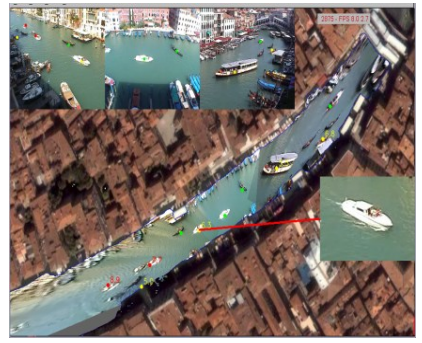
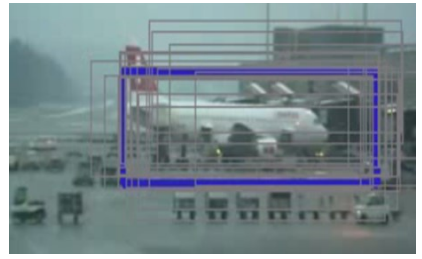
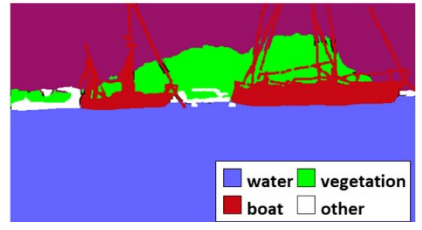
UNIVERSITÀ DEGLI STUDI DELLA BASILICATA



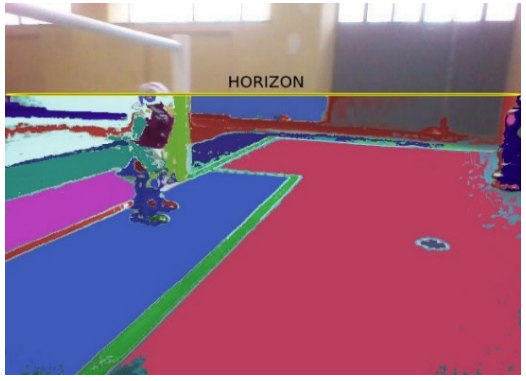
Corso di Visione e Percezione

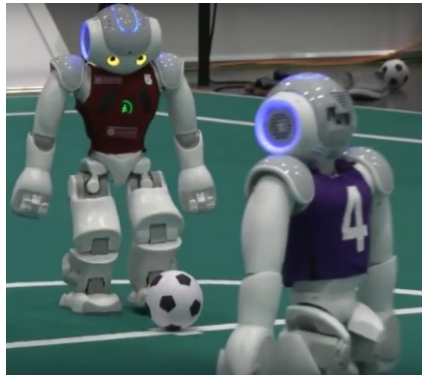
Docente
Domenico D. Bloisi



OpenCV (Python)

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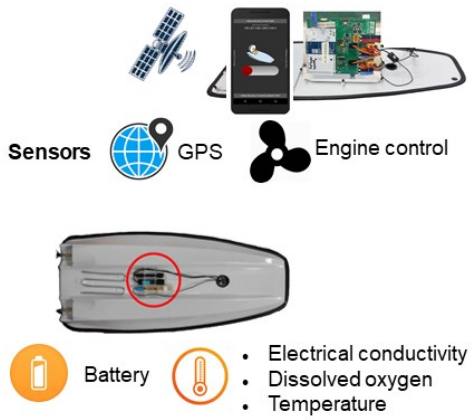
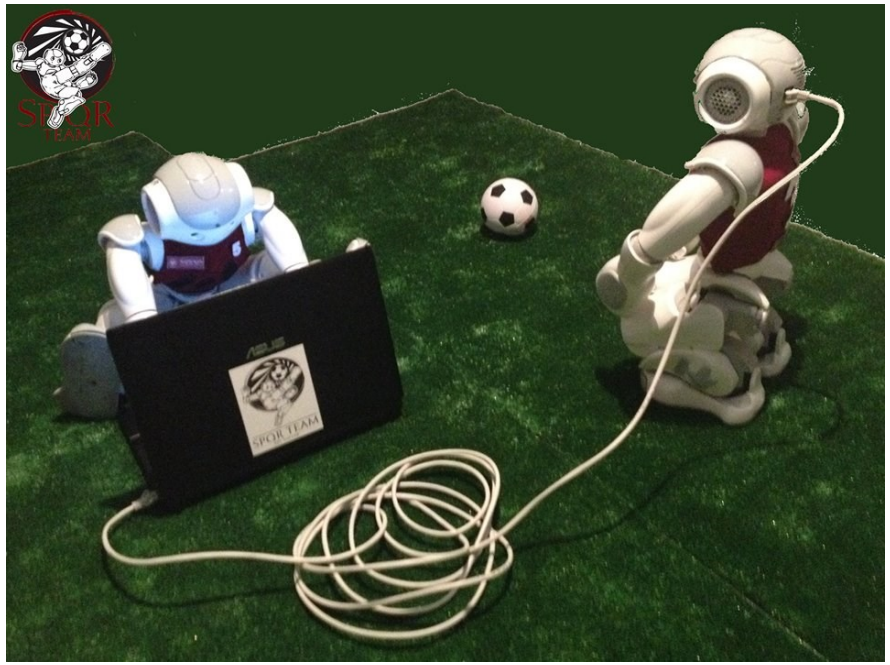




Informazioni sul corso

- Home page del corso
  http://web.unibas.it/bloisi/corsi/visione-e-percezione.html
- Docente: Domenico Daniele Bloisi
- Periodo: II semestre marzo 2021 – giugno 2021

  Martedì 17:00-19:00 (Aula COPERNICO)
  Mercoledì 8:30-10:30 (Aula COPERNICO)

Codice corso Google Classroom:
https://classroom.google.com/c/NjI2MjA4MzgzNDFa?cjc=xgolays

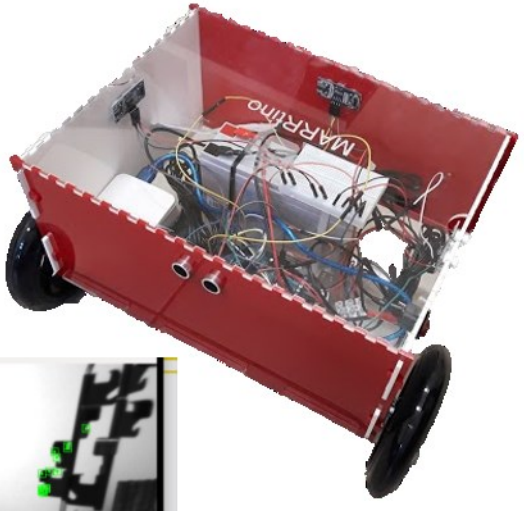
Ricevimento

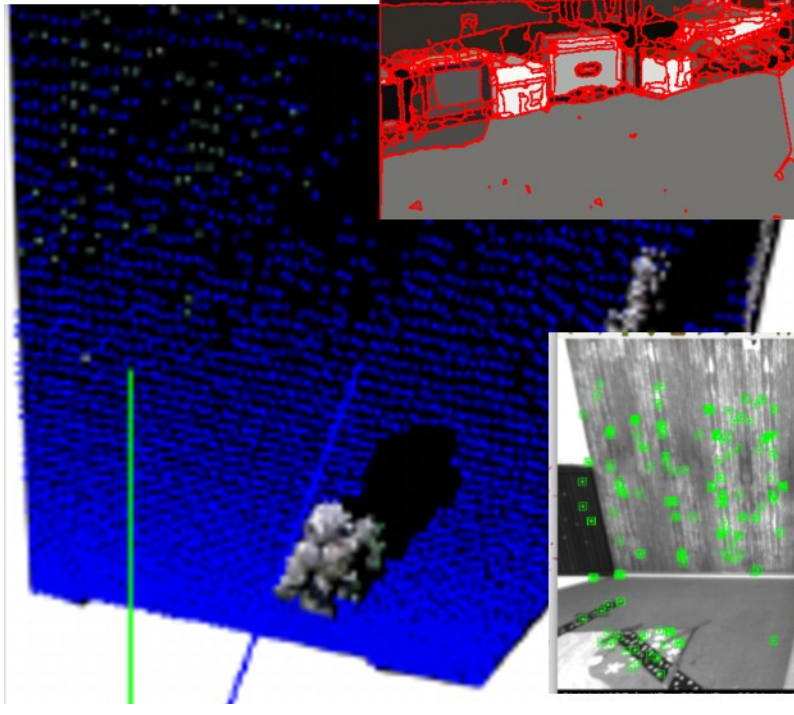
- Su appuntamento tramite Google Meet

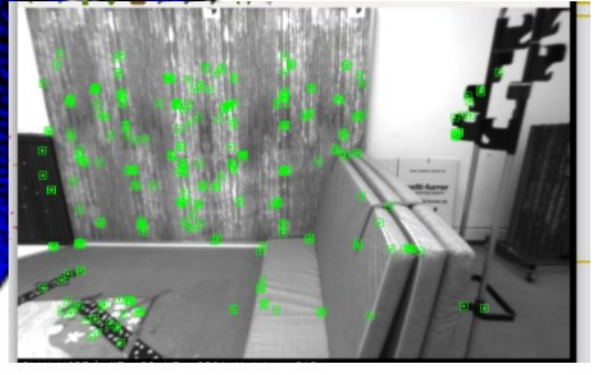
Per prenotare un appuntamento inviare una email a domenico.bloisi@unibas.it

Programma – Visione e Percezione

- Introduzione al linguaggio Python
- Elaborazione delle immagini con Python
- Percezione 2D – OpenCV
- Introduzione al Deep Learning
- ROS
- Il paradigma publisher and subscriber
- Simulatori
- Percezione 3D - PCL

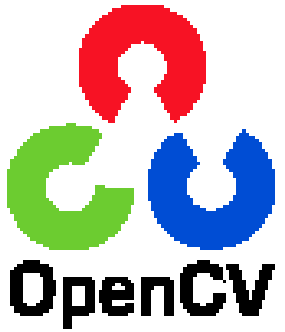






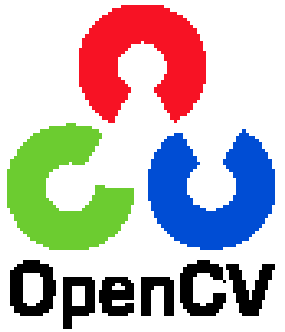
OpenCV

- OpenCV (Open Source Computer Vision Library) è una libreria software open source per la computer vision e il machine learning
- Distribuita con licensa BSD (è possibile utilizzarla per fini commerciali)
- Più di 2500 algoritmi disponibili
- Più di 47000 utenti nella community
- Più di 14 milioni di download



OpenCV

- Può essere utilizzata con C++, Python, Java e MATLAB
- Può essere installata su Windows, Linux, Android e Mac OS
- Dispone di interface per CUDA e OpenCL
- Viene usata da Google, Yahoo, Microsoft, Intel, IBM, Sony, Honda, Toyota

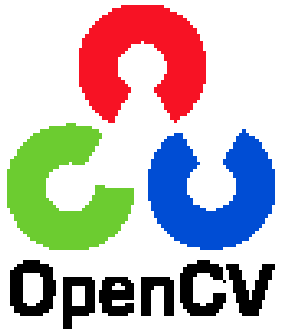


OpenCV - storia

- OpenCV was started at Intel in 1999 by **Gary Bradsky**, and the first release came out in 2000. **Vadim Pisarevsky** joined Gary Bradsky to manage Intel's Russian software OpenCV team.

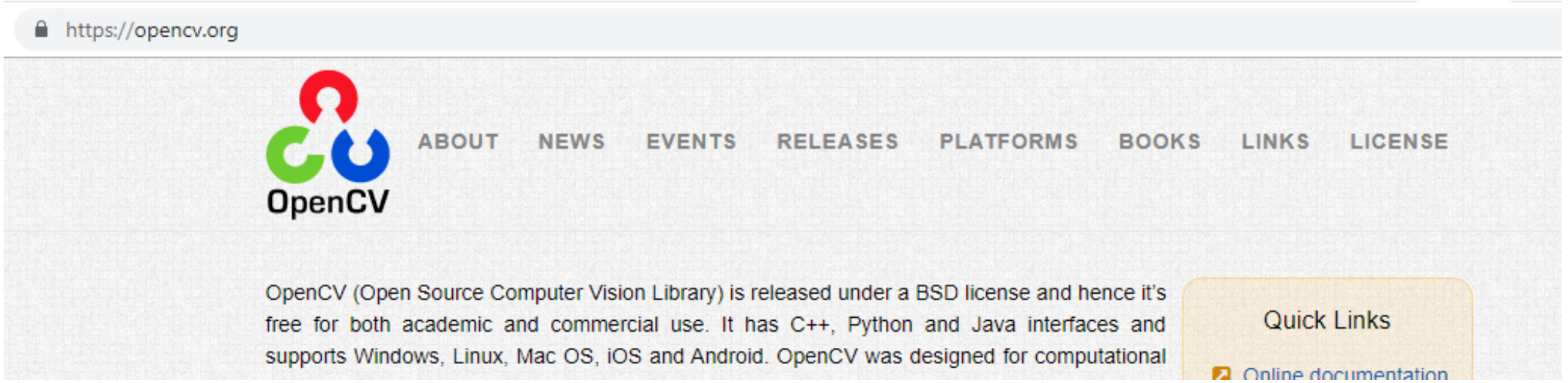
- In 2005, OpenCV was used on Stanley, the vehicle that won the 2005 DARPA Grand Challenge.

- Later, its active development continued under the support of Willow Garage with Gary Bradsky and Vadim Pisarevsky leading the project.



OpenCV - links

- Home: https://opencv.org/
- Documentatation: https://docs.opencv.org/
- Q&A forum: http://answers.opencv.org
- GitHub: https://github.com/opencv/

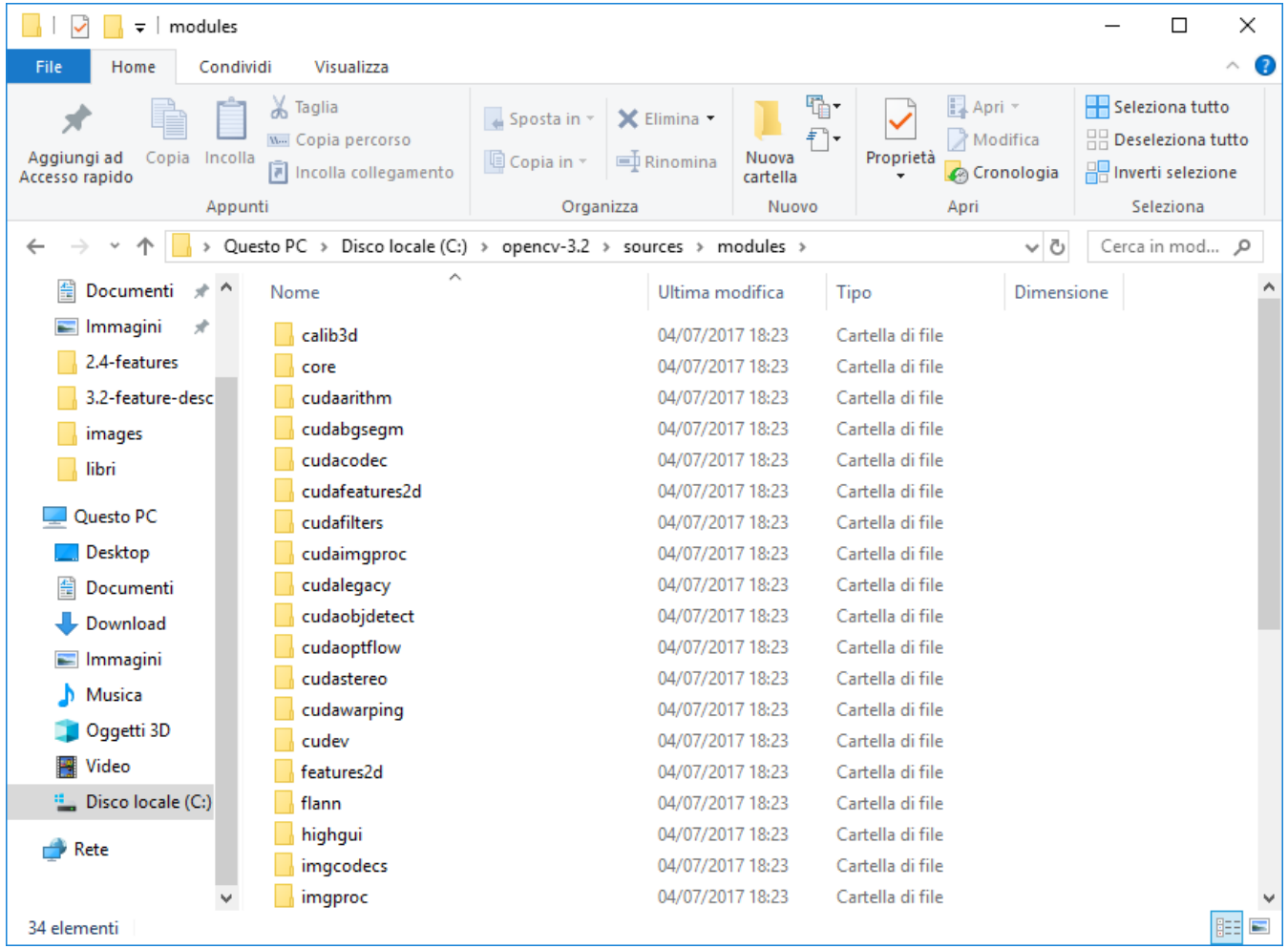


OpenCV - moduli

OpenCV ha una struttura modulare

I principali moduli sono:

- core
- imgproc
- video
- calib3d
- features2d
- objdetect
- highgui



OpenCV – core e imgproc

Core functionality (**core**)
A compact module defining basic data structures, including the dense multi-dimensional array Mat and basic functions used by all other modules.

Image Processing (**imgproc**)
An image processing module that includes linear and non-linear image filtering, geometrical image transformations (resize, affine and perspective warping, generic table-based remapping), color space conversion, histograms, and so on.

OpenCV – video e calib3d

Video Analysis (**video**)
A video analysis module that includes motion estimation, background subtraction, and object tracking algorithms.

Camera Calibration and 3D Reconstruction (**calib3d**)
Basic multiple-view geometry algorithms, single and stereo camera calibration, object pose estimation, stereo correspondence algorithms, and elements of 3D reconstruction.

OpenCV – features2d e objdetect

2D Features Framework (**features2d**)
Salient feature detectors, descriptors, and descriptor matchers.

Object Detection (**objdetect**)
Detection of objects and instances of the predefined classes (for example, faces, eyes, mugs, people, cars, and so on).

OpenCV – highgui e videoio

High-level GUI (**highgui**)
an easy-to-use interface to simple UI capabilities.

Video I/O (**videoio**)
An easy-to-use interface to video capturing and video codecs.

OpenCV – Python

- Python is slower compared to C++ or C. Python is built for its simplicity, portability and moreover, creativity where users need to worry only about their algorithm, not programming troubles.

- Python-OpenCV is just a wrapper around the original C/C++ code. It is normally used for combining best features of both the languages. Performance of C/C++ & Simplicity of Python.

- So when you call a function in OpenCV from Python, what actually run is underlying C/C++ source.

- Performance penalty is < 4%

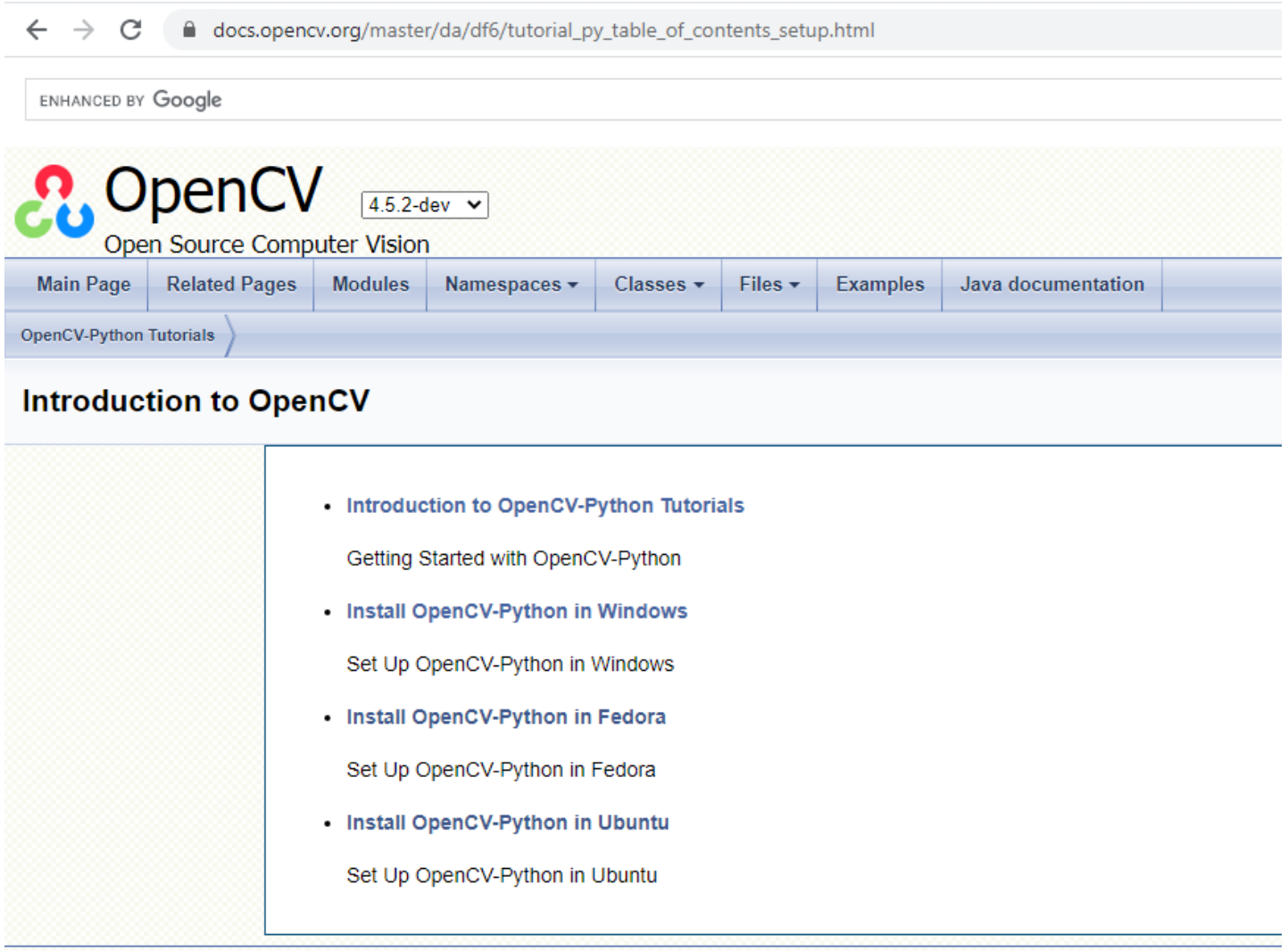
Source: Mašinska vizija

OpenCV Timeline

Version	Released	Reason	Lifetime
pre 1.0	2000 (first alpha)	-	6 years
1.0	2006 (ChangeLog)	maturity	3 years
2.0	2009 (ChangeLog)	C++ API	>3 years
3.0	2014	several (next level maturity, ...)	
4.0	**Nov. 2018**	better DNN support	

https://github.com/opencv/opencv/wiki/images/OpenCV3_0_CVPR_2014.pptx

Installare OpenCV-Python



pip install opencv-python

OpenCV in Colab

Per prima cosa andremo a vedere qual è la versione di OpenCV disponibile in Google Colab

```
import cv2 as cv

print(cv.__version__)
```

```
4.1.2
```

Import cv2

Perche usiamo `import cv2` se la versione di OpenCV è la 4.x.x?

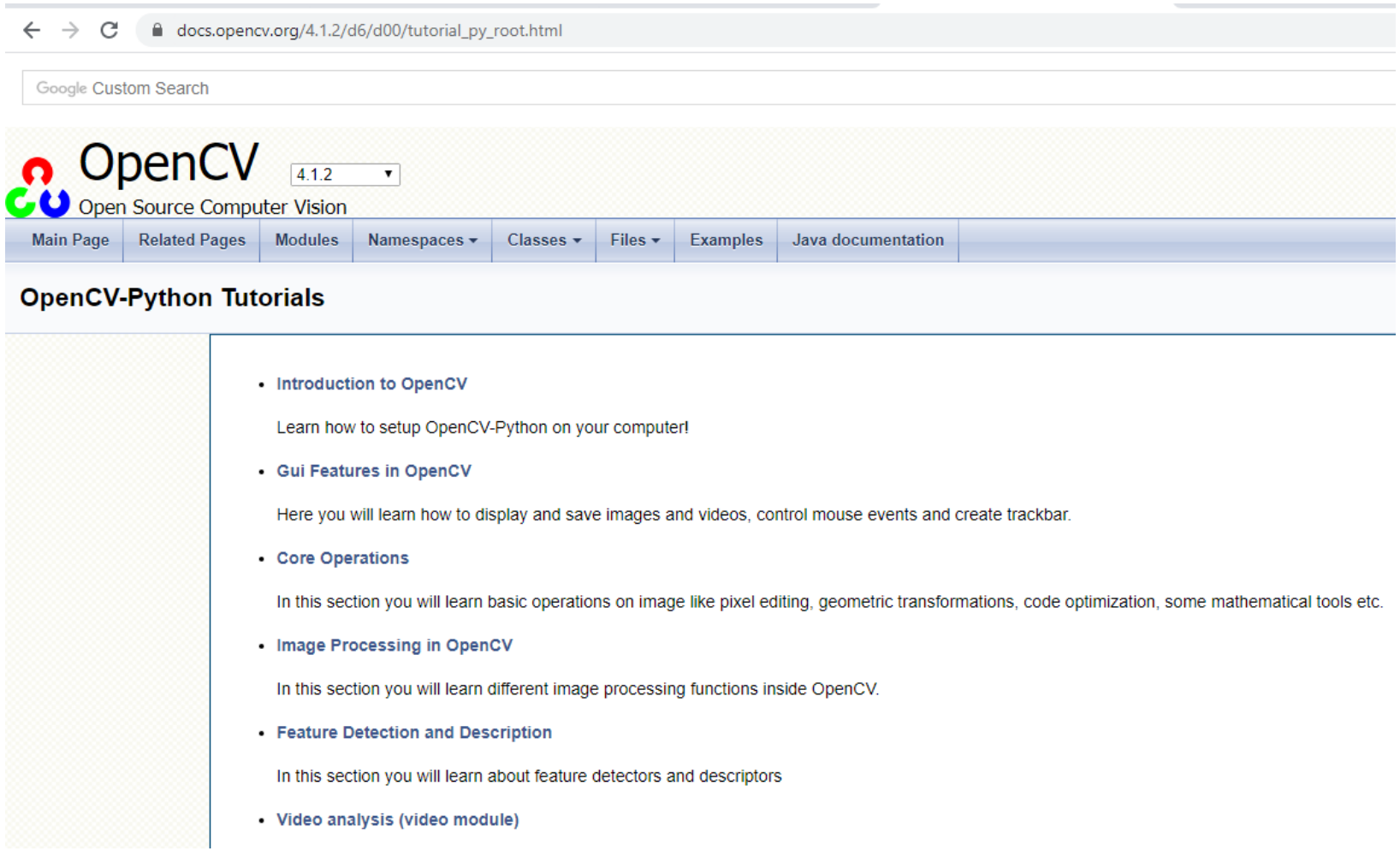
`cv2` non rappresenta la versione di OpenCV, ma la versione delle `API C++` sopra le quali poggiano le nuove versioni di OpenCV, in contrasto con la vecchia interfaccia `C` (denominata `cv`)

OpenCV 4.1.2 docs

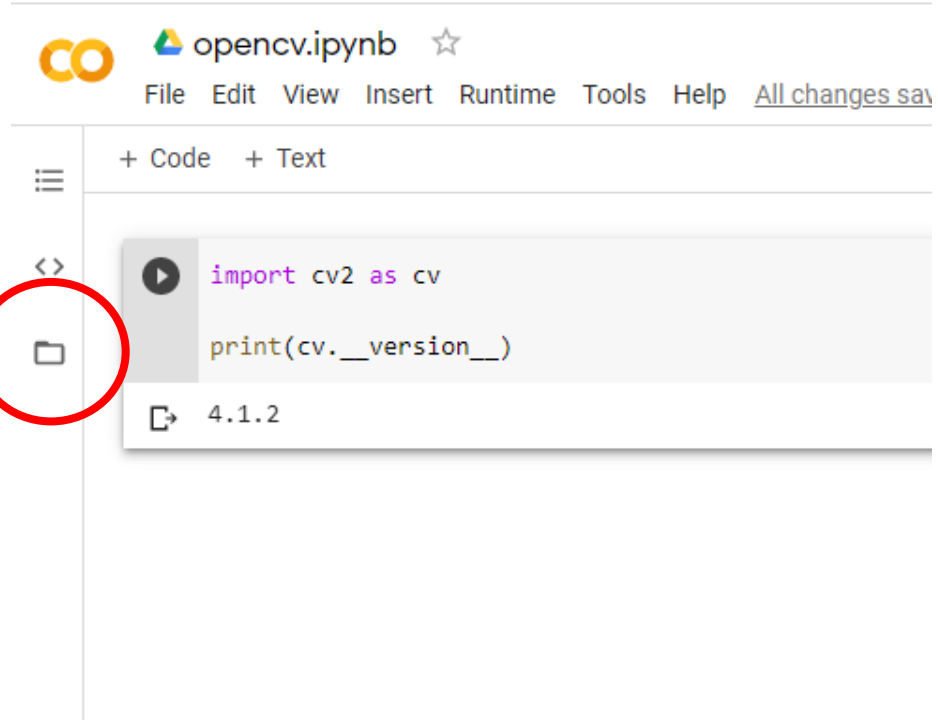
https://docs.opencv.org/4.1.2/

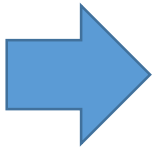
OpenCV-Python Tutorials

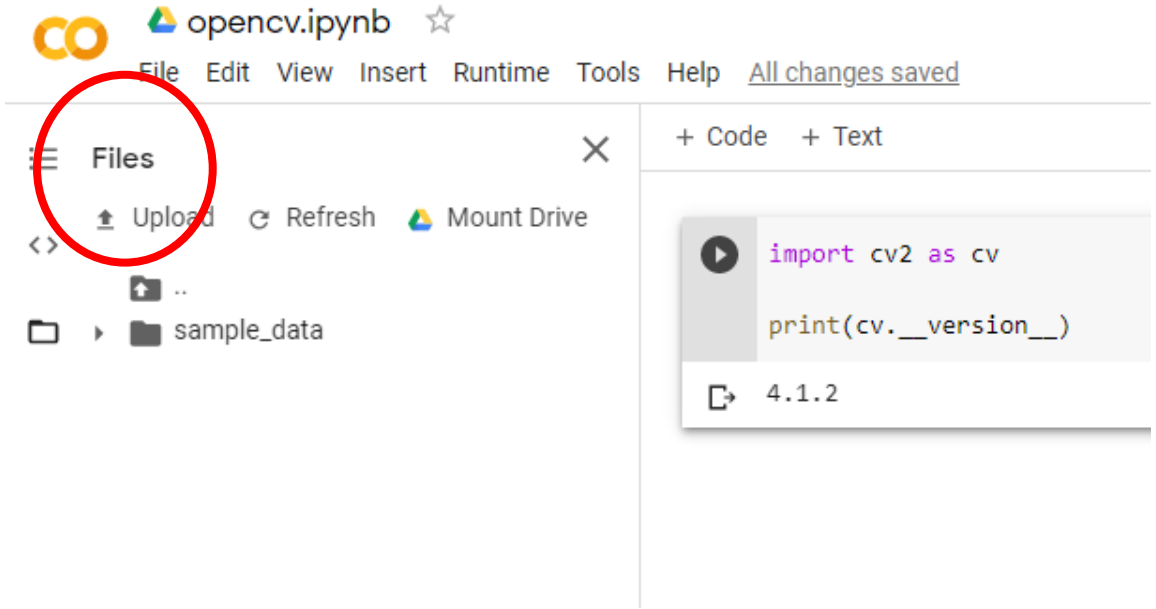
OpenCV fornisce una serie di tutorial specifici per Python che possono essere utilizzati per imparare ad utilizzare la libreria attraverso esempi pratici



Load an image in Colab

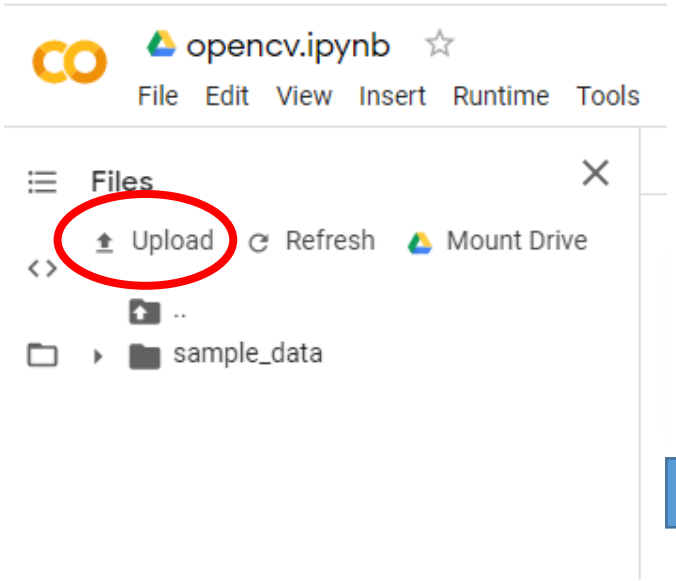


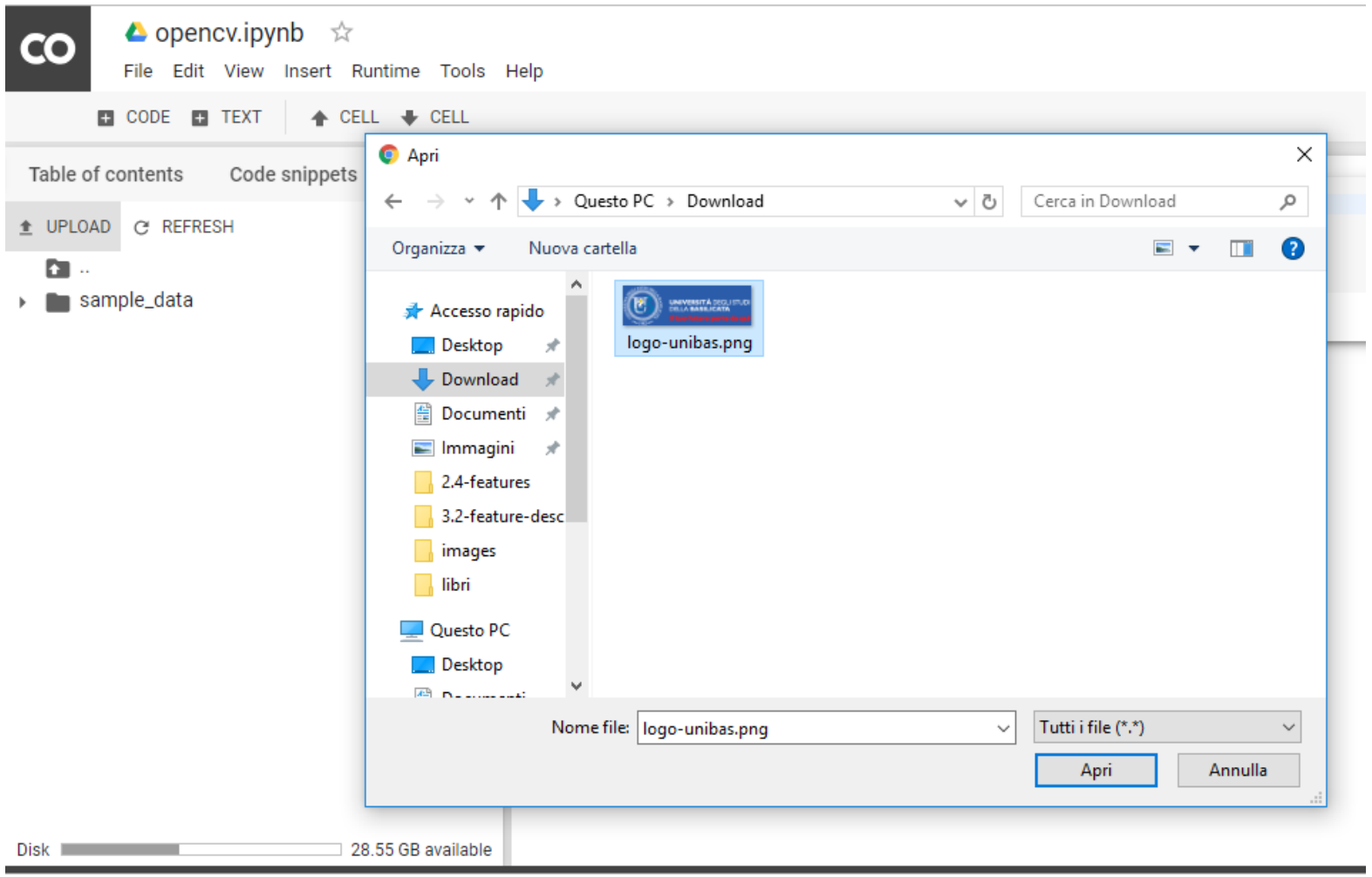




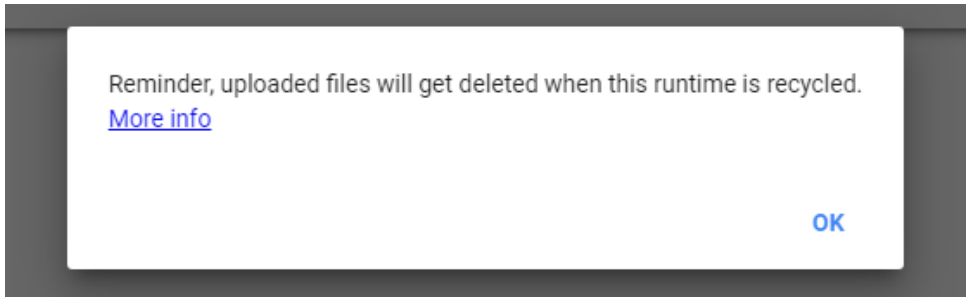
Load an image in Colab

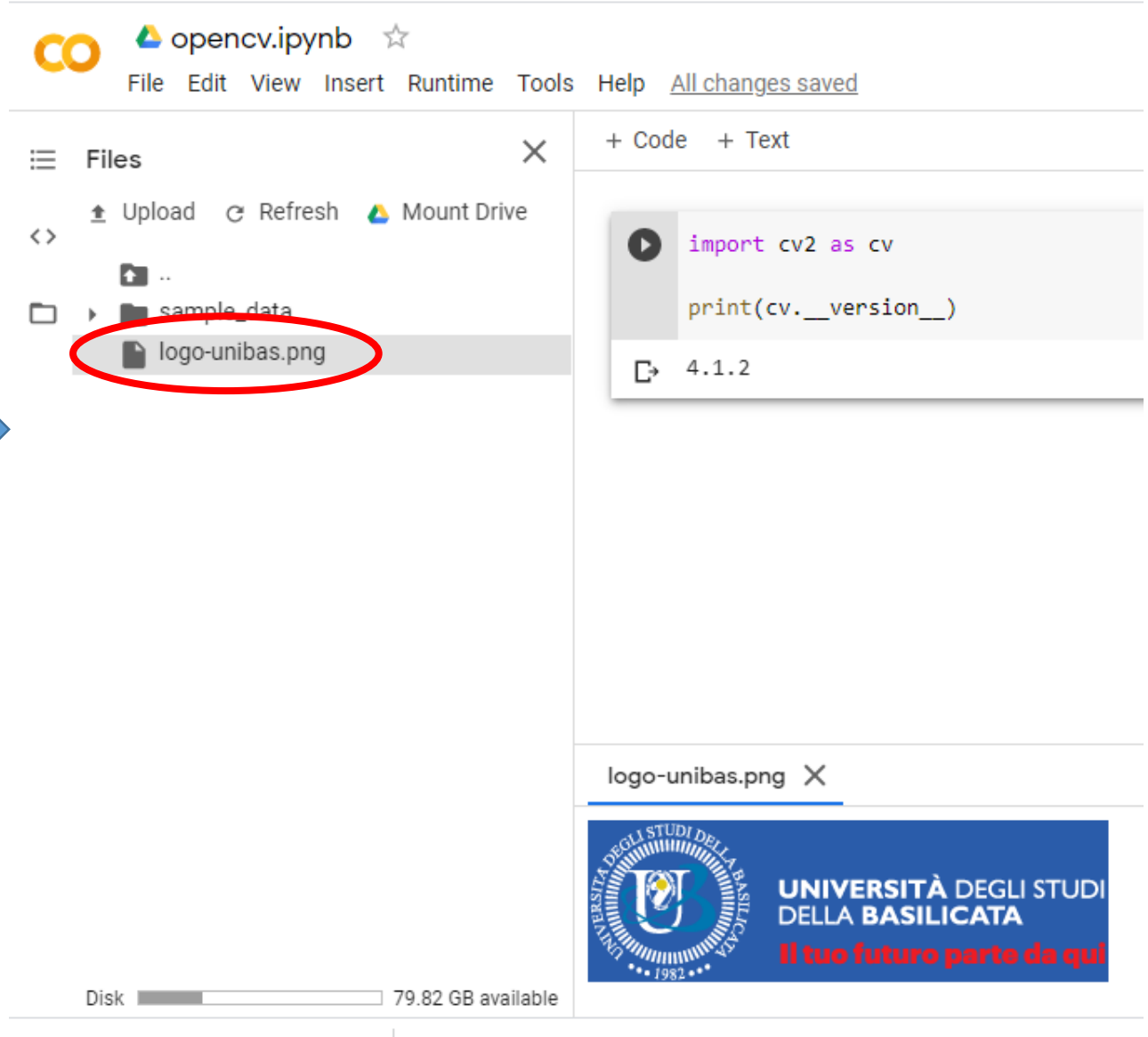
http://portale.unibas.it/contents/instance1/images/logo-unibas.png





Load an image in Colab





Read an image with OpenCV

```
import numpy as np
import cv2 as cv
from matplotlib import pyplot as plt
img = cv.imread('logo-unibas.png')
plt.imshow(img)
plt.xticks([]), plt.yticks([])  # to hide tick values on X and Y axis
plt.show()
```

warning
Color image loaded by OpenCV is in **BGR** mode. But Matplotlib displays in RGB mode. So color images will not be displayed correctly in Matplotlib if image is read with OpenCV.

Source image

Why does OpenCV use BGR color format?

The reason the early developers at OpenCV chose BGR color format is that back then BGR color format was popular among camera manufacturers and software providers.
E.g. in Windows, when specifying color value using COLORREF they use the BGR format **0x00bbggrr**.

BGR was a choice made for historical reasons and now we have to live with it.

https://learnopencv.com/why-does-opencv-use-bgr-color-format/

Images as NumPy arrays

Images in OpenCV-Python are NumPy arrays

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

print(type(img))
print(img.ndim)
print(img.shape)

plt.imshow(img)
plt.xticks([]), plt.yticks([])  # to hide tick values on X and Y axis
plt.show()
```

```
<class 'numpy.ndarray'>
3
(97, 312, 3)
```

RGB visualization in Matplotlib

```
import numpy as np
import cv2 as cv
from matplotlib import pyplot as plt
img = cv.imread('logo-unibas.png') #BGR color space

print(type(img))
print(img.ndim)
print(img.shape)

img_rgb = img[:,:,::-1]

plt.imshow(img_rgb)
plt.xticks([]), plt.yticks([])  # to hide tick values on X and Y axis
plt.show()
```

```
<class 'numpy.ndarray'>
3
(97, 312, 3)
```


```
a = [1, 2, 3]
b = a[0:3:1] # start=0, stop=3, step=1
print(b)
c = a[::1]
print(c)
d = a[::-1]
print(d)
```

```
[1, 2, 3]
[1, 2, 3]
[3, 2, 1]
```

Accessing and modifying pixel values

```python
import numpy as np
import cv2 as cv
from matplotlib import pyplot as plt
img = cv.imread('logo-unibas.png') #BGR color space

# accessing pixel in position (50,100)
px = img[50,100] #[y-value, x-value]
print(px)

# accessing only blue pixel
blue = img[50,100,0]
print(blue)

img[50,100] = [255,255,255]
print(img[50,100])
```

```
[170  92  42]
170
[255 255 255]
```

warning
Numpy is a optimized library for fast array calculations. So simply accessing each and every pixel values and modifying it will be very slow and it is discouraged.

item e itemset

```python
import numpy as np
import cv2 as cv
from matplotlib import pyplot as plt
img = cv.imread('logo-unibas.png') #BGR color space

# accessing only blue pixel
blue = img.item(50,100,0)
print(blue)

img.itemset((50,100,0),255)
print(img[50,100])
```

```
170
[255  92  42]
```

I metodi Numpy
array.item()
array.itemset()
sono considerati migliori per accedere agli elementi di una immagine.
Tuttavia, se si vuole accedere a tutti e tre i canali B,G,R è necessario ripetere la chiamata tre volte separatamente.

Accessing image properties

number of rows, columns, and channels (if image is color)

```
[28] print(img.shape)
```

```
(97, 312, 3)
```

Total number of pixels

```
[29] print(img.size)
```

```
90792
```

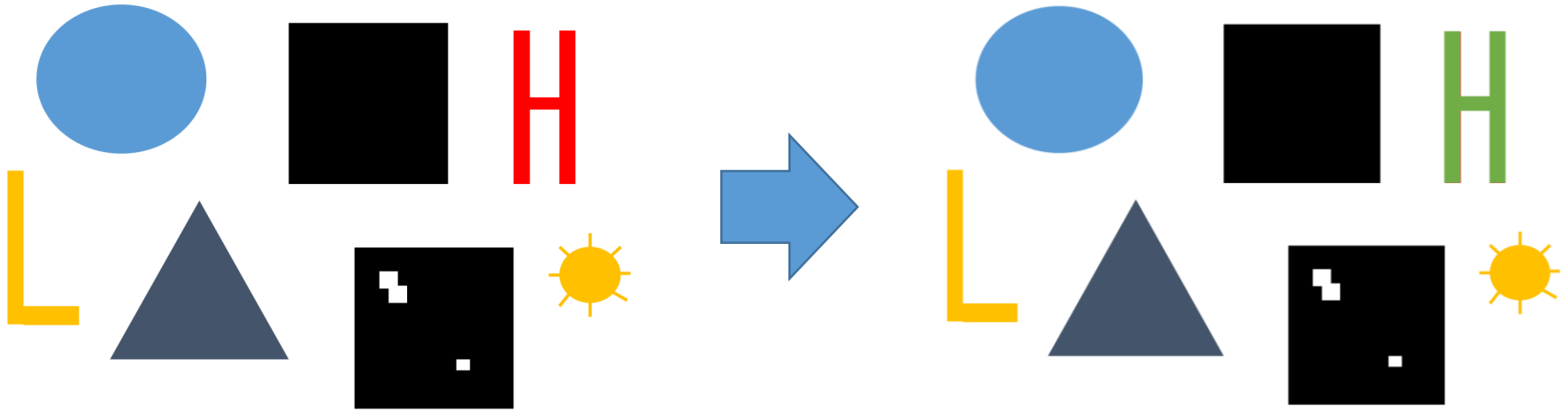
Image datatype

```
print(img.dtype)
```

```
uint8
```

Esercizio 10 – Lezione 2.4

Ricolorare la figura in rosso nella immagine
https://web.unibas.it/bloisi/corsi/images/forme.png
con il colore verde



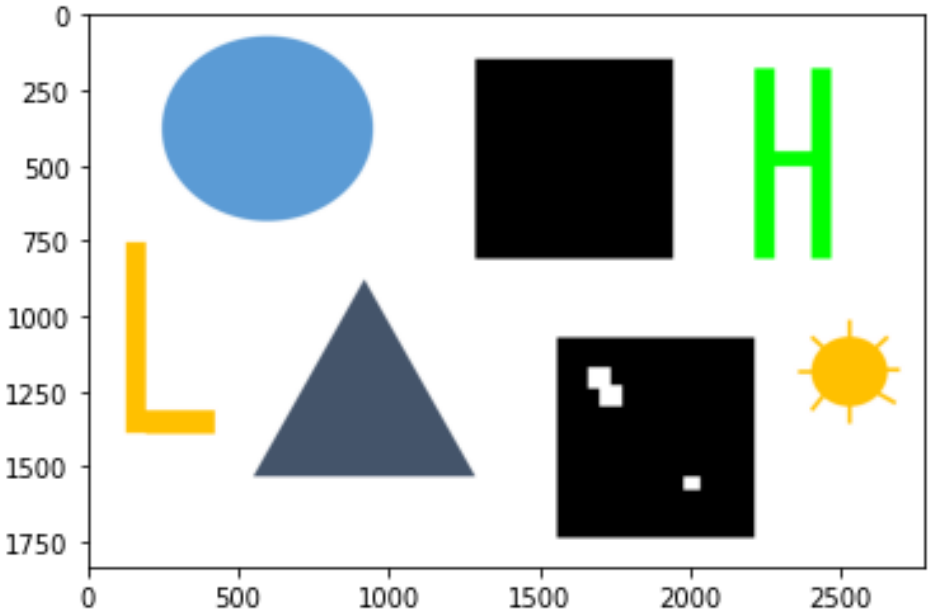
Soluzione con NumPy

```
from PIL import Image
from urllib.request import urlopen
import matplotlib.pyplot as plt
import numpy as np

url = "http://web.unibas.it/bloisi/corsi/images/forme.png"
pil_img = Image.open(urlopen(url)).convert('RGB')
img = np.array(pil_img)

h = img.shape[0]
w = img.shape[1]

for y in range(0, h):
    for x in range(0, w):
        if img.item(y,x,0) > 200 and \
           img.item(y,x,1) < 20 and \
           img.item(y,x,2) < 20 :
            img.itemset((y,x,0),0) #red
            img.itemset((y,x,1),255) #green
            img.itemset((y,x,2),0) #blue

_ = plt.imshow(img)
```

red

green

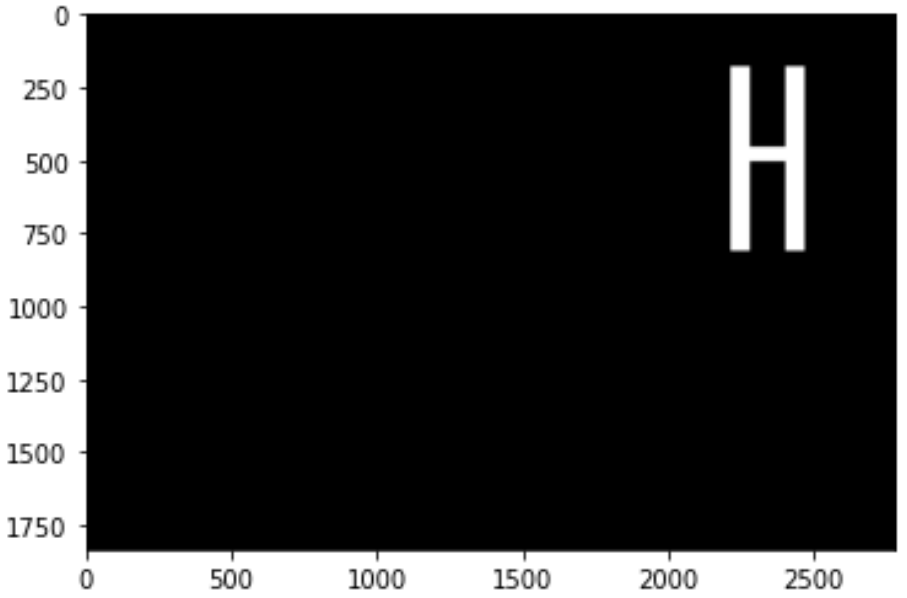
blue



Soluzione con OpenCV

```
from PIL import Image
from urllib.request import urlopen
import matplotlib.pyplot as plt
import numpy as np
import cv2 as cv

url = "http://web.unibas.it/bloisi/corsi/images/forme.png"
pil_img = Image.open(urlopen(url)).convert('RGB')
img = np.array(pil_img)
print(img.shape)

img2 = cv.inRange(img, (200, 0, 0), (255, 20, 20))
print(img2.shape)

_ = plt.imshow(img2, cmap="gray")
```

```
(1832, 2772, 3)
(1832, 2772)
```



mask

https://docs.opencv.org/4.1.2/da/d97/tutorial_threshold_inRange.html

Image ROI

```
import numpy as np
import cv2 as cv
from matplotlib import pyplot as plt
img = cv.imread('logo-unibas.png') #BGR color space

logo = img[0:98,0:98]
img[0:98, 100:198] = logo
img[0:98, 200:298] = logo

img_rgb = img[:,:,::-1]

plt.imshow(img_rgb)
plt.xticks([]), plt.yticks([])  # to hide tick values on X and Y axis
plt.show()
```

Changing color-space

Ci sono tantissimi metodi per cambiare il color-space disponibili in OpenCV.

```
import cv2 as cv
flags = [i for i in dir(cv) if i.startswith('COLOR_')]
print(flags)
print(len(flags))
```

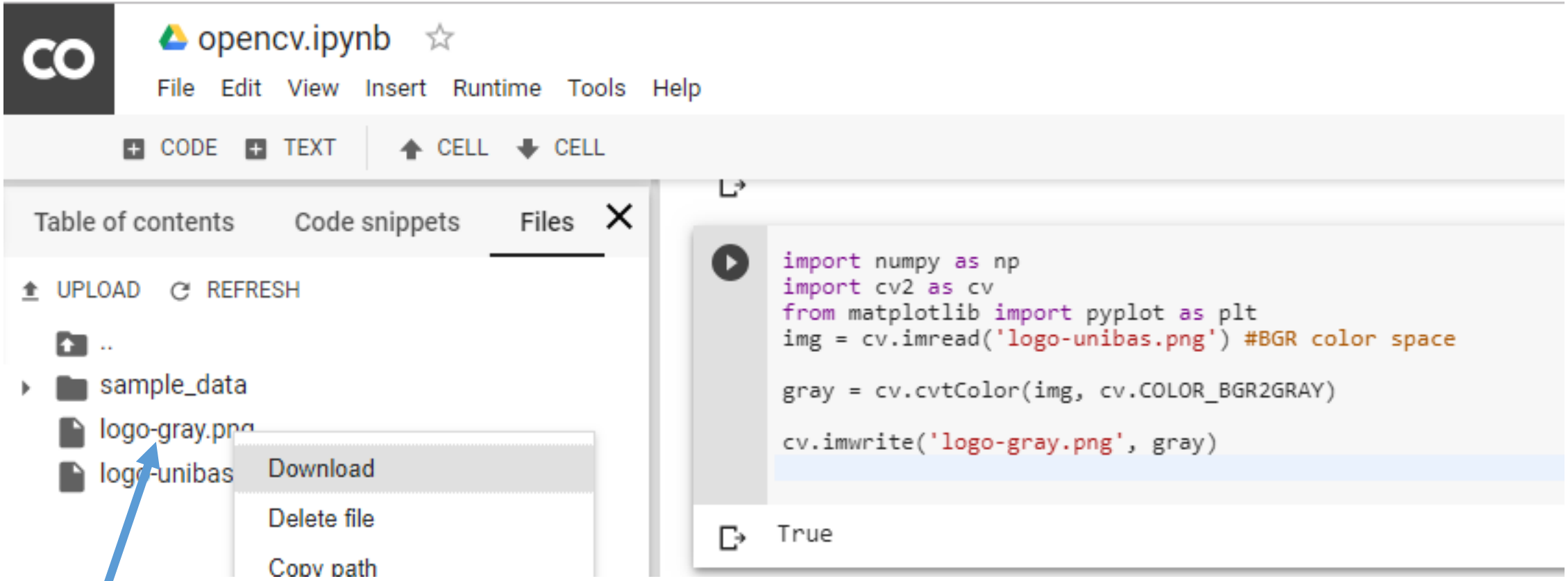
```
['COLOR_BAYER_BG2BGR', 'COLOR_BAYER_BG2BGRA', 'COLOR_BAYER_BG2BGR_EA', 'COLOR_BAYER_BG2BGR_VNG', 'COLOR_BAYER_BG2GRAY'
274
```

BGR2GRAY

```python
import numpy as np
import cv2 as cv
from matplotlib import pyplot as plt
img = cv.imread('logo-unibas.png') #BGR color space

gray = cv.cvtColor(img, cv.COLOR_BGR2GRAY)

cv.imwrite('logo-gray.png', gray)
```

```
True
```

Grayscale conversion



tasto destro del mouse

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Read an image from URL with OpenCV

```
import numpy as np
import cv2 as cv

import matplotlib.pyplot as plt
import urllib.request

url = "http://portale.unibas.it/contents/instance1/images/logo-unibas.png"
url_response = urllib.request.urlopen(url)

numpy_img = np.array(bytearray(url_response.read()), dtype=np.uint8)
img = cv.imdecode(numpy_img, -1)

plt.imshow(img)
plt.xticks([]), plt.yticks([])  # to hide tick values on X and Y axis
plt.show()
```

BGR2RGB

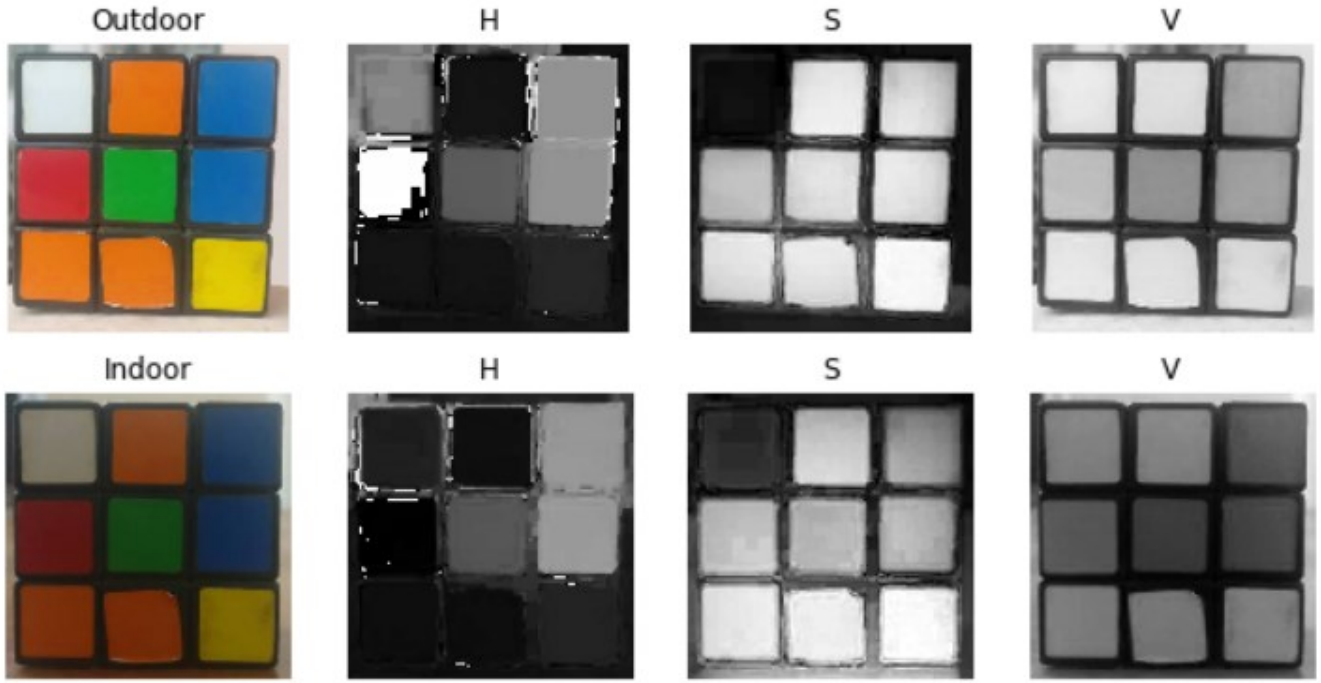
```
import cv2 as cv
import numpy as np
import matplotlib.pyplot as plt
import urllib.request

url = "http://portale.unibas.it/contents/instance1/images/logo-unibas.png"

url_response = urllib.request.urlopen(url)
numpy_img = np.array(bytearray(url_response.read()), dtype=np.uint8)
img = cv.imdecode(numpy_img, -1)

rgb = cv.cvtColor(img,cv.COLOR_BGR2RGB)

plt.axis('off')
plt.imshow(rgb)
plt.show()
```

HSV color space

The HSV color space has the following three components:

1. H – Hue (Dominant Wavelength)
2. S – Saturation (Purity/shades of the color)
3. V – Value (Intensity)

HSV color space

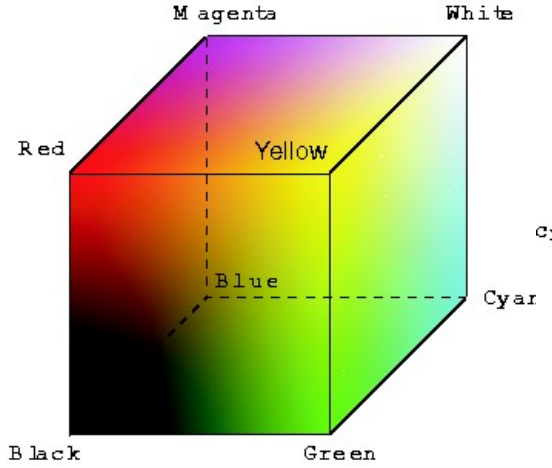


- The H component is very similar in both the images which indicates the color information is intact even under illumination changes
- The S component is also very similar in both images
- The V component captures the amount of light falling on it thus it changes due to illumination changes

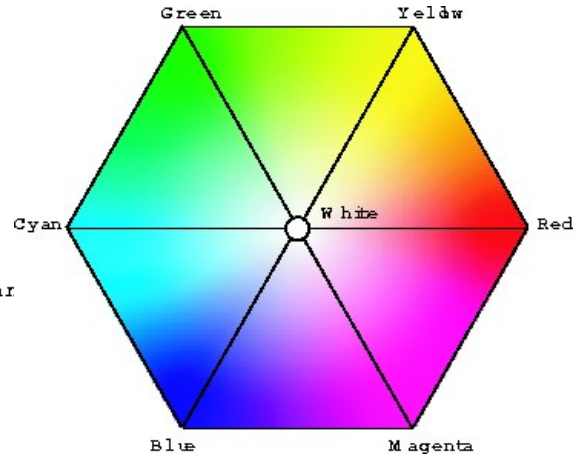
https://www.learnopencv.com/color-spaces-in-opencv-cpp-python/

HSV color-space

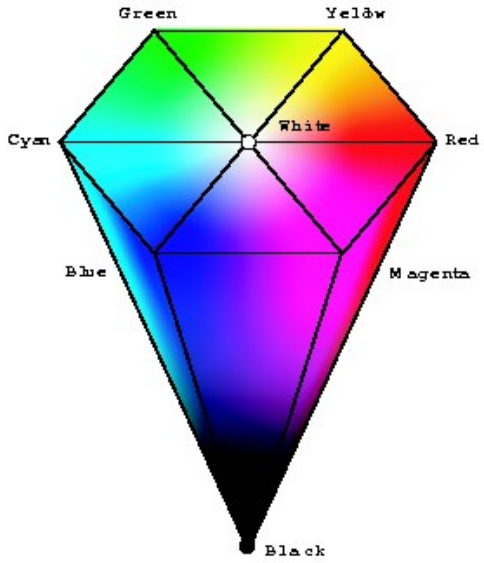
HSV is a projection of the RGB space



RGB cube



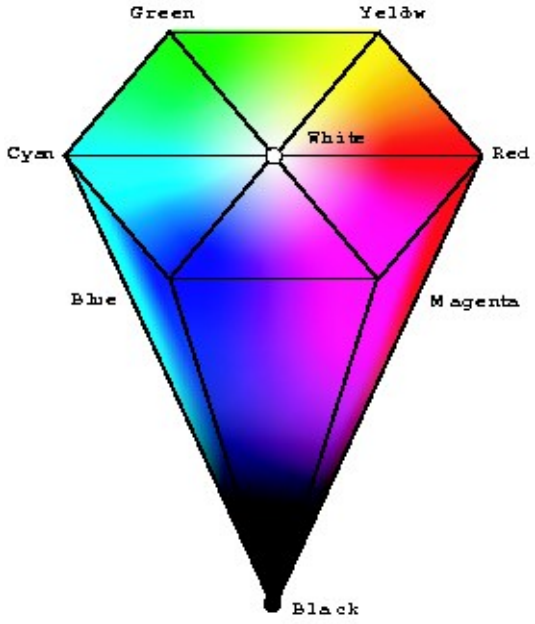
HSV top view

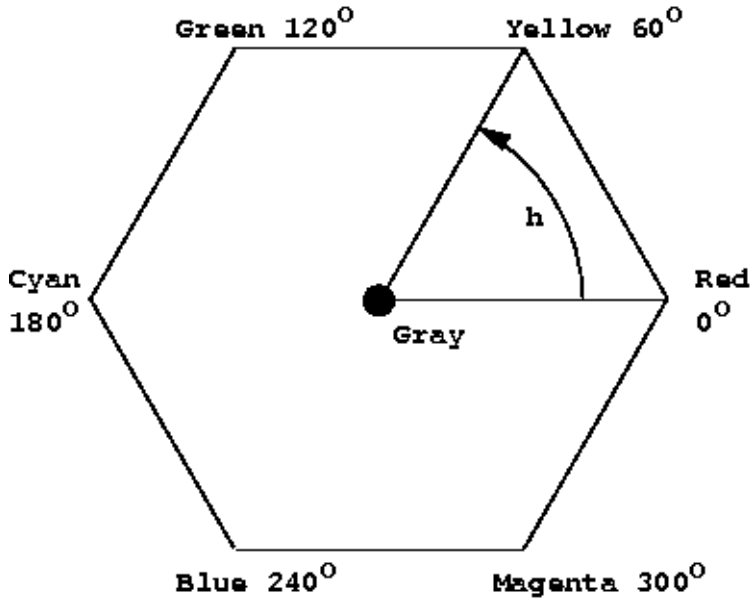


HSV cone

Source: Donald House

Hue



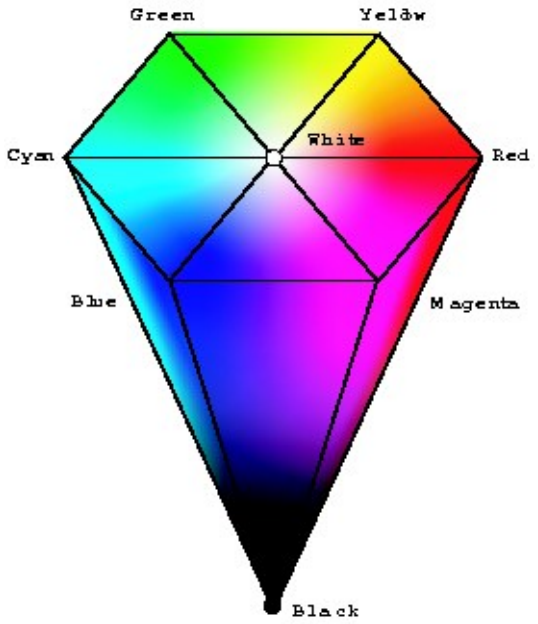


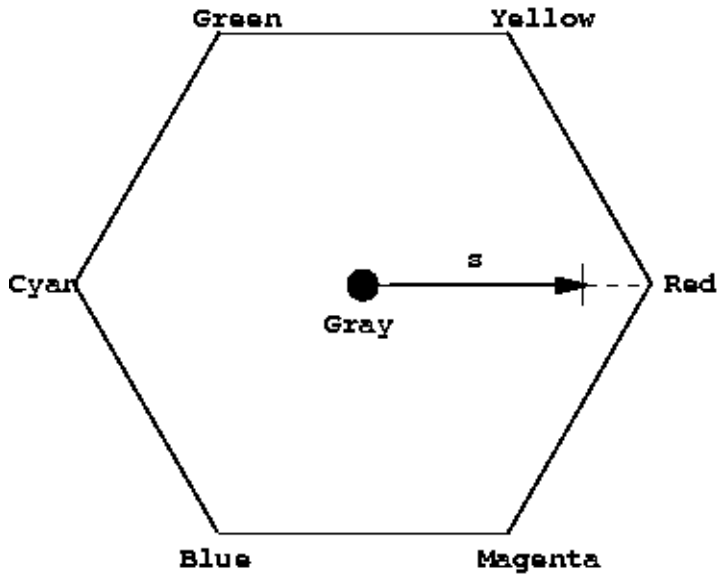
Hue, an angular measure (0 … 360)

Hue range is [0,179] in OpenCV

Source: Donald House

Saturation



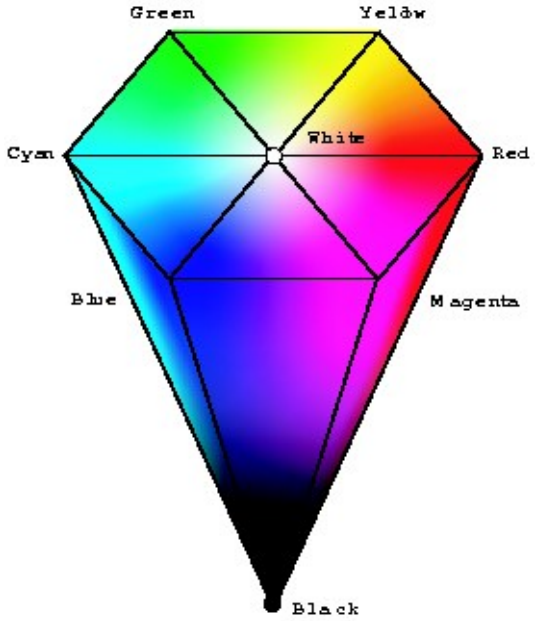


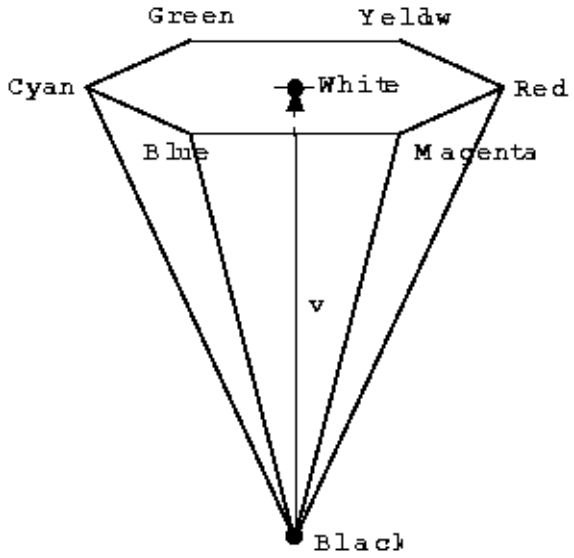
Saturation, a fractional measure (0.0 … 1.0)

Saturation range is [0,255] in OpenCV

Source: Donald House

Value





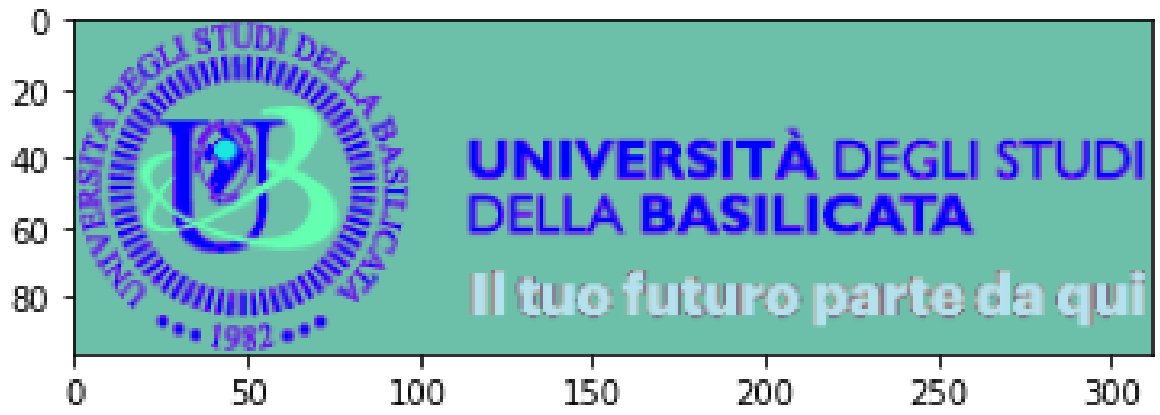
Value, a fractional measure (0.0 … 1.0)

Value range is [0,255] in OpenCV

Source: Donald House

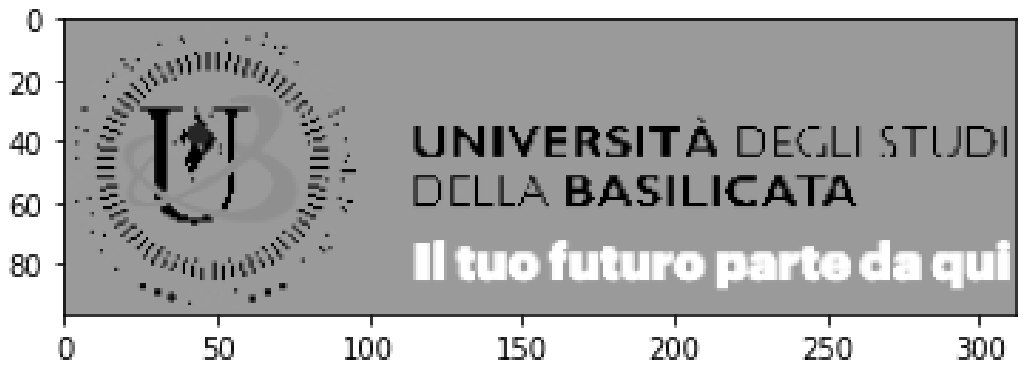
HSV conversion

```
import numpy as np
import cv2 as cv
from matplotlib import pyplot as plt
img = cv.imread('logo-unibas.png') #BGR colorspace

hsv = cv.cvtColor(img, cv.COLOR_BGR2HSV)

_ = plt.imshow(hsv)
```



H channel

```
import numpy as np
import cv2 as cv
from matplotlib import pyplot as plt
img = cv.imread('logo-unibas.png') #BGR colorspace

hsv = cv.cvtColor(img, cv.COLOR_BGR2HSV)

h,s,v = cv.split(hsv)

_ = plt.imshow(h, cmap="gray")
```



S channel

```python
import numpy as np
import cv2 as cv
from matplotlib import pyplot as plt
img = cv.imread('logo-unibas.png') #BGR colorspace

hsv = cv.cvtColor(img, cv.COLOR_BGR2HSV)

h,s,v = cv.split(hsv)

_ = plt.imshow(s, cmap="gray")
```

V channel

```
import numpy as np
import cv2 as cv
from matplotlib import pyplot as plt
img = cv.imread('logo-unibas.png') #BGR colorspace

hsv = cv.cvtColor(img, cv.COLOR_BGR2HSV)

h,s,v = cv.split(hsv)

_ = plt.imshow(v, cmap="gray")
```

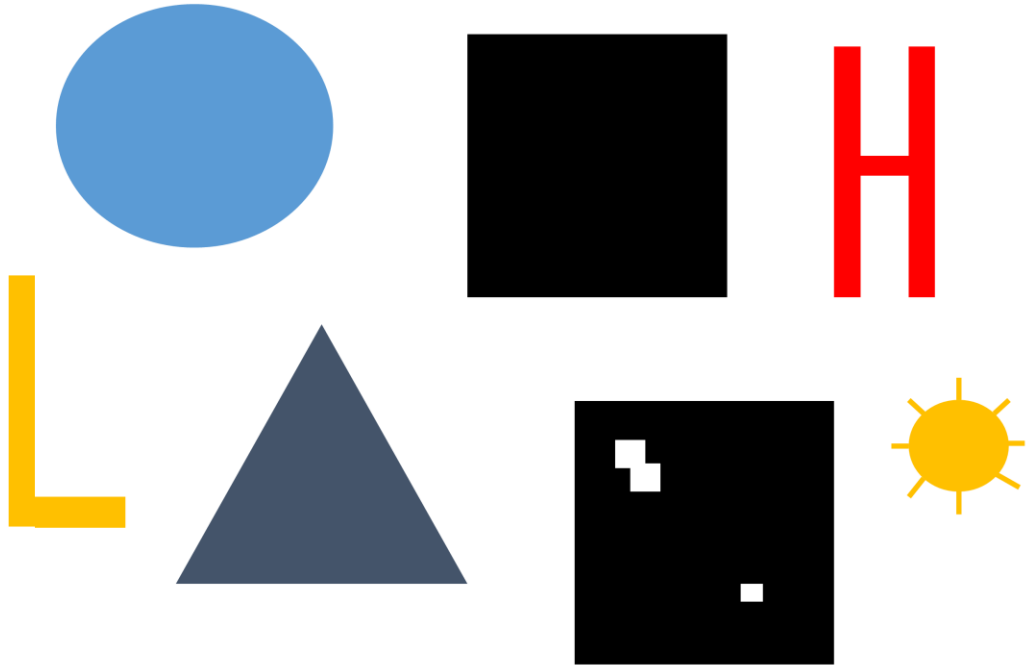
Merge

```python
import numpy as np
import cv2 as cv
from matplotlib import pyplot as plt
img = cv.imread('logo-unibas.png') #BGR color space

hsv = cv.cvtColor(img, cv.COLOR_BGR2HSV)

h,s,v = cv.split(hsv)

hsv_merged = cv.merge((h,s,v))

plt.imshow(hsv_merged)
plt.xticks([]), plt.yticks([])  # to hide tick values on X and Y axis
plt.show()
```

Esercizio 7 – Lezione 2.4

Applicare all'immagine
https://web.unibas.it/bloisi/corsi/images/forme.png
le operazioni di

- erosion
- dilation
- aperture
- closing

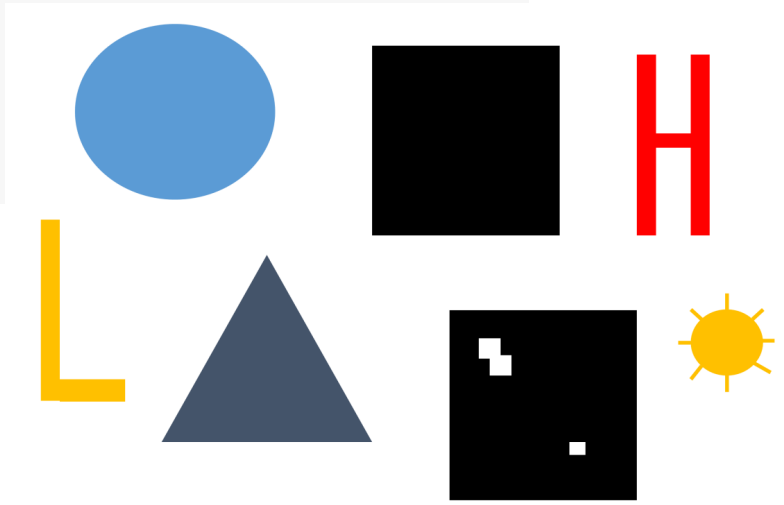


Soluzione

1. Carichiamo l’immagine in memoria
2. Trasformiamola in grayscale
3. Applichiamo la trasformazione
4. Mostriamo l’immagine trasformata

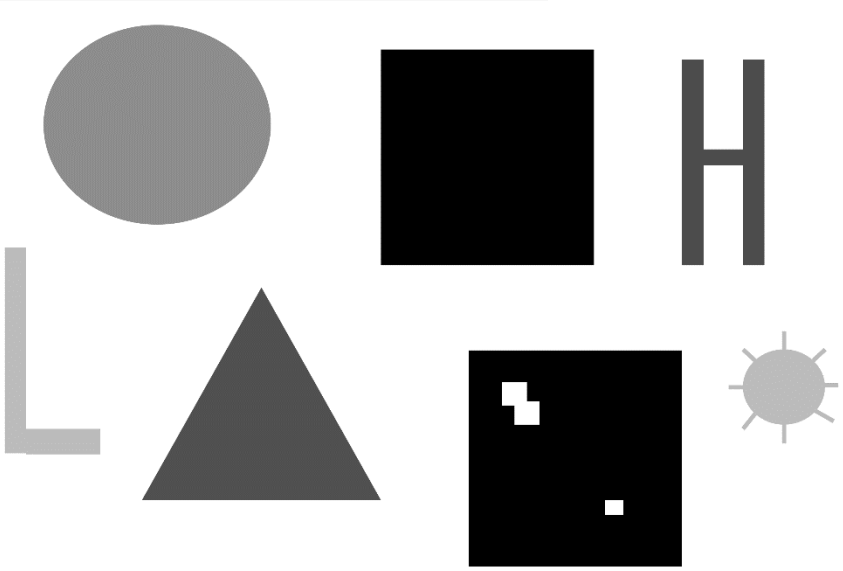
Carichiamo l’immagine in memoria

```
import cv2 as cv
from google.colab.patches import cv2_imshow
from urllib.request import urlopen
import numpy as np

req = urlopen('http://web.unibas.it/bloisi/corsi/images/forme.png')
arr = np.array(bytearray(req.read()), dtype=np.uint8)
img = cv.imdecode(arr, -1) # 'Load it as it is'

cv2_imshow(img)
```



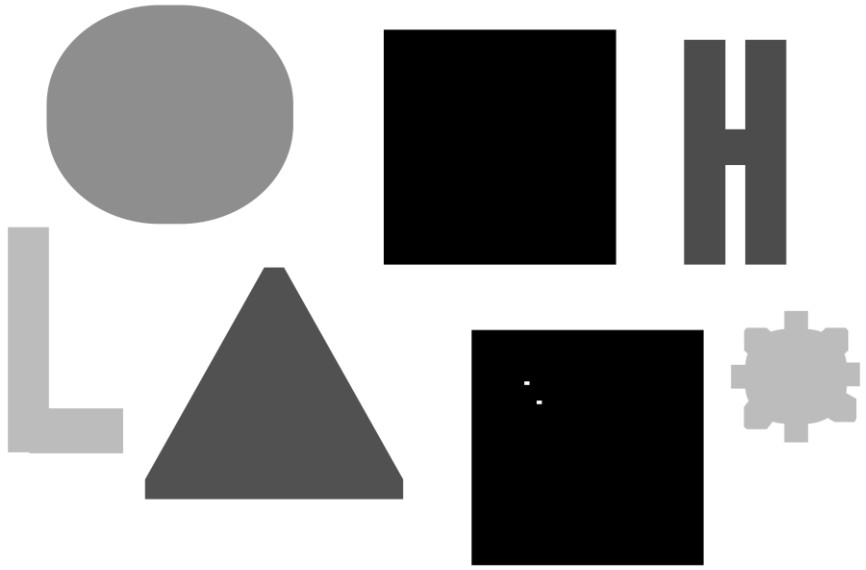
Trasformiamola in grayscale

```
import cv2 as cv
from google.colab.patches import cv2_imshow
from urllib.request import urlopen
import numpy as np

req = urlopen('http://web.unibas.it/bloisi/corsi/images/forme.png')
arr = np.array(bytearray(req.read()), dtype=np.uint8)
gray_img = cv.imdecode(arr, cv.IMREAD_GRAYSCALE) # Load as grayscale image

cv2_imshow(gray_img)
```



Erosione

```python
import cv2 as cv
from google.colab.patches import cv2_imshow
from urllib.request import urlopen
import numpy as np

req = urlopen('http://web.unibas.it/bloisi/corsi/images/forme.png')
arr = np.array(bytearray(req.read()), dtype=np.uint8)
gray_img = cv.imdecode(arr, cv.IMREAD_GRAYSCALE) # Load as grayscale image

kernel = np.ones((21,21),np.uint8)
erosion = cv.erode(gray_img,kernel,iterations = 3)

cv2_imshow(erosion)
```

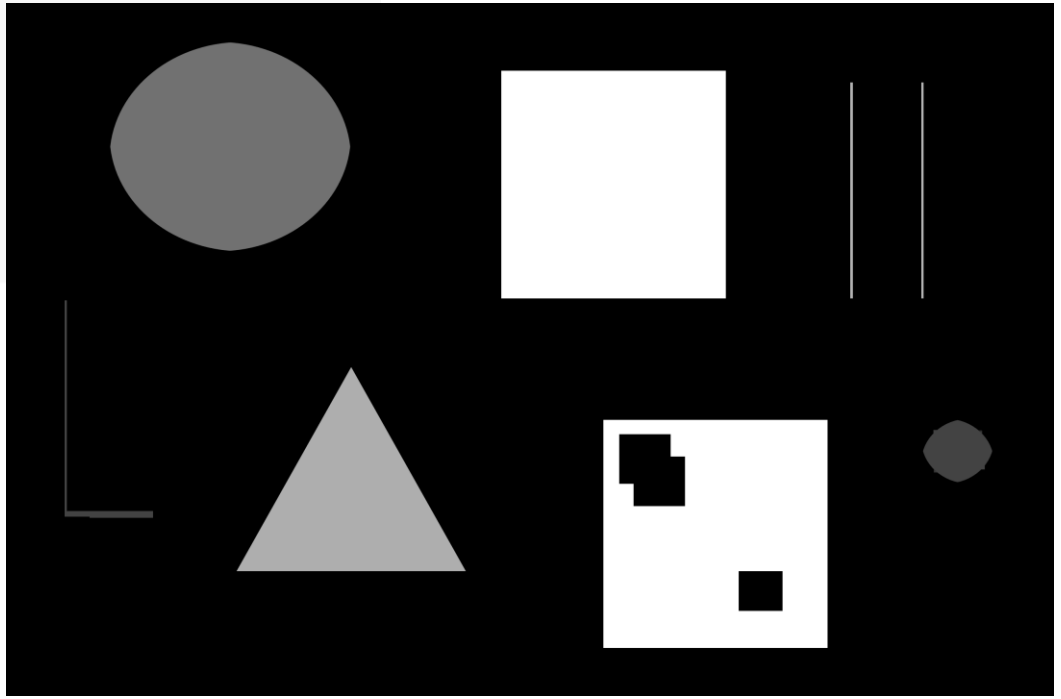


Qualcosa non torna!

https://opencv-python-tutroals.readthedocs.io/en/latest/py_tutorials/py_imgproc/py_morphological_ops/py_morphological_ops.html

Erosione

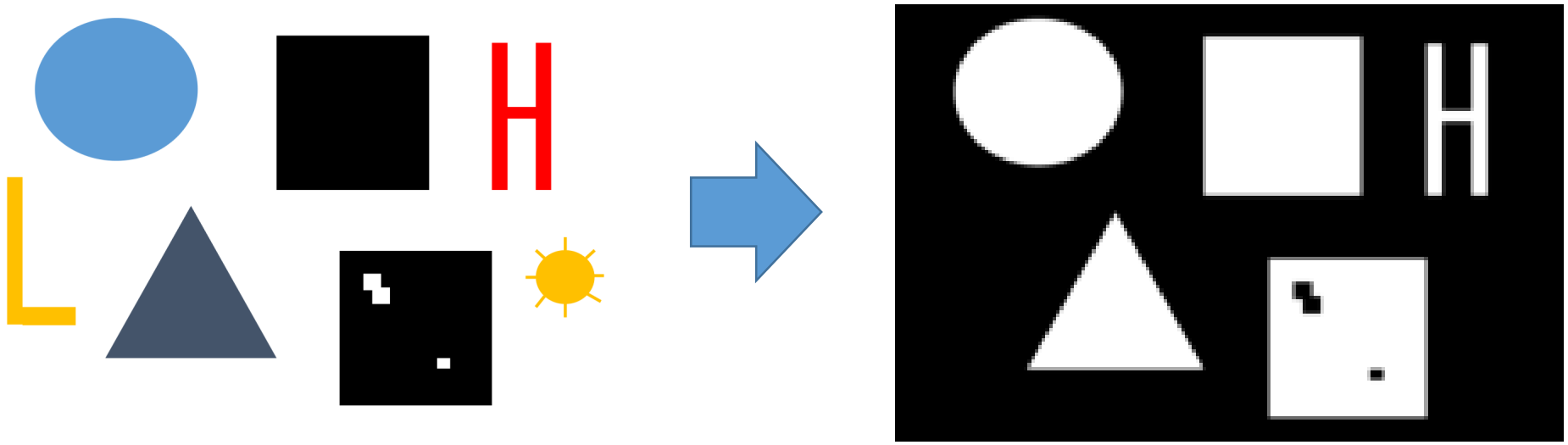
```python
import cv2 as cv
from google.colab.patches import cv2_imshow
from urllib.request import urlopen
import numpy as np

req = urlopen('http://web.unibas.it/bloisi/corsi/images/forme.png')
arr = np.array(bytearray(req.read()), dtype=np.uint8)
gray_img = cv.imdecode(arr, cv.IMREAD_GRAYSCALE) # Load as grayscale image
inv_img = cv.bitwise_not(gray_img)

kernel = np.ones((21,21),np.uint8)
erosion = cv.erode(inv_img,kernel,iterations = 3)

cv2_imshow(erosion)
```



https://docs.opencv.org/master/d0/d86/tutorial_py_image_arithmetics.html

Esercizio 8 – Lezione 2.4

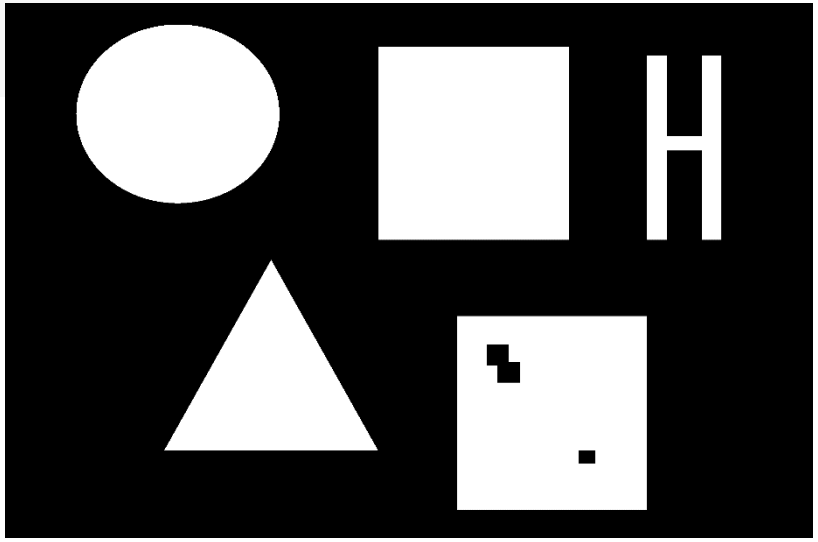
Applicare all'immagine
https://web.unibas.it/bloisi/corsi/images/forme.png
il metodo di thresholding di Otsu



Soluzione con OpenCV

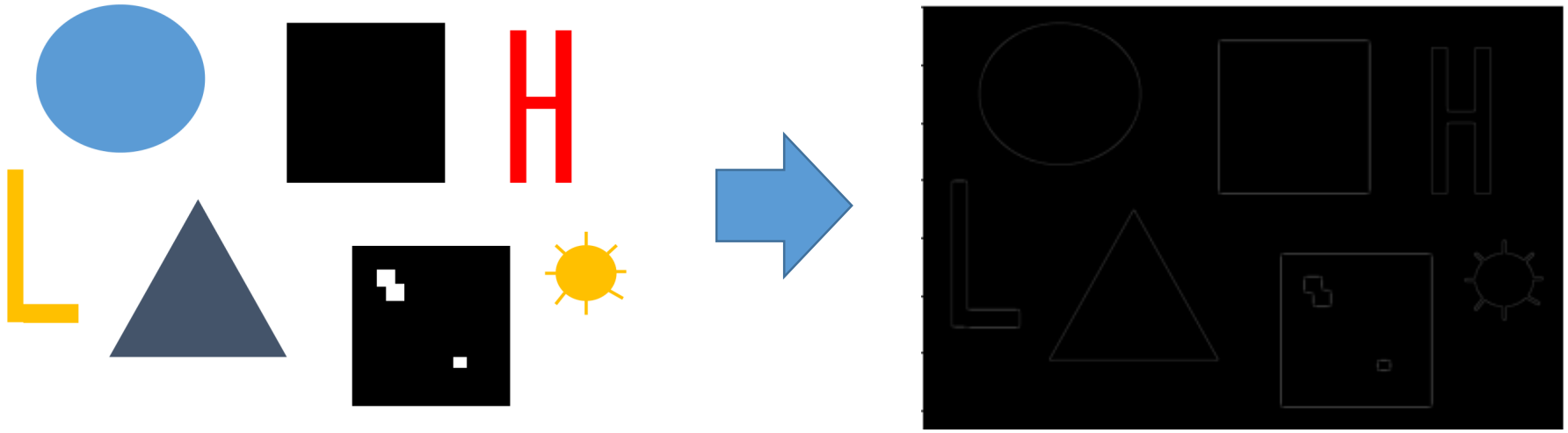
```
import cv2 as cv
from google.colab.patches import cv2_imshow
from urllib.request import urlopen
import numpy as np

req = urlopen('http://web.unibas.it/bloisi/corsi/images/forme.png')
arr = np.array(bytearray(req.read()), dtype=np.uint8)
gray_img = cv.imdecode(arr, cv.IMREAD_GRAYSCALE) # Load as grayscale image
inv_img = cv.bitwise_not(gray_img)

val,otsu = cv.threshold(inv_img,0,255,cv.THRESH_BINARY+cv.THRESH_OTSU)
print("Otsu's threshold:",val)
cv2_imshow(otsu)
```

Otsu's threshold: 103.0



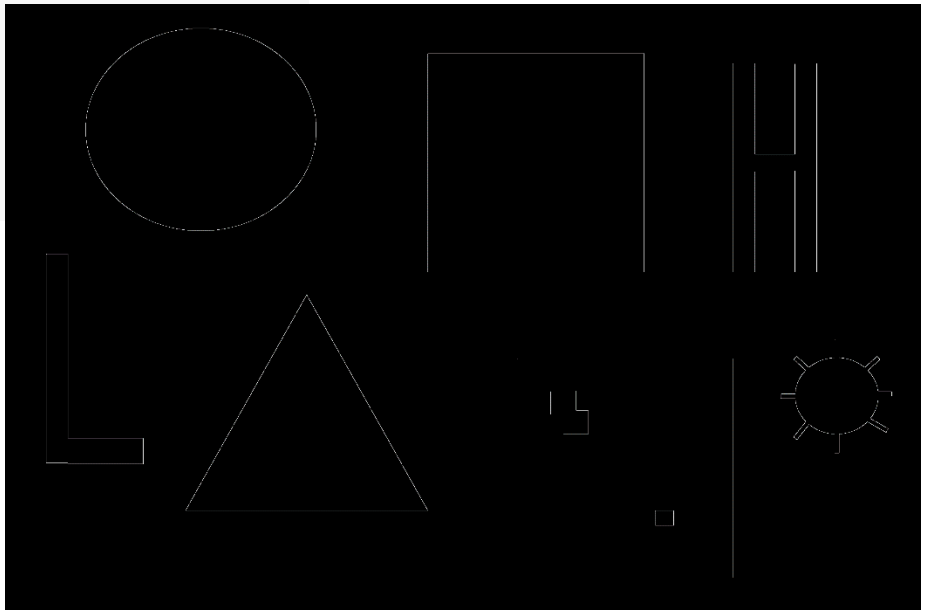
Esercizio 9 – Lezione 2.4

Estrarre i contorni dall'immagine
https://web.unibas.it/bloisi/corsi/images/forme.png



Soluzione con OpenCV

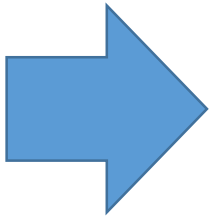
```
import cv2 as cv
from google.colab.patches import cv2_imshow
from urllib.request import urlopen
import numpy as np

req = urlopen('http://web.unibas.it/bloisi/corsi/images/forme.png')
arr = np.array(bytearray(req.read()), dtype=np.uint8)
gray_img = cv.imdecode(arr, cv.IMREAD_GRAYSCALE) # Load as grayscale image

edges = cv.Canny(gray_img,100,200)

cv2_imshow(edges)
```



https://opencv-python-tutroals.readthedocs.io/en/latest/py_tutorials/py_imgproc/py_canny/py_canny.html

Harris corner detection in OpenCV

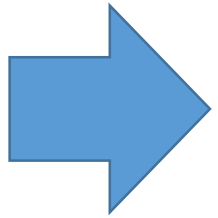
```
import cv2 as cv
from google.colab.patches import cv2_imshow
from urllib.request import urlopen
import numpy as np

req = urlopen('http://web.unibas.it/bloisi/corsi/images/forme.png')
arr = np.array(bytearray(req.read()), dtype=np.uint8)
img = cv.imdecode(arr, cv.IMREAD_COLOR)
gray_img = cv.cvtColor(img, cv.COLOR_BGR2GRAY)
```



https://docs.opencv.org/4.1.2/d4/d7d/tutorial_harris_detector.html

Harris corner detection in OpenCV

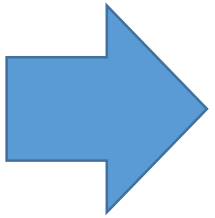
```
thresh = 100
# Detector parameters
blockSize = 2
apertureSize = 3
k = 0.04
# Detecting corners
dst = cv.cornerHarris(gray_img, blockSize, apertureSize, k)
```



https://docs.opencv.org/4.1.2/d4/d7d/tutorial_harris_detector.html

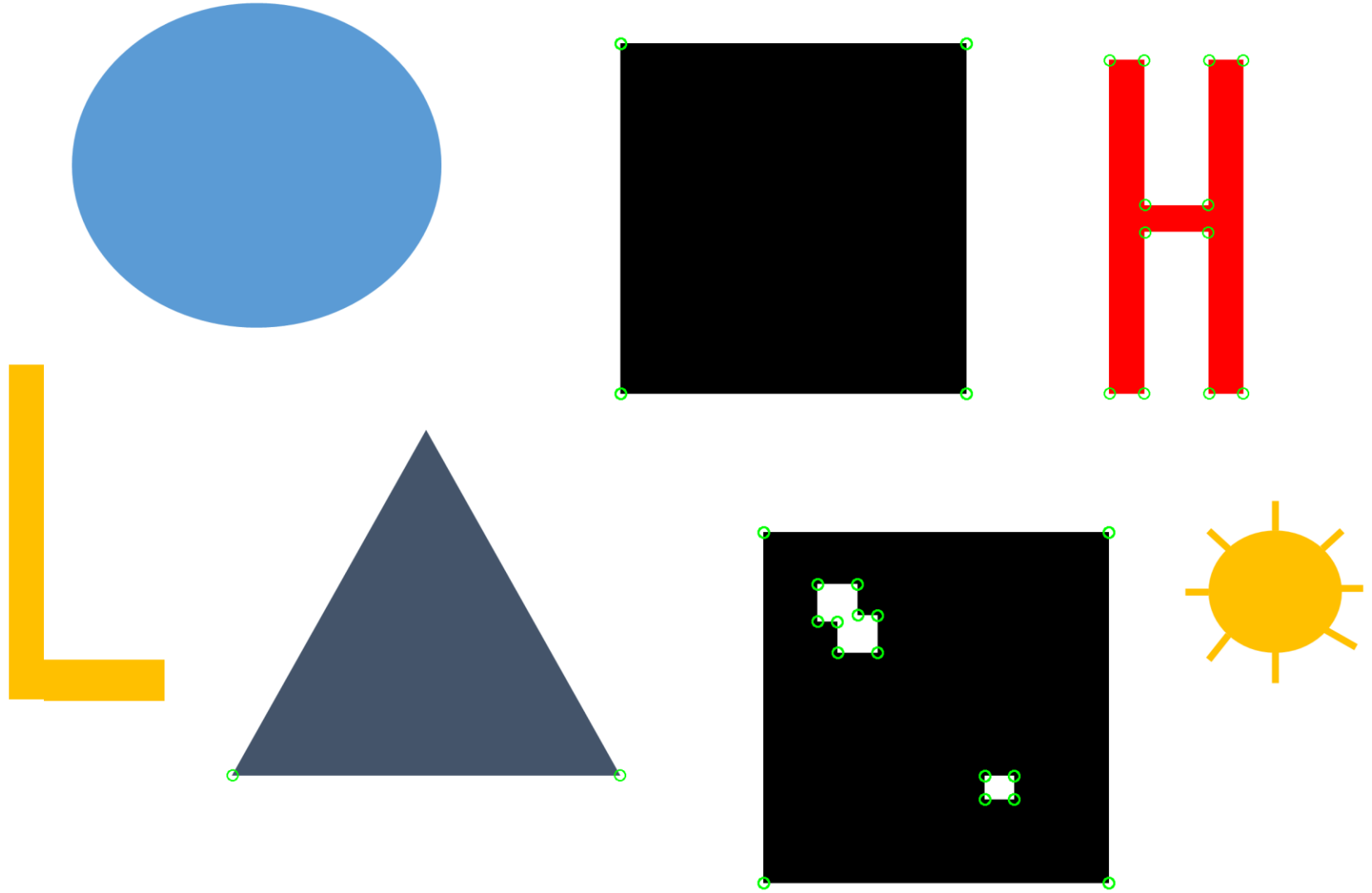
Harris corner detection in OpenCV

```
# Normalizing
dst_norm = np.empty(dst.shape, dtype=np.float32)
cv.normalize(dst, dst_norm, alpha=0, beta=255, norm_type=cv.NORM_MINMAX)

# Drawing a circle around corners
for i in range(dst_norm.shape[0]):
  for j in range(dst_norm.shape[1]):
    if int(dst_norm[i,j]) > thresh:
      cv.circle(img, (j,i), 10, (0,255,0), 2)

cv2_imshow(img)
```



https://docs.opencv.org/4.1.2/d4/d7d/tutorial_harris_detector.html

Risultato Harris corner detection in OpenCV



Esercizio GoodFeatures

Usare la funzione OpenCV `goodFeaturesToTrack()` per trovare i corner nell'immagine https://web.unibas.it/bloisi/corsi/images/forme.png

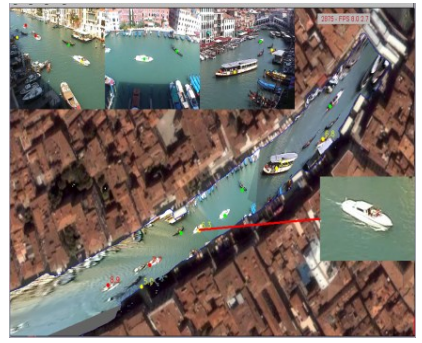
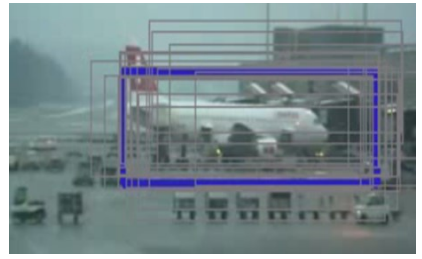
Suggerimento: si veda il tutorial a questo indirizzo https://docs.opencv.org/4.1.2/d4/d8c/tutorial_py_shi_tomasi.html

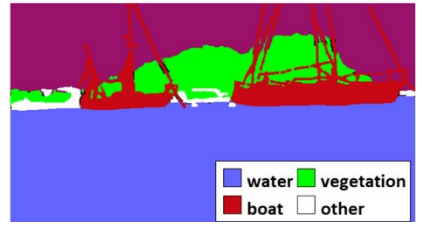
UNIVERSITÀ DEGLI STUDI DELLA BASILICATA



Corso di Visione e Percezione

Docente
Domenico D. Bloisi



OpenCV (Python)