```

Output

You will see the following output:





17. OpenCV-Python — Morphological Transformations

Simple operations on an image based on its shape are termed as morphological transformations. The two most common transformations are **erosion and dilation**.

Erosion

Erosion gets rid of the boundaries of the foreground object. Similar to 2D convolution, a kernel is slide across the image A. The pixel in the original image is retained, if all the pixels under the kernel are 1.

Otherwise it is made 0 and thus, it causes erosion. All the pixels near the boundary are discarded. This process is useful for removing white noises.

The command for the **erode()** function in OpenCV is as follows:

```
cv.erode(src, kernel, dst, anchor, iterations)
```

Parameters

The **erode()** function in OpenCV uses following parameters:

The src and dst parameters are input and output image arrays of the same size. Kernel is a matrix of structuring elements used for erosion. For example, 3X3 or 5X5.

The anchor parameter is -1 by default which means the anchor element is at center. Iterations refers to the number of times erosion is applied.

Dilation

It is just the opposite of erosion. Here, a pixel element is 1, if at least one pixel under the kernel is 1. As a result, it increases the white region in the image.

The command for the **dilate()** function is as follows:

```
cv.dilate(src, kernel, dst, anchor, iterations)
```

Parameters

The **dilate()** function has the same parameters such as that of erode() function. Both functions can have additional optional parameters as BorderType and borderValue.

BorderType is an enumerated type of image boundaries (CONSTANT, REPLICATE, TRANSPERANT etc.)

borderValue is used in case of a constant border. By default, it is 0.

Example Program

Given below is an example program showing erode() and dilate() functions in use:

```
import cv2 as cv
import numpy as np
img = cv.imread('LinuxLogo.jpg',0)
kernel = np.ones((5,5),np.uint8)
erosion = cv.erode(img,kernel,iterations = 1)
dilation = cv.dilate(img,kernel,iterations = 1)
cv.imshow('Original', img)
cv.imshow('Erosion', erosion)
cv.imshow('Dialation', dilation)
```

Output

On executing the above program, you will get the following result:

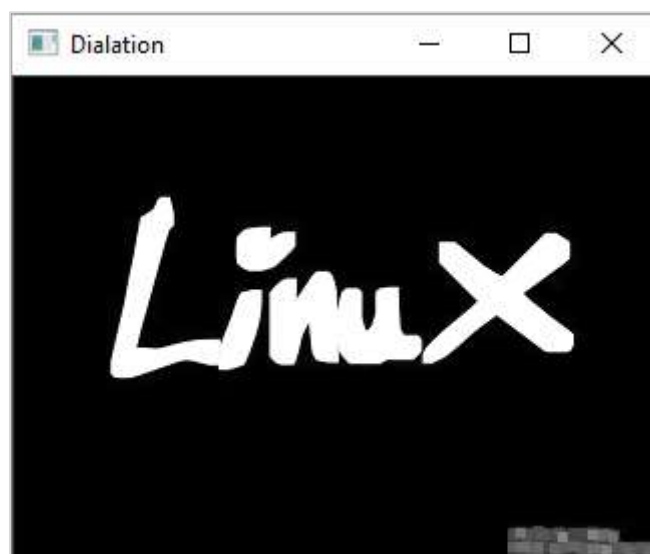
Original Image



Erosion



Dilation



18. OpenCV-Python — Image Contours

Contour is a curve joining all the continuous points along the boundary having the same color or intensity. The contours are very useful for shape analysis and object detection.

Find Contour

Before finding contours, we should apply threshold or canny edge detection. Then, by using **findContours()** method, we can find the contours in the binary image.

The command for the usage of **findContours()** function is as follows:

```
cv.findContours(image, mode, method, contours)
```

Parameters

The parameters of the **findContours()** function are as follows:

- **image**: Source, an 8-bit single-channel image.
- **mode**: Contour retrieval mode.
- **method**: Contour approximation method.

The mode parameter's values are enumerated as follows:

- **cv.RETR_EXTERNAL**: Retrieves only the extreme outer contours.
- **cv.RETR_LIST**: Retrieves all of the contours without establishing any hierarchical relationships.
- **cv.RETR_CCOMP**: Retrieves all of the contours and organizes them into a two-level hierarchy.
- **cv.RETR_TREE**: Retrieves all of the contours and reconstructs a full hierarchy of nested contours.

On the other hand, approximation method can be one from the following:

- **cv.CHAIN_APPROX_NONE**: Stores absolutely all the contour points.
- **cv.CHAIN_APPROX_SIMPLE**: Compresses horizontal, vertical, and diagonal segments and leaves only their end points.

Draw Contour

After detecting the contour vectors, contours are drawn over the original image by using the **cv.drawContours()** function.

The command for the **cv.drawContours()** function is as follows:

```
cv.drawContours(image, contours, contourIdx, color)
```

Parameters

The parameters of the **drawContours()** function are as follows:

- image: Destination image.
- contours: All the input contours. Each contour is stored as a point vector.
- contourIdx: Parameter indicating a contour to draw. If it is negative, all the contours are drawn.
- color: Color of the contours.

Code

Following code is an example of drawing contours on an input image having three shapes filled with black colours.

In the first step, we obtain a gray image and then perform the canny edge detection.

On the resultant image, we then call findContours() function. Its result is a point vector. We then call the drawContours() function.

The complete code is as below:

```
import cv2
import numpy as np

img = cv2.imread('shapes.png')
cv2.imshow('Original', img)
gray = cv2.cvtColor(img, cv2.COLOR_BGR2GRAY)

canny = cv2.Canny(gray, 30, 200)

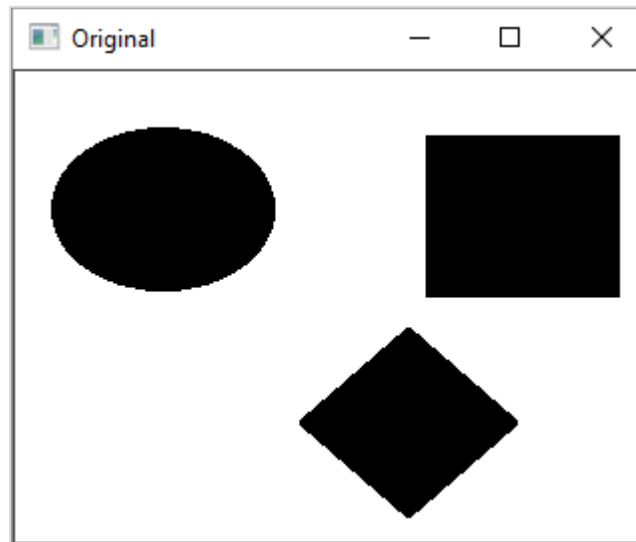
contours, hierarchy = cv2.findContours(canny,
                                       cv2.RETR_EXTERNAL, cv2.CHAIN_APPROX_NONE)
print("Number of Contours = ", len(contours))
cv2.imshow('Canny Edges', canny)

cv2.drawContours(img, contours, -1, (0, 255, 0), 3)

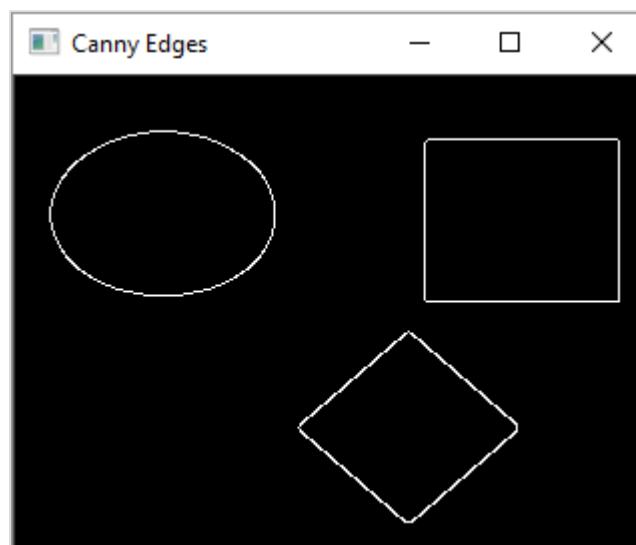
cv2.imshow('Contours', img)
cv2.waitKey(0)
cv2.destroyAllWindows()
```

Output

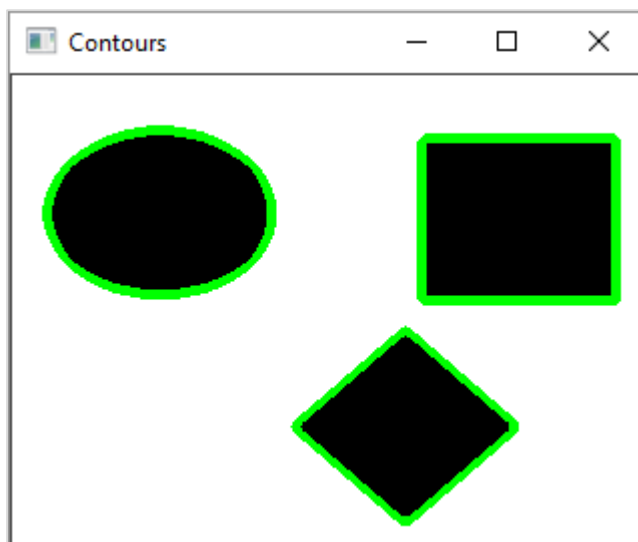
The original image, after canny edge detection and one with contours drawn will be displayed in separate windows as shown here:



After the **canny edge detection**, the image will be as follows:



After the **contours are drawn**, the image will be as follows:



19. OpenCV-Python — Template Matching

The technique of template matching is used to detect one or more areas in an image that matches with a sample or template image.

Cv.matchTemplate() function in OpenCV is defined for the purpose and the command for the same is as follows:

```
cv.matchTemplate(image, templ, method)
```

Where image is the input image in which the templ (template) pattern is to be located. The method parameter takes one of the following values:

- cv.TM_CCOEFF,
- cv.TM_CCOEFF_NORMED, cv.TM_CCORR,
- cv.TM_CCORR_NORMED,
- cv.TM_SQDIFF,
- cv.TM_SQDIFF_NORMED

This method slides the template image over the input image. This is a similar process to convolution and compares the template and patch of input image under the template image.

It returns a grayscale image, whose each pixel denotes how much it matches with the template. If the input image is of size (WxH) and template image is of size (wxh), the output image will have a size of (W-w+1, H-h+1). Hence, that rectangle is your region of template.

Example program

In an example below, an image having Indian cricketer Virat Kohli's face is used as a template to be matched with another image which depicts his photograph with another Indian cricketer M.S.Dhoni.

Following program uses a threshold value of 80% and draws a rectangle around the matching face:

```
import cv2
import numpy as np

img = cv2.imread('Dhoni-and-Virat.jpg',1)
cv2.imshow('Original',img)
gray = cv2.cvtColor(img, cv2.COLOR_BGR2GRAY)

template = cv2.imread('virat.jpg',0)
cv2.imshow('Template',template)
```

```

w,h = template.shape[0], template.shape[1]

matched = cv2.matchTemplate(gray,template,cv2.TM_CCOEFF_NORMED)
threshold = 0.8

loc = np.where( matched >= threshold)

for pt in zip(*loc[::-1]):
    cv2.rectangle(img, pt, (pt[0] + w, pt[1] + h), (0,255,255), 2)

cv2.imshow('Matched with Template',img)

```

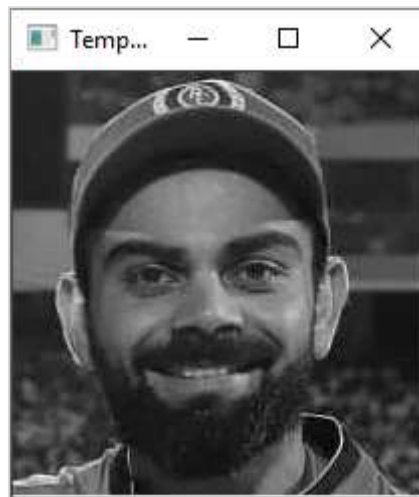
Output

The original image, the template and matched image of the result as follows:

Original image



The **template** is as follows:



The image when **matched with template** is as follows:



20. OpenCV-Python — Image Pyramids

Occasionally, we may need to convert an image to a size different than its original. For this, you either Upsize the image (zoom in) or Downsize it (zoom out).

An image pyramid is a collection of images (constructed from a single original image) successively down sampled a specified number of times.

The Gaussian pyramid is used to down sample images while the Laplacian pyramid reconstructs an up sampled image from an image lower in the pyramid with less resolution.

Consider the pyramid as a set of layers. The image is shown below:

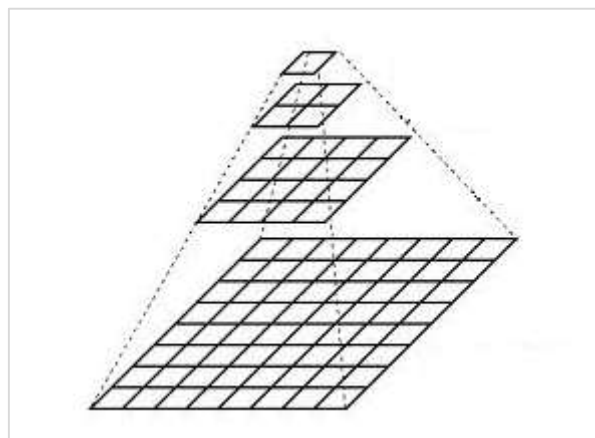


Image at the higher layer of the pyramid is smaller in size. To produce an image at the next layer in the Gaussian pyramid, we convolve a lower level image with a Gaussian kernel.

$$\frac{1}{16} \begin{bmatrix} 1 & 4 & 6 & 4 & 1 \\ 4 & 16 & 24 & 16 & 4 \\ 6 & 24 & 36 & 24 & 6 \\ 4 & 16 & 24 & 16 & 4 \\ 1 & 4 & 6 & 4 & 1 \end{bmatrix}$$

Now remove every even-numbered row and column. Resulting image will be 1/4th the area of its predecessor. Iterating this process on the original image produces the entire pyramid.

To make the images bigger, the columns filled with zeros. First, upsize the image to double the original in each dimension, with the new even rows and then perform a convolution with the kernel to approximate the values of the missing pixels.

The **cv.pyrUp()** function doubles the original size and **cv.pyrDown()** function decreases it to half.

Program

Following program calls `pyrUp()` and `pyrDown()` functions depending on user input "I" or "o" respectively.

Note that when we reduce the size of an image, information of the image is lost. Once, we scale down and if we rescale it to the original size, we lose some information and the resolution of the new image is much lower than the original one.

```
import sys
import cv2 as cv

filename = 'chicky_512.png'

src = cv.imread(filename)

while 1:
    print ("press 'i' for zoom in 'o' for zoom out esc to stop")
    rows, cols, _channels = map(int, src.shape)
    cv.imshow('Pyramids', src)
    k = cv.waitKey(0)

    if k == 27:
        break

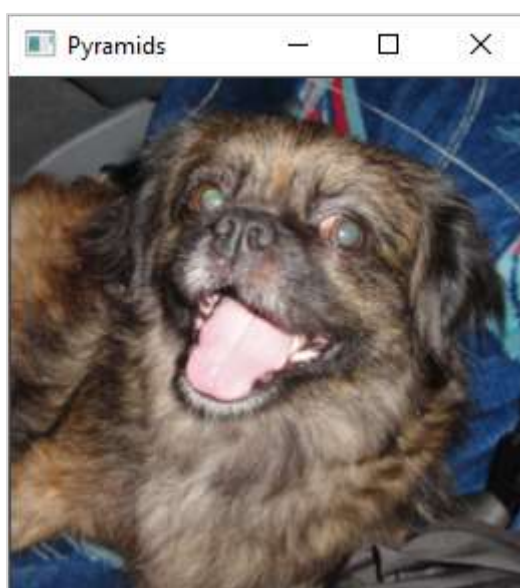
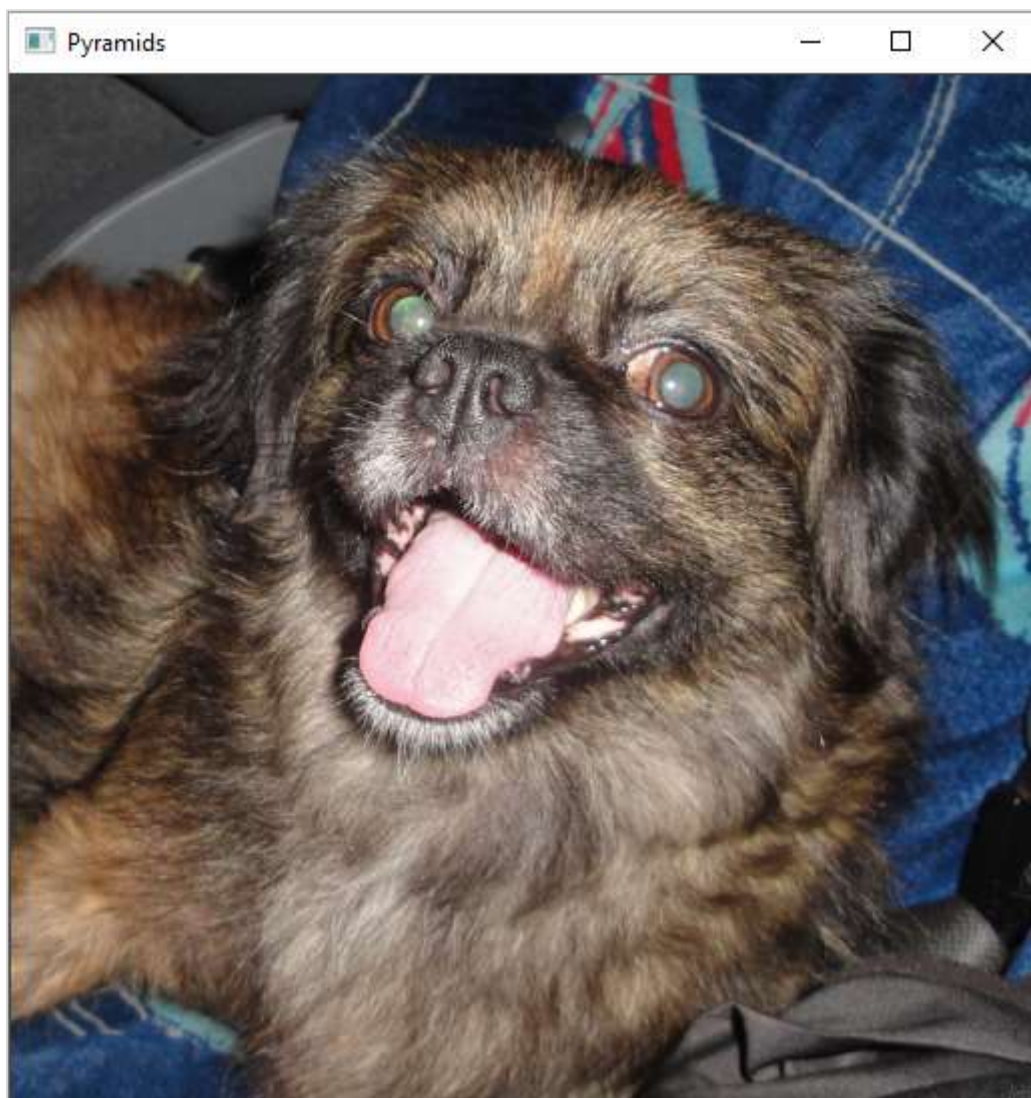
    elif chr(k) == 'i':
        src = cv.pyrUp(src, dstsize=(2 * cols, 2 * rows))

    elif chr(k) == 'o':
        src = cv.pyrDown(src, dstsize=(cols // 2, rows // 2))

cv.destroyAllWindows()
```

Output

On executing the above program, you will get the following result:





21. OpenCV-Python — Image Addition

When an image is read by `imread()` function, the resultant image object is really a two or three dimensional matrix depending upon if the image is grayscale or RGB image.

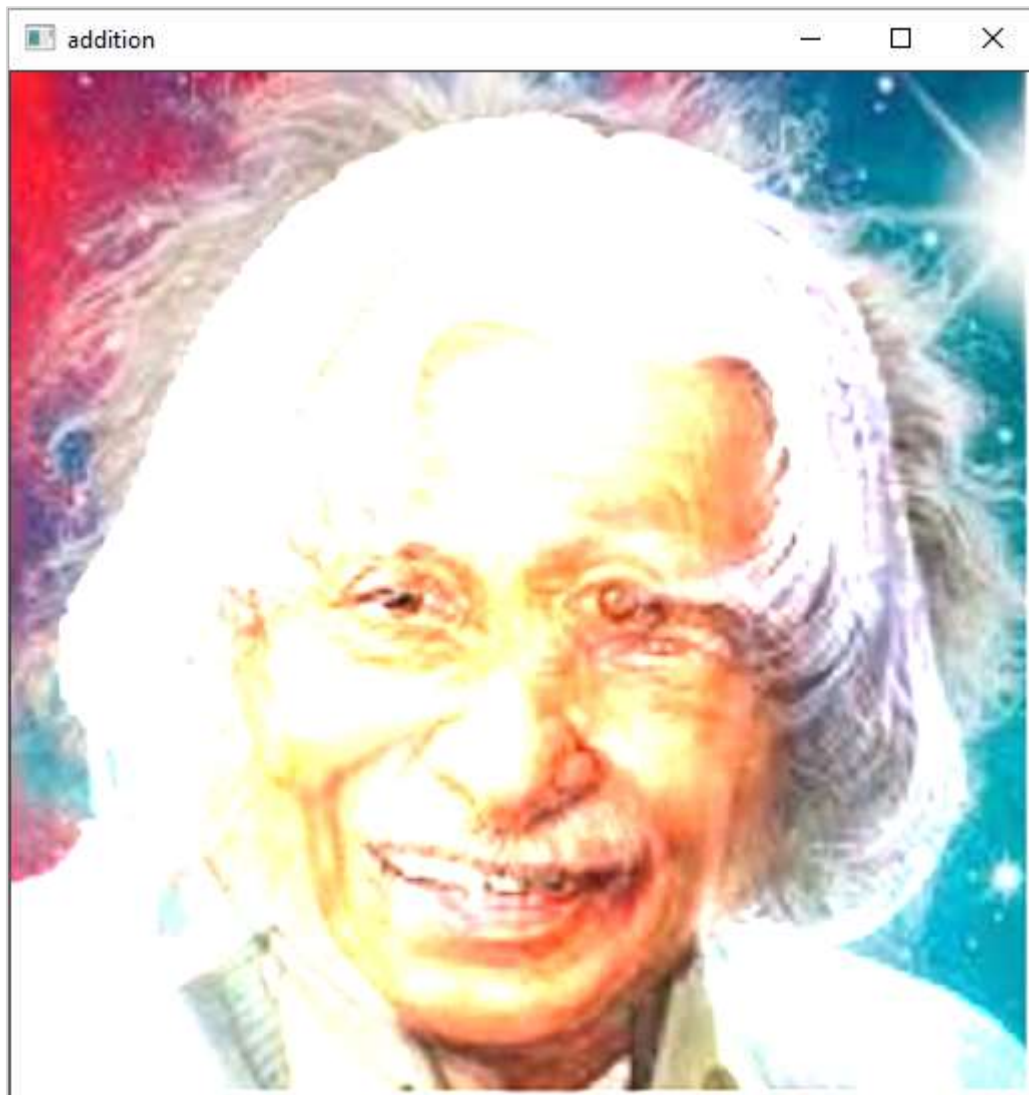
Hence, **`cv2.add()`** functions add two image matrices and returns another image matrix.

Following code reads two images and performs their binary addition:

```
kalam = cv2.imread('kalam.jpg')
einst = cv2.imread('einstein.jpg')
img = cv2.add(kalam, einst)
cv2.imshow('addition', img)
```

Result

When you run the code, you will see the following output:



Instead of a linear binary addition, OpenCV has a **addWeighted()** function that performs weighted sum of two arrays. The command for the same is as follows:

```
Cv2.addWeighted(src1, alpha, src2, beta, gamma)
```

Parameters

The parameters of the **addWeighted()** function are as follows:

- src1: First input array.
- alpha: Weight of the first array elements.
- src2: Second input array of the same size and channel number as first
- beta: Weight of the second array elements.
- gamma: Scalar added to each sum.

This function adds the images as per following equation:

$$g(x)=(1-\alpha)f_0(x)+\alpha f_1(x)$$

The image matrices obtained in the above example are used to perform weighted sum.

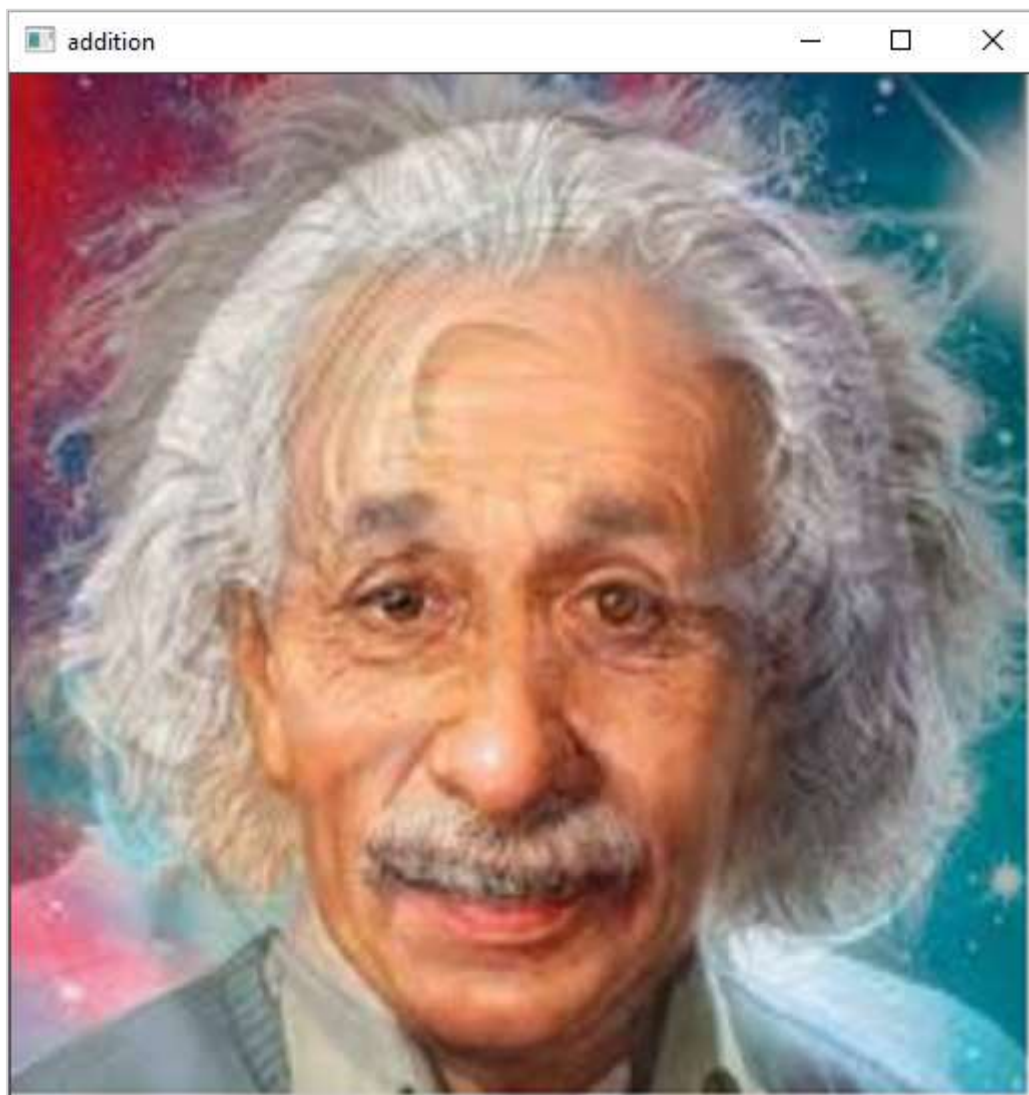
By varying α from 0 -> 1, a smooth transition takes place from one image to another, so that they blend together.

First image is given a weight of 0.3 and the second image is given 0.7. The gamma factor is taken as 0.

The command for **addWeighted()** function is as follows:

```
img = cv2.addWeighted(kalam, 0.3, einst, 0.7, 0)
```

It can be seen that the image addition is smoother compared to binary addition.



22. OpenCV-Python — Image Blending with Pyramids

The discontinuity of images can be minimised by the use of image pyramids. This results in a seamless blended image.

Following steps are taken to achieve the final result:

First load the images and find Gaussian pyramids for both. The program for the same is as follows:

```
import cv2
import numpy as np,sys

kalam = cv2.imread('kalam.jpg')
einst = cv2.imread('einstein.jpg')
### generate Gaussian pyramid for first
G = kalam.copy()
gpk = [G]
for i in range(6):
    G = cv2.pyrDown(G)
    gpk.append(G)
# generate Gaussian pyramid for second
G = einst.copy()
gpe = [G]
for i in range(6):
    G = cv2.pyrDown(G)
    gpe.append(G)
```

From the Gaussian pyramids, obtain the respective Laplacian Pyramids. The program for the same is as follows:

```
# generate Laplacian Pyramid for first
lpk = [gpk[5]]
for i in range(5,0,-1):
    GE = cv2.pyrUp(gpk[i])
    L = cv2.subtract(gpk[i-1],GE)
    lpk.append(L)

# generate Laplacian Pyramid for second
```



```
lpe = [gpe[5]]
for i in range(5,0,-1):
    GE = cv2.pyrUp(gpe[i])
    L = cv2.subtract(gpe[i-1],GE)
    lpe.append(L)
```

Then, join the left half of the first image with the right half of second in each level of pyramids. The program for the same is as follows:

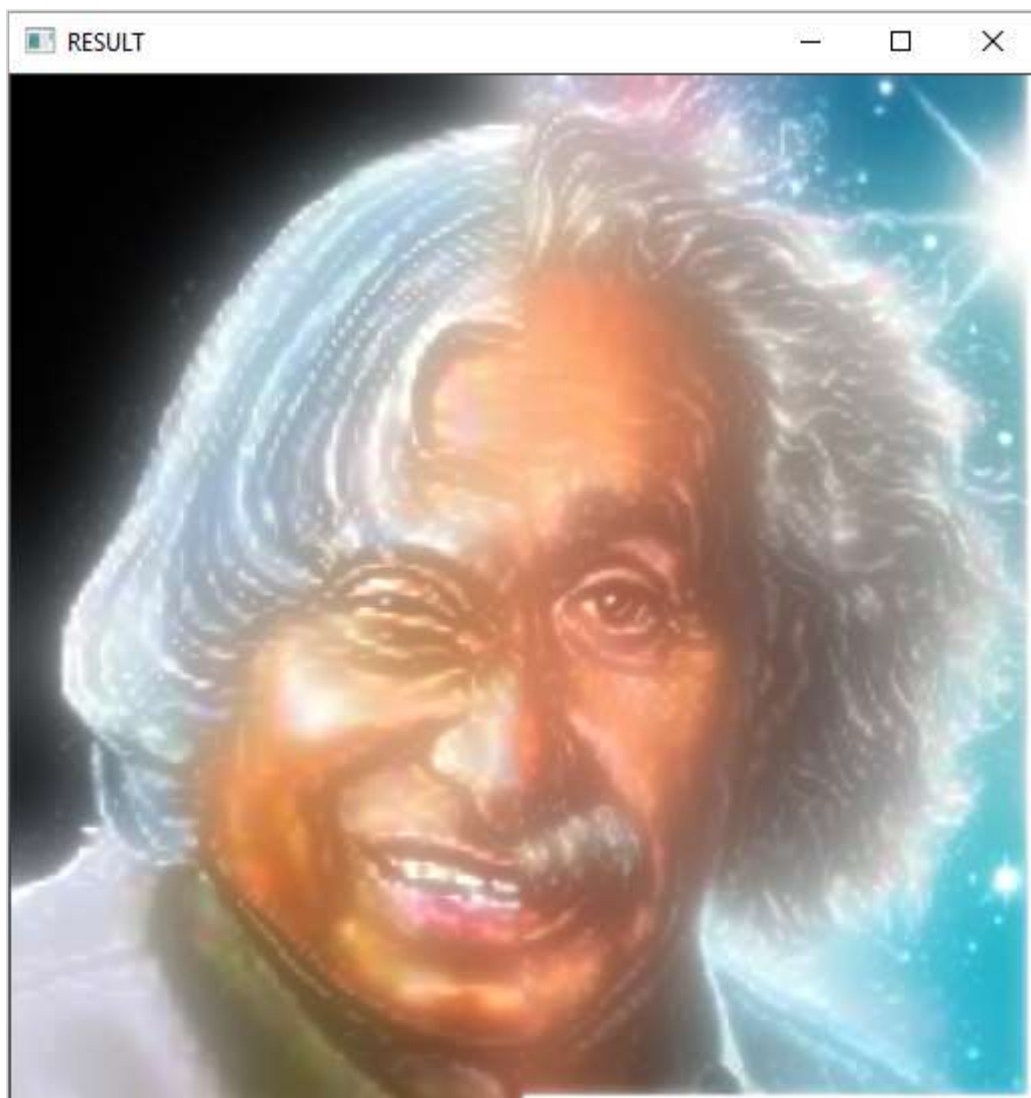
```
# Now add left and right halves of images in each level
LS = []
for la,lb in zip(lpk,lpe):
    rows,cols,dpt = la.shape
    ls = np.hstack((la[:,0:int(cols/2)], lb[:,int(cols/2):]))
    LS.append(ls)
```

Finally, reconstruct the image from this joint pyramid. The program for the same is given below:

```
ls_ = LS[0]
for i in range(1,6):
    ls_ = cv2.pyrUp(ls_)
    ls_ = cv2.add(ls_, LS[i])
    cv2.imshow('RESULT',ls_)
```

Output

The blended result should be as follows:



23. OpenCV-Python — Fourier Transform

The Fourier Transform is used to transform an image from its spatial domain to its frequency domain by decomposing it into its sinus and cosines components.

In case of digital images, a basic gray scale image values usually are between zero and 255. Therefore, the Fourier Transform too needs to be a **Discrete Fourier Transform** (DFT). It is used to find the frequency domain.

Mathematically, Fourier Transform of a two dimensional image is represented as follows:

$$F(k, l) = \sum_{i=0}^{N-1} \sum_{j=0}^{N-1} f(i, j) e^{-i2\pi(\frac{ki}{N} + \frac{lj}{N})}$$

If the amplitude varies so fast in a short time, you can say it is a high frequency signal. If it varies slowly, it is a low frequency signal.

In case of images, the amplitude varies drastically at the edge points, or noises. So edges and noises are high frequency contents in an image. If there are no much changes in amplitude, it is a low frequency component.

OpenCV provides the functions **cv.dft()** and **cv.idft()** for this purpose.

cv.dft() performs a Discrete Fourier transform of a 1D or 2D floating-point array. The command for the same is as follows:

```
cv.dft(src, dst, flags)
```

Here,

- src: Input array that could be real or complex.
- dst: Output array whose size and type depends on the flags.
- flags: Transformation flags, representing a combination of the DftFlags.

cv.idft() calculates the inverse Discrete Fourier Transform of a 1D or 2D array. The command for the same is as follows:

```
cv.idft(src, dst, flags)
```

In order to obtain a discrete fourier transform, the input image is converted to np.float32 datatype. The transform obtained is then used to Shift the zero-frequency component to the center of the spectrum, from which magnitude spectrum is calculated.

Given below is the program using Matplotlib, we plot the original image and magnitude spectrum:

```
import numpy as np
import cv2 as cv
```

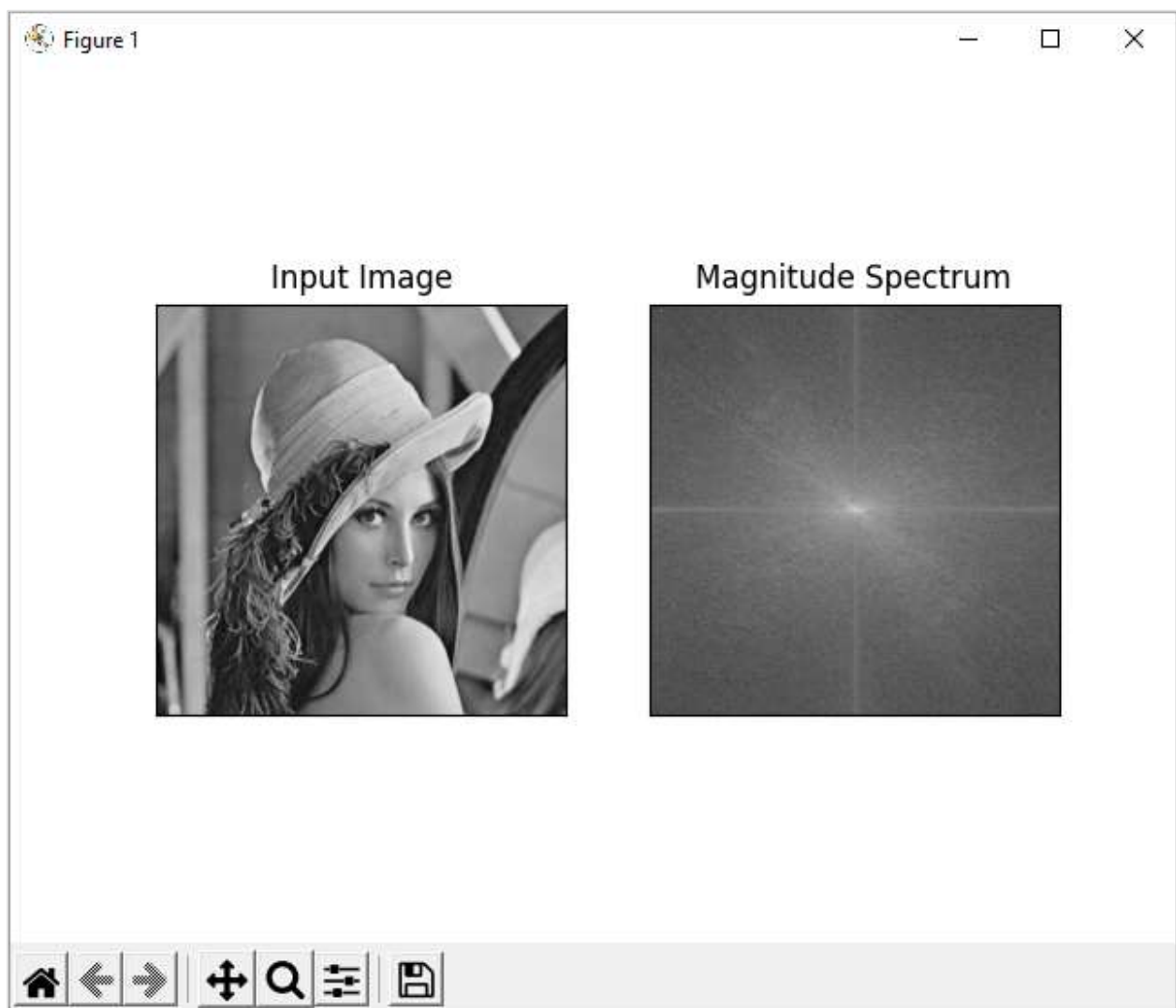
```

from matplotlib import pyplot as plt
img = cv.imread('lena.jpg',0)
dft = cv.dft(np.float32(img),flags = cv.DFT_COMPLEX_OUTPUT)
dft_shift = np.fft.fftshift(dft)
magnitude_spectrum = 20*np.log(cv.magnitude(dft_shift[:, :,0],dft_shift[:, :,1]))
plt.subplot(121),plt.imshow(img, cmap = 'gray')
plt.title('Input Image'), plt.xticks([]), plt.yticks([])
plt.subplot(122),plt.imshow(magnitude_spectrum, cmap = 'gray')
plt.title('Magnitude Spectrum'), plt.xticks([]), plt.yticks([])
plt.show()

```

Output

You will receive the following output:



24. OpenCV-Python — Capture Video from Camera

By using the **VideoCapture()** function in OpenCV library, it is very easy to capture a live stream from a camera on the OpenCV window.

This function needs a device index as the parameter. Your computer may have multiple cameras attached. They are enumerated by an index starting from 0 for built-in webcam. The function returns a VideoCapture object

```
cam = cv.VideoCapture(0)
```

After the camera is opened, we can read successive frames from it with the help of **read()** function

```
ret, frame = cam.read()
```

The read() function reads the next available frame and a return value (True/False). This frame is now rendered in desired color space with the **cvtColor()** function and displayed on the OpenCV window.

```
img = cv.cvtColor(frame, cv.COLOR_BGR2RGB)
# Display the resulting frame
cv.imshow('frame', img)
```

To capture the current frame to an image file, you can use **imwrite()** function.

```
cv2.imwrite("capture.png", img)
```

To save the live stream from camera to a video file, OpenCV provides a VideoWriter() function.

```
cv.VideoWriter( filename, fourcc, fps, frameSize)
```

The fourcc parameter is a standardized code for video codecs. OpenCV supports various codecs such as DIVX, XVID, MJPG, X264 etc. The fps and framesize parameters depend on the video capture device.

The VideoWriter() function returns a VideoWrite stream object, to which the grabbed frames are successively written in a loop. Finally, release the frame and VideoWriter objects to finalize the creation of video.

Example Program

Following example reads live feed from built-in webcam and saves it to output.avi file.

```
import cv2 as cv
cam = cv.VideoCapture(0)
cc = cv.VideoWriter_fourcc(*'XVID')
```

```
file = cv.VideoWriter('output.avi', cc, 15.0, (640, 480))
if not cam.isOpened():
    print("error opening camera")
    exit()
while True:
    # Capture frame-by-frame
    ret, frame = cam.read()
    # if frame is read correctly ret is True
    if not ret:
        print("error in retrieving frame")
        break
    img = cv.cvtColor(frame, cv.COLOR_BGR2RGB)
    cv.imshow('frame', img)
    file.write(img)

    if cv.waitKey(1) == ord('q'):
        break

cam.release()
file.release()
cv.destroyAllWindows()
```

25. OpenCV-Python — Play Video from File

The **VideoCapture()** function can also retrieve frames from a video file instead of a camera. Hence, we have only replaced the camera index with the video file's name to be played on the OpenCV window.

```
video=cv2.VideoCapture(file)
```

While this should be enough to start rendering a video file, if it is accompanied by sound. The sound will not play along. For this purpose, you will need to install the `ffpyplayer` module.

FFPyPlayer

FFPyPlayer is a python binding for the FFmpeg library for playing and writing media files. To install, use pip installer utility by using the following command.

```
pip3 install ffpyplayer
```

The **get_frame()** method of the MediaPlayer object in this module returns the audio frame which will play along with each frame read from the video file.

Following is the complete code for playing a video file along with its audio:

```
import cv2

from ffpyplayer.player import MediaPlayer
file="video.mp4"

video=cv2.VideoCapture(file)
player = MediaPlayer(file)
while True:
    ret, frame=video.read()
    audio_frame, val = player.get_frame()
    if not ret:
        print("End of video")
        break
    if cv2.waitKey(1) == ord("q"):
        break
    cv2.imshow("Video", frame)
    if val != 'eof' and audio_frame is not None:
        #audio
```

```
img, t = audio_frame  
video.release()  
cv2.destroyAllWindows()
```


26. OpenCV-Python — Extract Images from Video

A video is nothing but a sequence of frames and each frame is an image. By using OpenCV, all the frames that compose a video file can be extracted by executing **imwrite()** function till the end of video.

The **cv2.read()** function returns the next available frame. The function also gives a return value which continues to be true till the end of stream. Here, a counter is incremented inside the loop and used as a file name.

Following program demonstrates how to extract images from the video:

```
import cv2
import os

cam = cv2.VideoCapture("video.avi")

framenno = 0

while(True):

    ret,frame = cam.read()

    if ret:
        # if video is still left continue creating images
        name = str(framenno) + '.jpg'
        print ('new frame captured...' + name)

        cv2.imwrite(name, frame)

        framenno += 1
    else:
        break

cam.release()
cv2.destroyAllWindows()
```

27. OpenCV-Python — Video from Images

In the previous chapter, we have used the `VideoWriter()` function to save the live stream from a camera as a video file. To stitch multiple images into a video, we shall use the same function.

First, ensure that all the required images are in a folder. Python's `glob()` function in the built-in `glob` module builds an array of images so that we can iterate through it.

Read the image object from the images in the folder and append to an image array.

Following program explains how to stitch multiple images in a video:

```
import cv2
import numpy as np
import glob

img_array = []
for filename in glob.glob('*.png'):
    img = cv2.imread(filename)
    height, width, layers = img.shape
    size = (width,height)
    img_array.append(img)
```

The create a video stream by using `VideoWriter()` function to write the contents of the image array to it. Given below is the program for the same.

```
out = cv2.VideoWriter('video.avi',cv2.VideoWriter_fourcc(*'DIVX'), 15, size)

for i in range(len(img_array)):
    out.write(img_array[i])
out.release()
```

You should find the file named '**video.avi**' in the current folder.

28. OpenCV-Python — Face Detection

OpenCV uses **Haar** feature-based cascade classifiers for the object detection. It is a machine learning based algorithm, where a cascade function is trained from a lot of positive and negative images. It is then used to detect objects in other images. The algorithm uses the concept of Cascade of Classifiers.

Pretrained classifiers for face, eye etc. can be downloaded from <https://github.com/opencv/opencv/tree/master/data/haarcascades>.

For the following example, download and **copy haarcascade_frontalface_default.xml** and **haarcascade_eye.xml** from this URL. Then, load our input image to be used for face detection in grayscale mode.

The **DetectMultiScale()** method of CascadeClassifier class detects objects in the input image. It returns the positions of detected faces as in the form of Rectangle and its dimensions (x,y,w,h). Once we get these locations, we can use it for eye detection since eyes are always on the face!

The complete code for face detection is as follows:

```
import numpy as np
import cv2

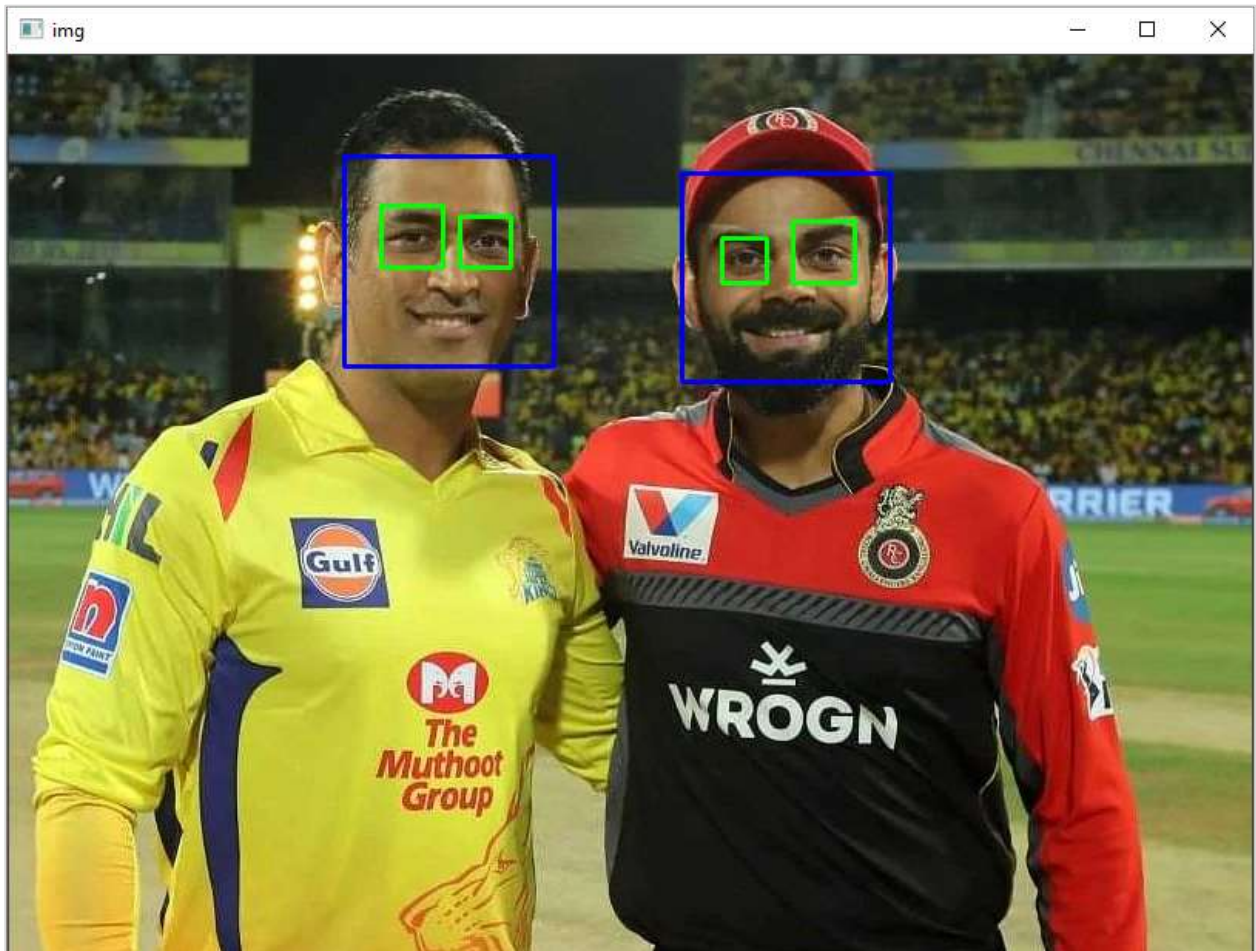
face_cascade = cv2.CascadeClassifier('haarcascade_frontalface_default.xml')
eye_cascade = cv2.CascadeClassifier('haarcascade_eye.xml')

img = cv2.imread('Dhoni-and-virat.jpg')
gray = cv2.cvtColor(img, cv2.COLOR_BGR2GRAY)
faces = face_cascade.detectMultiScale(gray, 1.3, 5)
for (x,y,w,h) in faces:
    img = cv2.rectangle(img,(x,y),(x+w,y+h),(255,0,0),2)
    roi_gray = gray[y:y+h, x:x+w]
    roi_color = img[y:y+h, x:x+w]
    eyes = eye_cascade.detectMultiScale(roi_gray)
    for (ex,ey,ew,eh) in eyes:
        cv2.rectangle(roi_color,(ex,ey),(ex+ew,ey+eh),(0,255,0),2)

cv2.imshow('img',img)
cv2.waitKey(0)
cv2.destroyAllWindows()
```

Output

You will get rectangles drawn around faces in the input image as shown below:



29. OpenCV-Python — Meanshift and Camshift

In this chapter, let us learn about the meanshift and the camshift in the OpenCV-Python. First, let us understand what is meanshift.

Meanshift

The mean shift algorithm identifies places in the data set with a high concentration of data points, or clusters. The algorithm places a kernel at each data point and sums them together to make a **Kernel Density Estimation** (KDE).

The KDE will have places with a high and low data point density, respectfully. Meanshift is a very useful method to keep the track of a particular object inside a video.

Every instance of the video is checked in the form of pixel distribution in that frame. An initial window as region of interest (**ROI**) is generally a square or a circle. For this, the positions are specified by hardcoding and the area of maximum pixel distribution is identified.

The ROI window moves towards the region of maximum pixel distribution as the video runs. The direction of movement depends upon the difference between the center of our tracking window and the centroid of all the k-pixels inside that window.

In order to use Meanshift in OpenCV, first, find the histogram (of which, only Hue is considered) of our target and can back project its target on each frame for calculation of Meanshift. We also need to provide an initial location of the ROI window.

We repeatedly calculate the back projection of the histogram and calculate the Meanshift to get the new position of track window. Later on, we draw a rectangle using its dimensions on the frame.

Functions

The openCV functions used in the program are:

- **cv.calcBackProject()**: Calculates the back projection of a histogram.
- **cv.meanShift()**: Back projection of the object histogram using initial search window and Stop criteria for the iterative search algorithm.

Example Program

Here is the example program of Meanshift:

```
import numpy as np
import cv2 as cv

cap = cv.VideoCapture('traffic.mp4')

ret, frame = cap.read()
```

```

# dimensions of initial location of window
x, y, w, h = 300, 200, 100, 50
tracker = (x, y, w, h)

region = frame[y:y+h, x:x+w]
hsv_reg = cv.cvtColor(region, cv.COLOR_BGR2HSV)
mask = cv.inRange(hsv_reg, np.array((0., 60.,32.)), np.array((180.,255.,255.)))
reg_hist = cv.calcHist([hsv_reg],[0],mask,[180],[0,180])
cv.normalize(reg_hist,reg_hist,0,255,cv.NORM_MINMAX)

# Setup the termination criteria
criteria = ( cv.TERM_CRITERIA_EPS | cv.TERM_CRITERIA_COUNT, 10, 1 )

while(1):
    ret, frame = cap.read()

    if ret == True:
        hsv = cv.cvtColor(frame, cv.COLOR_BGR2HSV)
        dst = cv.calcBackProject([hsv],[0],reg_hist,[0,180],1)

        # apply meanshift
        ret, tracker = cv.meanShift(dst, tracker, criteria)

        # Draw it on image
        x,y,w,h = tracker
        img = cv.rectangle(frame, (x,y), (x+w,y+h), 255,2)
        cv.imshow('img',img)

        k = cv.waitKey(30) & 0xff
        if k==115:
            cv.imwrite('capture.png', img)
        if k == 27:
            break

```

As the program is run, the Meanshift algorithm moves our window to the new location with maximum density.

Output

Here's a snapshot of moving window:



Camshift

One of the disadvantages of Meanshift algorithm is that the size of the tracking window remains the same irrespective of the object's distance from the camera. Also, the window will track the object only if it is in the region of that object. So, we must do manual hardcoding of the window and it should be done carefully.

The solution to these problems is given by CAMshift (stands for **Continuously Adaptive Meanshift**). Once meanshift converges, the Camshift algorithm updates the size of the window such that the tracking window may change in size or even rotate to better correlate to the movements of the tracked object.

In the following code, instead of `meanshift()` function, the `camshift()` function is used.

First, it finds an object center using `meanShift` and then adjusts the window size and finds the optimal rotation. The function returns the object position, size, and orientation. The position is drawn on the frame by using `polylines()` draw function.

Instead of `Meanshift()` function in earlier program, use `CamShift()` function as below:

```
# apply camshift
ret, tracker = cv.CamShift(dst, tracker, criteria)
pts = cv.boxPoints(ret)
pts = np.int0(pts)
img = cv.polylines(frame,[pts],True, 255,2)
cv.imshow('img',img)
```

Output

One snapshot of the result of modified program showing rotated rectangle of the tracking window is as follows:



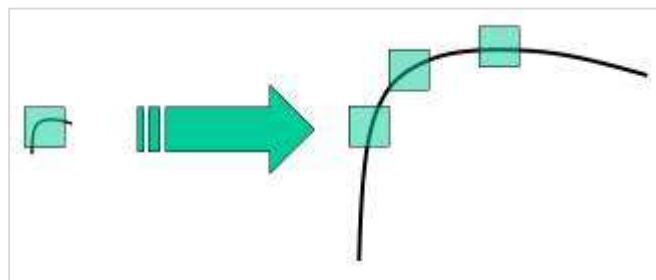
30. OpenCV-Python — Feature Detection

In the context of image processing, features are mathematical representations of key areas in an image. They are the vector representations of the visual content from an image.

Features make it possible to perform mathematical operations on them. Various computer vision applications include object detection, motion estimation, segmentation, image alignment etc.

Prominent features in any image include edges, corners or parts of an image. OpenCV supports **Harris corner detection** and **Shi-Tomasi corner detection** algorithms. OpenCV library also provides functionality to implement **SIFT** (Scale-Invariant Feature Transform), **SURF** (Speeded-Up Robust Features) and FAST algorithm for corner detection.

Harris and Shi-Tomasi algorithms are rotation-invariant. Even if the image is rotated, we can find the same corners. But when an image is scaled up, a corner may not be a corner if the image. The figure given below depicts the same.



D.Lowe's new algorithm, **Scale Invariant Feature Transform** (SIFT) extracts the key points and computes its descriptors.

This is achieved by following steps:

- Scale-space Extrema Detection.
- Keypoint Localization.
- Orientation Assignment.
- Keypoint Descriptor.
- Keypoint Matching.

As far as implementation of SIFT in OpenCV is concerned, it starts from loading an image and converting it into grayscale. The **cv.SHIFT_create()** function creates a SIFT object.

Calling its **detect()** method obtains key points which are drawn on top of the original image. Following code implements this procedure:

```
import numpy as np
import cv2 as cv
```

```
img = cv.imread('home.jpg')
gray= cv.cvtColor(img,cv.COLOR_BGR2GRAY)
sift = cv.SIFT_create()
kp = sift.detect(gray,None)
img=cv.drawKeypoints(gray,kp,img)
cv.imwrite('keypoints.jpg',img)
```

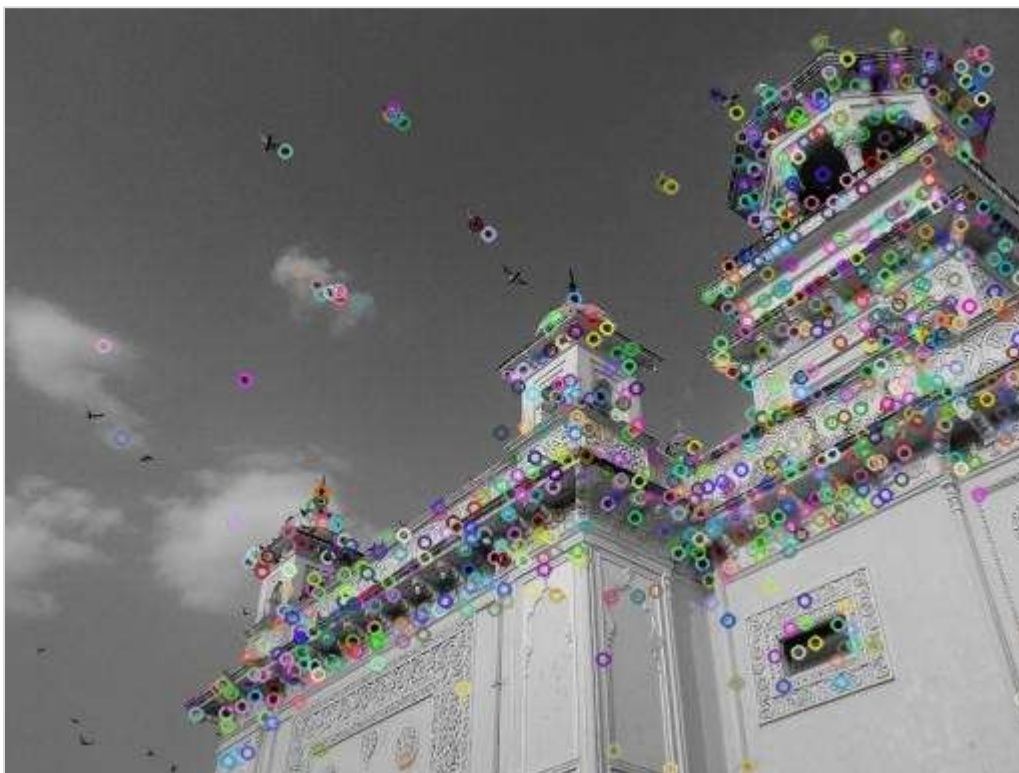
Output

The original image and the one with keypoints drawn are shown below:

This is an **original image**.



An image given below is the **one with keypoints**:



31. OpenCV-Python — Feature Matching

OpenCV provides two techniques for feature matching. Brute force matching and FLANN matcher technique.

Following example uses brute-force method:

```
import numpy as np
import cv2

img1 = cv2.imread('lena.jpg')
img2 = cv2.imread('lena-test.jpg')

# Convert it to grayscale
img1_bw = cv2.cvtColor(img1,cv2.COLOR_BGR2GRAY)
img2_bw = cv2.cvtColor(img2, cv2.COLOR_BGR2GRAY)

orb = cv2.ORB_create()

queryKeypoints, queryDescriptors = orb.detectAndCompute(img1_bw,None)
trainKeypoints, trainDescriptors = orb.detectAndCompute(img2_bw,None)

matcher = cv2.BFMatcher()
matches = matcher.match(queryDescriptors,trainDescriptors)

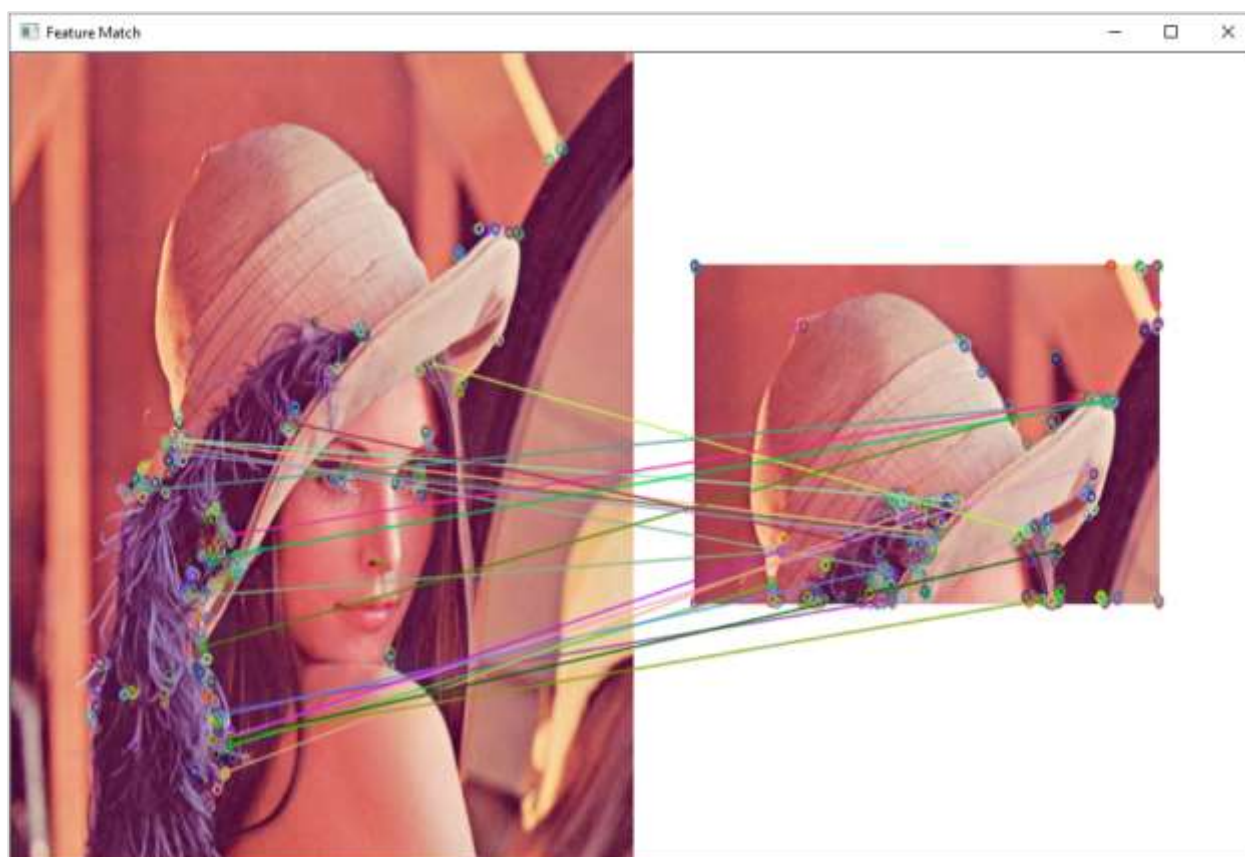
img = cv2.drawMatches(img1, queryKeypoints,
img2, trainKeypoints, matches[:20],None)

img = cv2.resize(img, (1000,650))

cv2.imshow("Feature Match", img)
```

Output

Upon execution, you will receive the following output:



32. OpenCV-Python — Digit Recognition with KNN

KNN which stands for **K-Nearest Neighbour** is a Machine Learning algorithm based on Supervised Learning. It tries to put a new data point into the category that is most similar to the available categories. All the available data is classified into distinct categories and a new data point is put in one of them based on the similarity.

The KNN algorithm works on following principle:

- Choose preferably an odd number as K for the number of neighbours to be checked.
- Calculate their Euclidean distance.
- Take the K nearest neighbors as per the calculated Euclidean distance.
- count the number of the data points in each category.
- Category with maximum data points is the category in which the new data point is classified.

As an example of implementation of KNN algorithm using OpenCV, we shall use the following image digits.png consisting of 5000 images of handwritten digits, each of 20X20 pixels.



First task is to split this image into 5000 digits. This is our feature set. Convert it to a NumPy array. The program is given below:

```
import numpy as np
import cv2

image = cv2.imread('digits.png')
```

```

gray = cv2.cvtColor(image, cv2.COLOR_BGR2GRAY)

fset=[]
for i in np.vsplit(gray,50):
    x=np.hsplit(i,100)
    fset.append(x)

NP_array = np.array(fset)

```

Now we divide this data in training set and testing set, each of size (2500,20x20) as follows:

```

trainset = NP_array[:, :50].reshape(-1,400).astype(np.float32)
testset = NP_array[:, 50:100].reshape(-1,400).astype(np.float32)

```

Next, we have to create 10 different labels for each digit, as shown below:

```

k = np.arange(10)
train_labels = np.repeat(k,250)[:,np.newaxis]
test_labels = np.repeat(k,250)[:,np.newaxis]

```

We are now in a position to start the KNN classification. Create the classifier object and train the data.

```

knn = cv2.ml.KNearest_create()
knn.train(trainset, cv2.ml.ROW_SAMPLE, train_labels)

```

Choosing the value of k as 3, obtain the output of the classifier.

```

ret, output, neighbours, distance = knn.findNearest(testset, k = 3)

```

Compare the output with test labels to check the performance and accuracy of the classifier.

The program shows an accuracy of 91.64% in detecting the handwritten digit accurately.

```

result = output==test_labels
correct = np.count_nonzero(result)

accuracy = (correct*100.0)/(output.size)

print(accuracy)

```

