JÖNKÖPING UNIVERSITY
School of Engineering

DIGITAL IMAGE PROCESSING

A practical introduction with Python and OpenCV

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OUTLINE

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2. What is an image?
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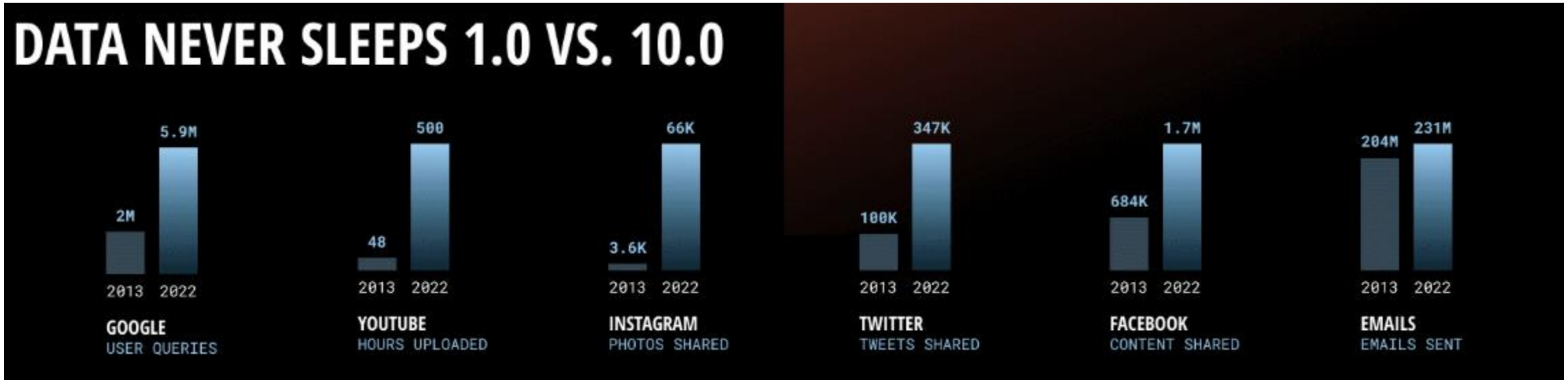
1. What is Digital Image Processing?

DIGITAL IMAGE PROCESSING

- More and more digital images are produced every day from our phones, cameras, computers…
- Every MINUTE on the Internet:



Source: https://www.domo.com/data-never-sleeps

DIGITAL IMAGE PROCESSING

- “Digital image processing is the use of a digital computer to process digital images through an algorithm.” from https://en.wikipedia.org/wiki/Digital_image_processing

DIGITAL IMAGE PROCESSING

- The goal is to extract useful information from images in order to detect/track/find/identify/sort/classify objects in one or more image(s).
- Applications of Digital Image Processing:
  - Image restoration,
  - Robot vision,
  - Medical Imaging,
  - Pattern recognition,
  - Image/Video analysis…

2. What is a digital image?

WHAT IS A DIGITAL IMAGE?

WHAT IS A DIGITAL IMAGE?

- A 2D array M of pixels

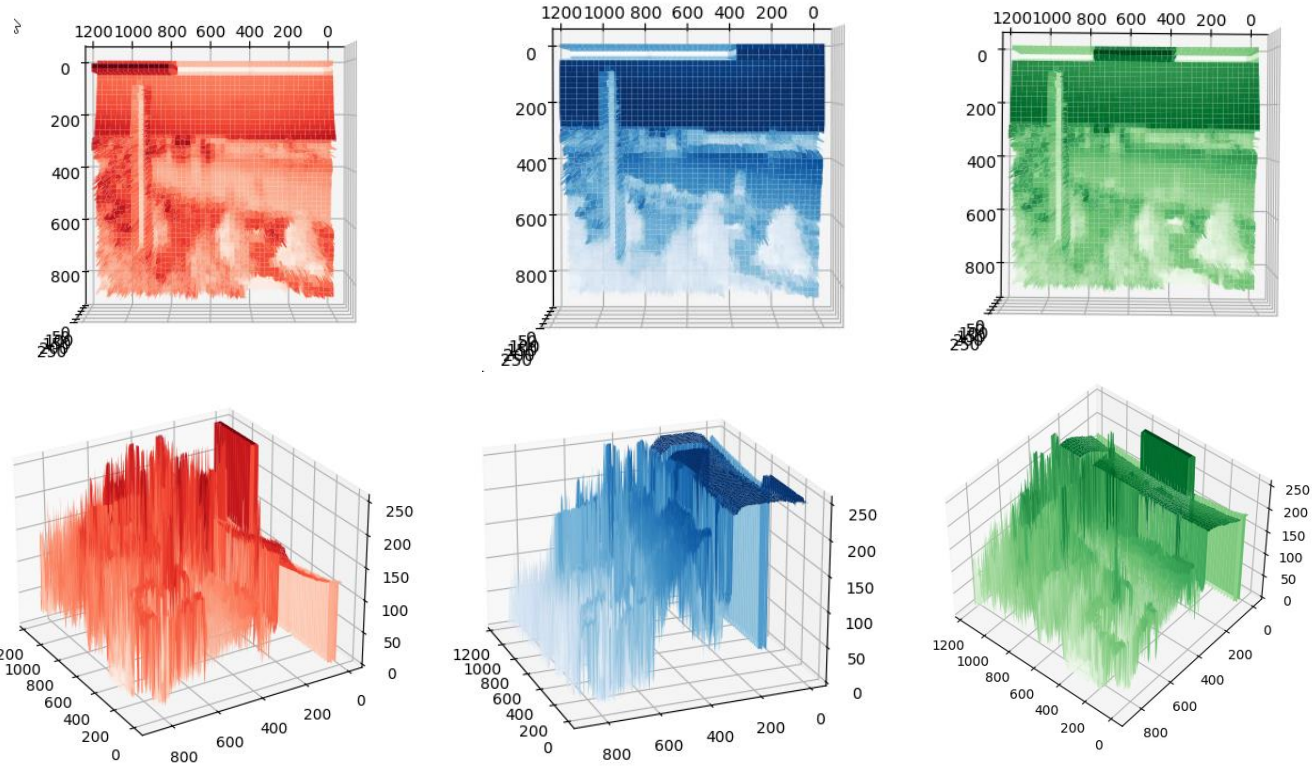
#RGB: 755844

WHAT IS A DIGITAL IMAGE?

- A 2D array of pixels

#RGB: 755844

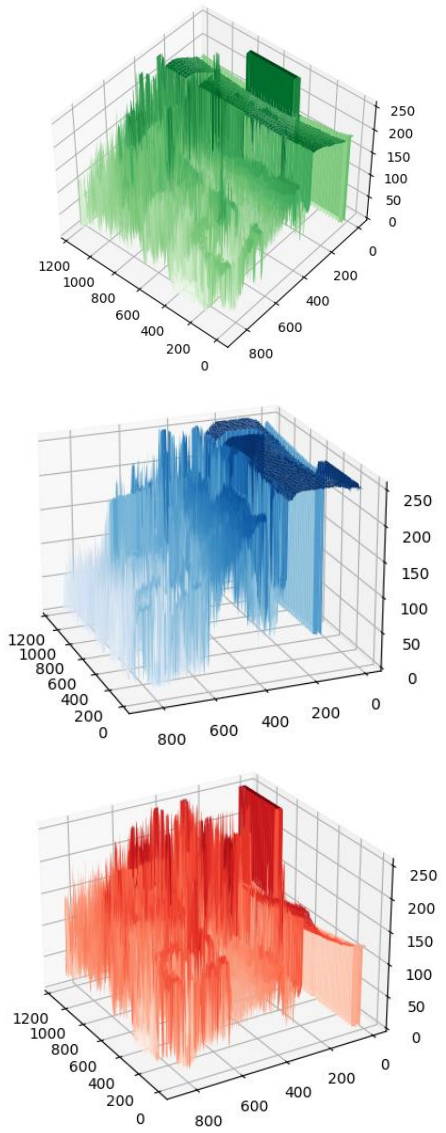
- A 2D signal f(x,y) obtained from a real measurable phenomenon



GENERATING 3D VIEWS

improc-0005.py > ...

```python
# we import all libraries used in our program
import cv2
import matplotlib.pyplot as plt
from matplotlib import cm
import numpy as np
# we read an image from disk to memory
img = cv2.imread('img/jonkoping-01.jpg')
# we flip the image to get the good view during 3d projection
img2 = cv2.flip(src = img, flipCode = 1)
# we show the image and wait for a key to be pressed
cv2.imshow('Jonkoping', img)
key = cv2.waitKey(0)
# 3d mesh grid of an image
#source: https://www.geeksforgeeks.org/3d-surface-plotting-in-python-using-matplotlib/
# we make the data from our image
X = np.arange(img2.shape[1])
Y = np.arange(img2.shape[0])
X, Y = np.meshgrid(X, Y)
# we plot the surface
fig1, ax1 = plt.subplots(subplot_kw={"projection": "3d"})
fig2, ax2 = plt.subplots(subplot_kw={"projection": "3d"})
fig3, ax3 = plt.subplots(subplot_kw={"projection": "3d"})
ax1.plot_surface(X, Y, img2[:,:,0], vmin = img2[:,:,0].min() * 2, cmap = cm.Blues)
ax2.plot_surface(X, Y, img2[:,:,1], vmin = img2[:,:,1].min() * 2, cmap = cm.Greens)
ax3.plot_surface(X, Y, img2[:,:,2], vmin = img2[:,:,2].min() * 2, cmap = cm.Reds)
# we show the surfaces
plt.show()
cv2.destroyAllWindows()

```



WHAT IS A DIGITAL IMAGE?

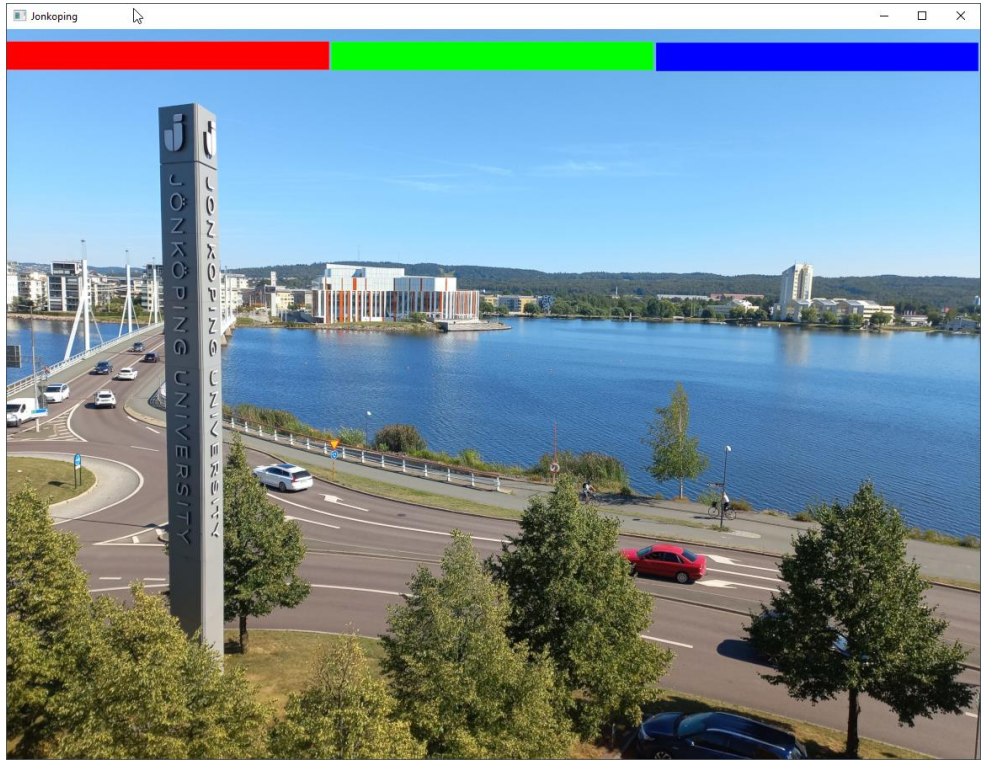
- A 2D array M of pixels
  - Many algorithms available working on pixels, regions, sliding window, columns, rows:
    - Color spaces
    - Image resizing
    - Image thresholding
    - Image transformations: translation, rotation, scale, perspective projections…
    - Image segmentation
    - Sliding Window
    - …

- A 2D signal f(x,y) obtained from a real measurable phenomenon
  - Many algorithms coming from signal processing available:
    - Image filtering (convolution)
    - Edge detection
    - Fourier Transform
    - Wavelets Transforms
    - …

READING AN IMAGE

improc-0000.py > ...

```python
# we import all libraries used in our program
import cv2

# we read an image from disk to memory
img = cv2.imread('img/jonkoping-01.jpg')

# we print the information concerning this image
print('---> Shape: ', img.shape)
print('---> Size: ', img.size)
print('---> Number of dimensions', img.ndim)
print('---> Image nd-array: ', img)

# we show the image and wait for a key to be pressed
cv2.imshow('Jonkoping', img)
key = cv2.waitKey(0)

cv2.destroyAllWindows()

```



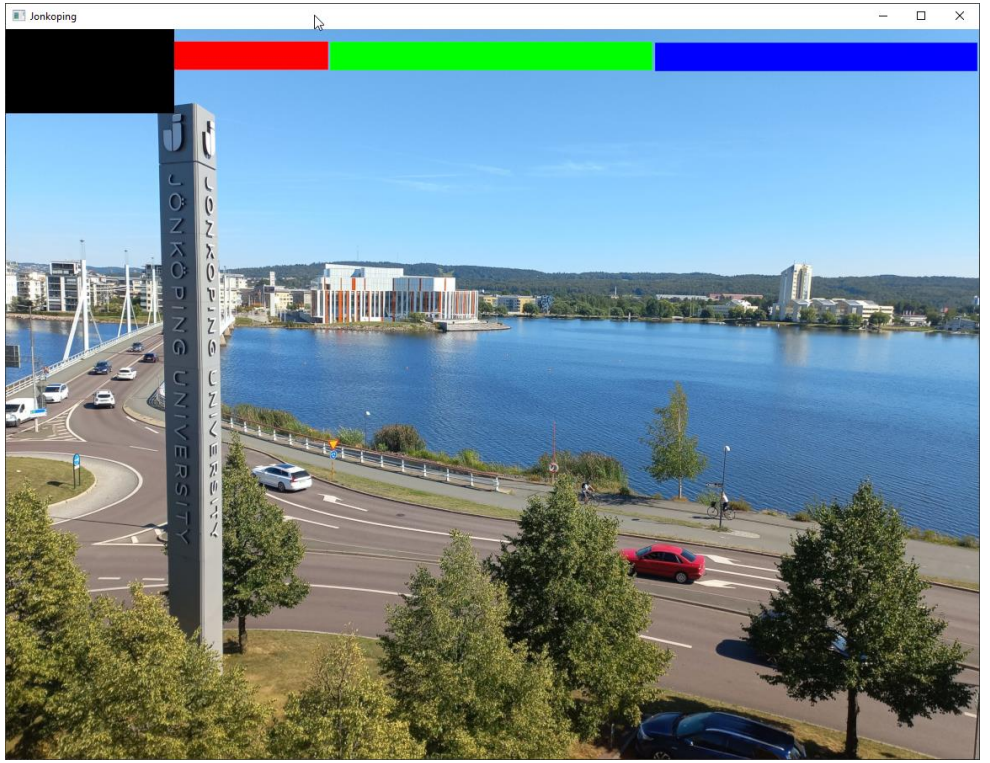

```
C:\Users\lanjer\Desktop\box\ju2023\teaching\courses\semester2\intelligent-mobile-platform\cours-jerome\code>python improc-0000.py
---> Shape:  (867, 1156, 3)
---> Size:  3006756
---> Number of dimensions 3
---> Image nd-array:  [[[244 183 119]
  [244 183 119]
  [244 181 120]
  ...
  [247 189 124]
  [247 189 124]
  [247 189 124]]

 [[244 183 119]
  [244 183 119]
  [244 181 120]
  ...
  [247 189 124]
```

Be careful: OpenCV uses the **BGR** pixel representation! For instance the first pixel of the image is [244 183 169], It is blue (upper left part of the sky) because of the high blue value: 244.

CHANGING THE PIXELS VALUES (1)

improc-0001.py > ...

```python
# we import all libraries used in our program
import cv2

# we read an image from disk to memory
img = cv2.imread('img/jonkoping-01.jpg')

# we change some pixels values
img[0:100, 0:200, :] = 0

# we print the information concerning this image
print('Shape: ', img.shape)
print(img)

# we show the image and wait for a key to be pressed
cv2.imshow('Jonkoping', img)
key = cv2.waitKey(0)

cv2.destroyAllWindows()

```

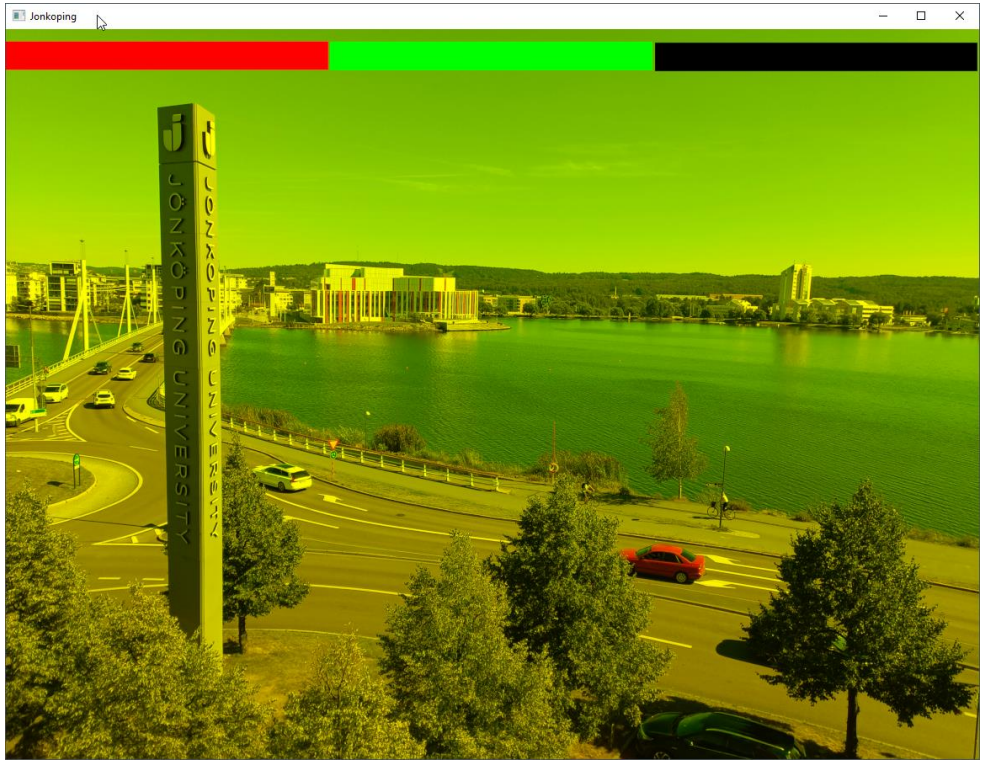



```
PS C:\Users\lanjer\Desktop\ju2022\teaching\COURSES\semester2\intelligent-mobile-platform\cours-jerome\code> python .\improc-0001.py
Shape:  (867, 1156, 3)
[[[  0   0   0]
  [  0   0   0]
  [  0   0   0]
  ...
  [247 189 124]
  [247 189 124]
  [247 189 124]]

 [[  0   0   0]
```

CHANGING THE PIXELS VALUES (2)

improc-0002.py > ...

```python
# we import all libraries used in our program
import cv2

# we read an image from disk to memory
img = cv2.imread('img/jonkoping-01.jpg')

# we change some pixels values
img[:, :, 0] = 0

# we print the information concerning this image
print('Shape: ', img.shape)
print(img)

# we show the image and wait for a key to be pressed
cv2.imshow('Jonkoping', img)
key = cv2.waitKey(0)

cv2.destroyAllWindows()

```




```
PS C:\Users\lanjer\Desktop\ju2022\teaching\COURSES\semester2\intelligent-mobile-platform\cours-jerome\code> python .\improc-0002.py
Shape:  (867, 1156, 3)
[[[  0 183 119]
  [  0 183 119]
  [  0 181 120]
  ...
  [  0 189 124]
  [  0 189 124]
  [  0 189 124]]

 [[  0 183 119]
```

3. Methodology for Image Processing

METHODOLOGY FOR IMAGE PROCESSING

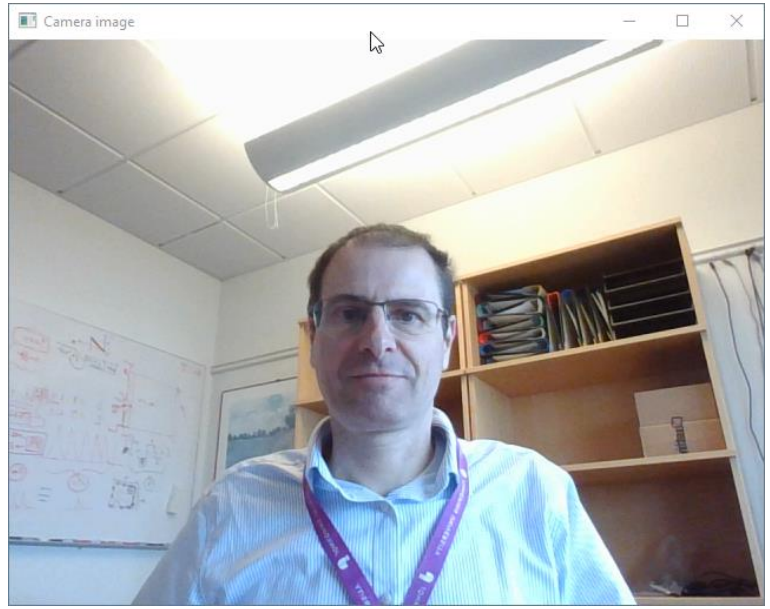
- Where to start?
  - 1) How many image sources do I have/need?
  - 2) Is the camera is fixed or moving?
  - 3) What kind of images do I need?
  - 4) Do I need color images?
  - 5) Do I need to remove the background of my images?
  - 6) Do I need to find edges or regions in my images?
  - 7) Will I work on the whole image or on a region?
  - 8) What information do I want to extract from my images? How?
  - 9) Do I need Machine Learning to solve my problem?
  - 10) Can I find useful tools included in OpenCV?
  - …

1) IMAGE SOURCES (WEBCAM)

- How many image sources do I have/need?
  - It depends on the application you want to build.
  - In general, we have an infinite loop to capture images from the camera and we process the images in the heart of this loop

improc-0003.py > ...

```python
# we import all libraries used in our program
import cv2

# Initialize Camera
cap = cv2.VideoCapture(0)

# infinite loop
while True:
    # we read an image from the camera
    ret, frame = cap.read()
    # there is an image
    if ret:
        frame = cv2.flip(frame, flipCode = 1)
        # we display it
        cv2.imshow('Camera image', frame)
        # we wait for a key pressed
        k = cv2.waitKey(10)
        # if it is 'q', we quit
        if k == ord('q'):
            break
    # there is no image
    else:
        print('ERROR ---> Camera not found!')

# we close all windows
cv2.destroyAllWindows()

```



1) IMAGE SOURCES (INTEL REALSENSE)

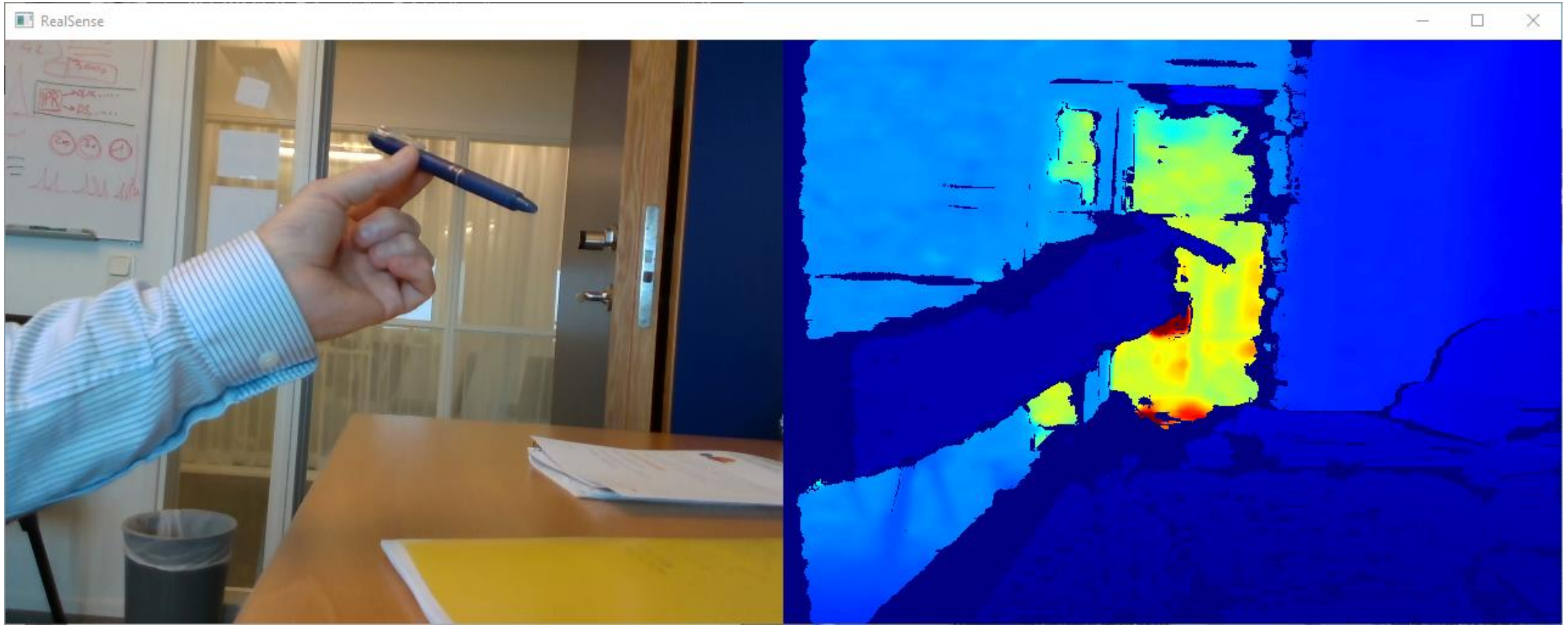
improc-0020.py > ...

```python
import pyrealsense2 as rs
import numpy as np
import cv2
# Configure depth and color streams
pipeline = rs.pipeline()
config = rs.config()
# Get device product line for setting a supporting resolution
pipeline_wrapper = rs.pipeline_wrapper(pipeline)
pipeline_profile = config.resolve(pipeline_wrapper)
device = pipeline_profile.get_device()
device_product_line = str(device.get_info(rs.camera_info.product_line))

found_rgb = False
for s in device.sensors:
    if s.get_info(rs.camera_info.name) == 'RGB Camera':
        found_rgb = True
        break
if not found_rgb:
    print("The demo requires Depth camera with Color sensor")
    exit(0)

config.enable_stream(rs.stream.depth, 640, 480, rs.format.z16, 30)
if device_product_line == 'L500':
    config.enable_stream(rs.stream.color, 960, 540, rs.format.bgr8, 30)
else:
    config.enable_stream(rs.stream.color, 640, 480, rs.format.bgr8, 30)
# Start streaming
pipeline.start(config)
```

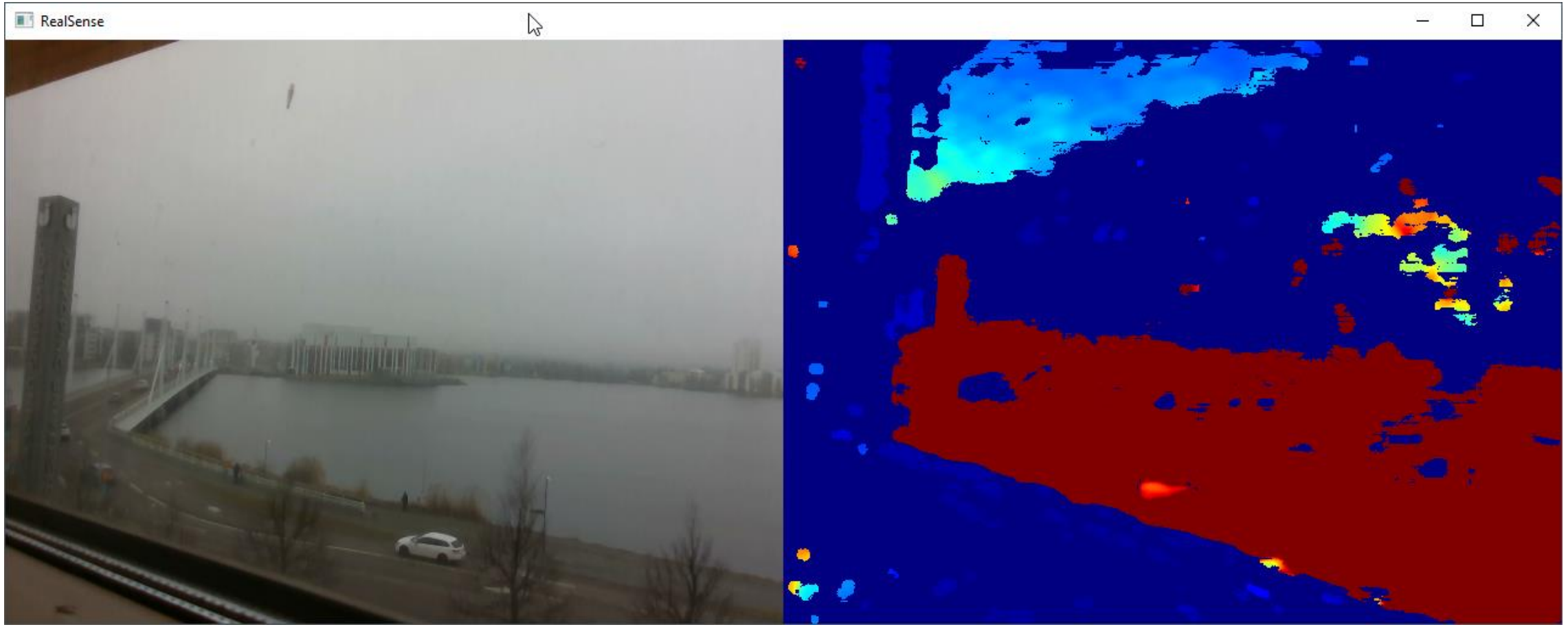
```python
try:
    while True:
        # Wait for a coherent pair of frames: depth and color
        frames = pipeline.wait_for_frames()
        depth_frame = frames.get_depth_frame()
        color_frame = frames.get_color_frame()
        if not depth_frame or not color_frame:
            continue

        # Convert images to numpy arrays
        depth_image = np.asanyarray(depth_frame.get_data())
        color_image = np.asanyarray(color_frame.get_data())

        # Apply colormap on depth image (image must be converted to 8-bit per pixel first)
        depth_colormap = cv2.applyColorMap(cv2.convertScaleAbs(depth_image, alpha=0.03), cv2.COLORMAP_JET)

        depth_colormap_dim = depth_colormap.shape
        color_colormap_dim = color_image.shape

        # If depth and color resolutions are different, resize color image to match depth image for display
        if depth_colormap_dim != color_colormap_dim:
            resized_color_image = cv2.resize(color_image, dsize=(depth_colormap_dim[1],
                                                                  depth_colormap_dim[0]), interpolation=cv2.INTER_AREA)
            images = np.hstack((resized_color_image, depth_colormap))
        else:
            images = np.hstack((color_image, depth_colormap))
        # Show images
        cv2.namedWindow('RealSense', cv2.WINDOW_AUTOSIZE)
        cv2.imshow('RealSense', images)
        k = cv2.waitKey(1)
        if k==ord('q'):
            break
finally:
    # Stop streaming
    pipeline.stop()
    cv2.destroyAllWindows()

```

Be careful: the code works with an Intel Realsense camera **only**,
If you have another camera, you must change this code.

1) IMAGE SOURCES (INTEL REALSENSE)



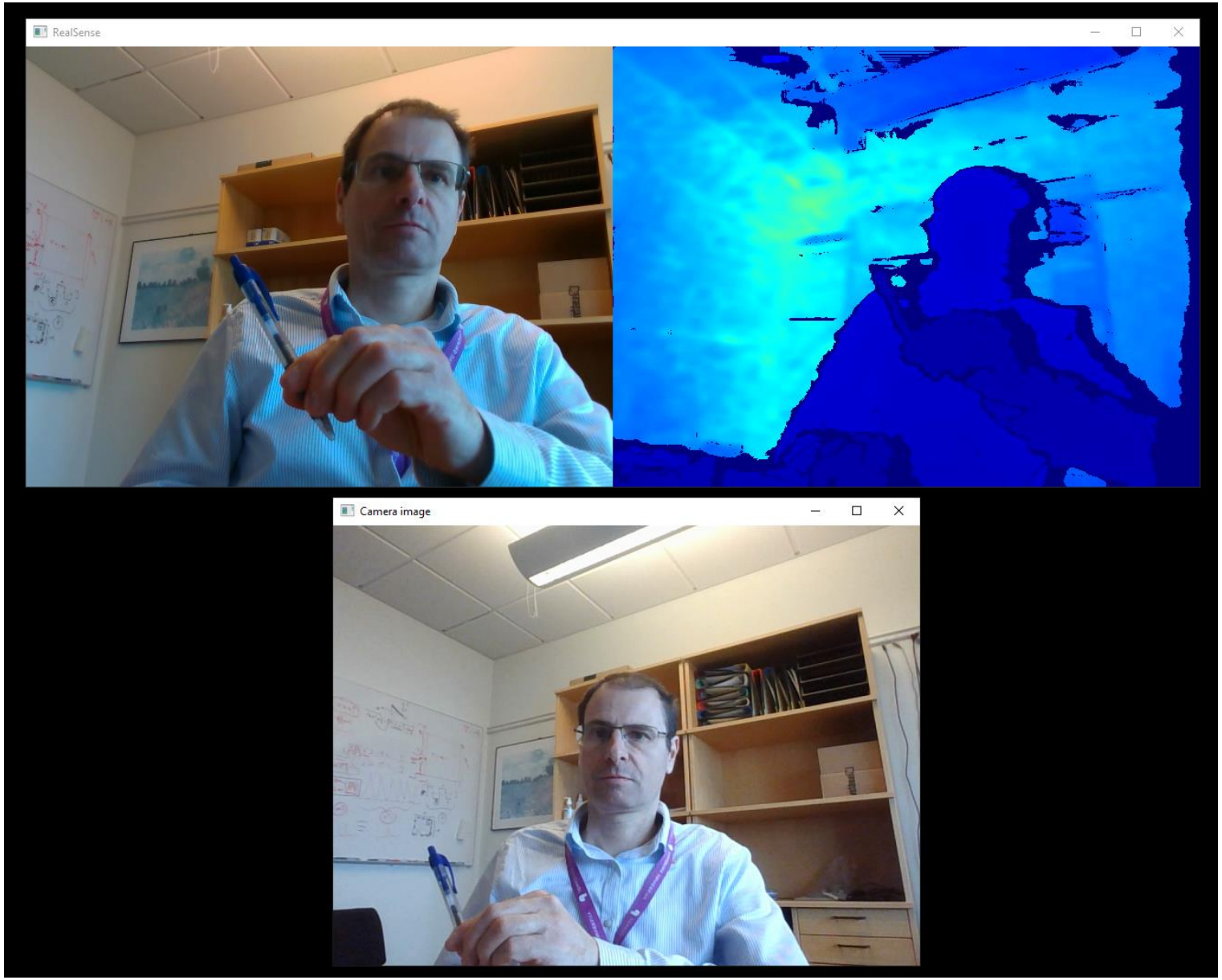
1) IMAGE SOURCES (INTEL REALSENSE)



1) IMAGE SOURCES (BOTH)

improc-0030.py > ...

```python
import pyrealsense2 as rs
import numpy as np
import cv2
# Configure depth and color streams
pipeline = rs.pipeline()
config = rs.config()
# Get device product line for setting a supporting resolution
pipeline_wrapper = rs.pipeline_wrapper(pipeline)
pipeline_profile = config.resolve(pipeline_wrapper)
device = pipeline_profile.get_device()
device_product_line = str(device.get_info(rs.camera_info.product_line))

found_rgb = False
for s in device.sensors:
    if s.get_info(rs.camera_info.name) == 'RGB Camera':
        found_rgb = True
        break
if not found_rgb:
    print("The demo requires Depth camera with Color sensor")
    exit(0)

config.enable_stream(rs.stream.depth, 640, 480, rs.format.z16, 30)
if device_product_line == 'L500':
    config.enable_stream(rs.stream.color, 960, 540, rs.format.bgr8, 30)
else:
    config.enable_stream(rs.stream.color, 640, 480, rs.format.bgr8, 30)
# Start streaming
pipeline.start(config)

# Initialize Camera
cap = cv2.VideoCapture(0)
try:
    while True:
        # we read an image from the camera
        ret, frame = cap.read()
        # there is an image
        if ret:
            frame = cv2.flip(frame, flipCode = 1)
            # we display it
            cv2.imshow('Camera image', frame)
        # Wait for a coherent pair of frames: depth and color
        frames = pipeline.wait_for_frames()
        depth_frame = frames.get_depth_frame()
        color_frame = frames.get_color_frame()
        if not depth_frame or not color_frame:
            continue
        # Convert images to numpy arrays
        depth_image = np.asanyarray(depth_frame.get_data())
        depth_image = cv2.flip(depth_image, flipCode = 1)
        color_image = np.asanyarray(color_frame.get_data())
        color_image = cv2.flip(color_image, flipCode = 1)

        # Apply colormap on depth image (image must be converted to 8-bit per pixel first)
        depth_colormap = cv2.applyColorMap(cv2.convertScaleAbs(depth_image, alpha=0.03), cv2.COLORMAP_JET)

        depth_colormap_dim = depth_colormap.shape
        color_colormap_dim = color_image.shape

        # If depth and color resolutions are different, resize color image to match depth image for display
        if depth_colormap_dim != color_colormap_dim:
            resized_color_image = cv2.resize(color_image, dsize=(depth_colormap_dim[1],
                                                                  depth_colormap_dim[0]), interpolation=cv2.INTER_AREA)
            images = np.hstack((resized_color_image, depth_colormap))
        else:
            images = np.hstack((color_image, depth_colormap))
        # Show images
        cv2.namedWindow('RealSense', cv2.WINDOW_AUTOSIZE)
        cv2.imshow('RealSense', images)
        k = cv2.waitKey(10)
        if k==ord('q'):
            break
finally:
    # Stop streaming
    pipeline.stop()
    cv2.destroyAllWindows()

```


RealSense
Camera image

2) FIXED OR MOVING CAMERA

- The problem is not exactly the same with a fixed or moving camera
- **But** there is always **NOISE** on your images in both case
- Let's do an **experiment**

improc-0031.py > depth_colormap_dim

```
29  pipeline.start(config)
30
31  # Initialize Camera
32  cap = cv2.VideoCapture(0)
33  ret, frame = cap.read()
34  x = datetime.datetime.now()
35  fileRGB = 'outRGB'+str(x.year)+str(x.month)+str(x.day)+str(x.hour)+str(x.minute)+str(x.second)+'.avi'
36  outRGB = cv2.VideoWriter(fileRGB,cv2.VideoWriter_fourcc(*'MJPG'), 30, (frame.shape[1],frame.shape[0]))
37  numberOfImagesInVideo = 300
38  nb = 0
39
40  try:
41      while True:
42          # we read an image from the camera
43          ret, frame = cap.read()
44          # there is an image
45          if ret:
46              frame = cv2.flip(frame, flipCode = 1)
47              if nb<numberOfImagesInVideo:
48                  outRGB.write(frame)
49                  nb += 1
50              # we display it
51              cv2.imshow('Camera image', frame)
52          # Wait for a coherent pair of frames: depth and color
53          frames = pipeline.wait_for_frames()
54          depth_frame = frames.get_depth_frame()
```

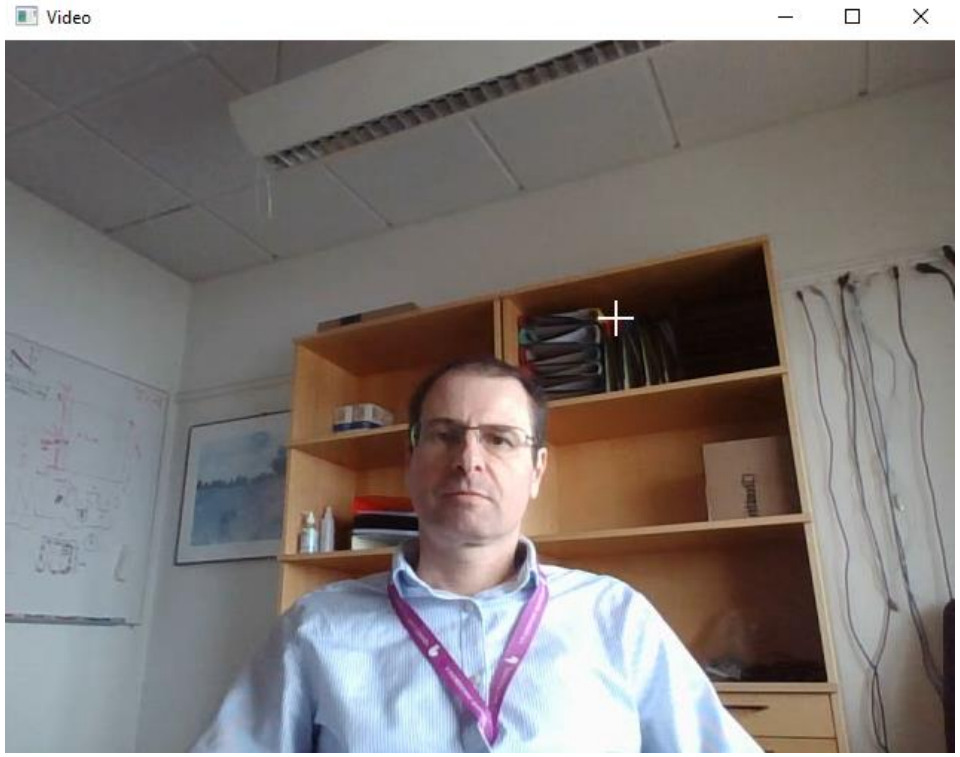
2) FIXED OR MOVING CAMERA

- We obtain a **video file**
- Let’s try to see if the image pixels are ”stable” in time!

2) FIXED OR MOVING CAMERA

improc-0032.py > ...

```python
import cv2
import numpy as np

#source: https://learnopencv.com/read-write-and-display-a-video-using-opencv-cpp-python/
cap = cv2.VideoCapture('outRGB2023414131958.avi')

# Check if camera opened successfully
if (cap.isOpened()== False):
  print("Error opening video stream or file")

# Read until video is completed
while(cap.isOpened()):
  # Capture frame-by-frame
  ret, frame = cap.read()
  if ret == True:
    # Display the resulting frame
    cv2.imshow('Video', frame)
    # Press Q on keyboard to  exit
    k = cv2.waitKey(25)
    if k == ord('q'):
      break
  else:
    break

# When everything done, release the video capture object
cap.release()

# Closes all the frames
cv2.destroyAllWindows()
```



2) FIXED OR MOVING CAMERA

improc-0034.py > ...

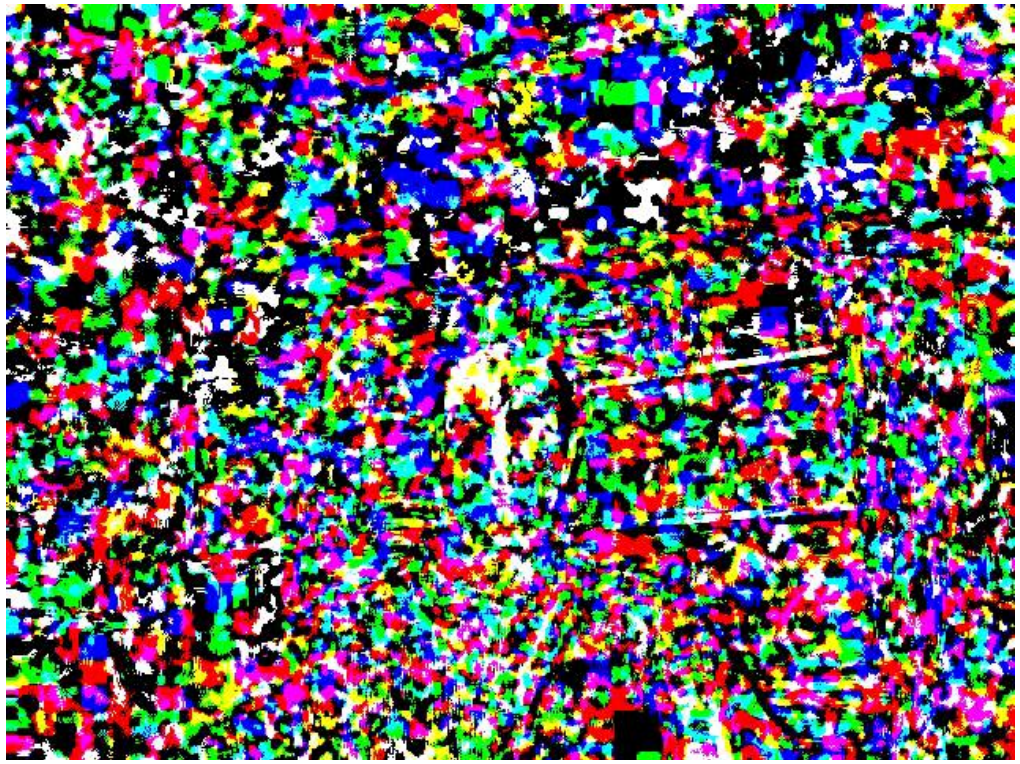
```python
import cv2
import datetime

#source: https://learnopencv.com/read-write-and-display-a-video-using-opencv-cpp-python/
cap = cv2.VideoCapture('outRGB2023414131958.avi')

# Check if camera opened successfully
if (cap.isOpened()== False):
  print("Error opening video stream or file")

x = datetime.datetime.now()
ret, frame = cap.read()
fileRGB = 'noiseRGB'+str(x.year)+str(x.month)+str(x.day)+str(x.hour)+str(x.minute)+str(x.second)+'.avi'
outRGB = cv2.VideoWriter(fileRGB,cv2.VideoWriter_fourcc(*'MJPG'), 30, (frame.shape[1],frame.shape[0]))

ret, oldFrame = cap.read()

# Read until video is completed
while(cap.isOpened()):
  # Capture frame-by-frame
  ret, newFrame = cap.read()
  if ret == True:
    # Display the resulting frame
    cv2.imshow('Video', newFrame-oldFrame)
    outRGB.write(newFrame-oldFrame)

    oldFrame = newFrame.copy()
    # Press Q on keyboard to  exit
    k = cv2.waitKey(25)
    if k == ord('q'):
      break
  else:
    break

# When everything done, release the video capture object
cap.release()
outRGB.release()

# Closes all the frames
cv2.destroyAllWindows()

```

2) FIXED OR MOVING CAMERA

improc-0035.py > ...

```python
import cv2
import datetime

#source: https://learnopencv.com/read-write-and-display-a-video-using-opencv-cpp-python/
cap = cv2.VideoCapture('outRGB2023414131958.avi')

# Check if camera opened successfully
if (cap.isOpened()== False):
  print("Error opening video stream or file")

x = datetime.datetime.now()
ret, frame = cap.read()
fileRGB = 'noiseRGB'+str(x.year)+str(x.month)+str(x.day)+str(x.hour)+str(x.minute)+str(x.second)+'.avi'
outRGB = cv2.VideoWriter(fileRGB,cv2.VideoWriter_fourcc(*'MJPG'), 30, (frame.shape[1],frame.shape[0]))

ret, oldFrame = cap.read()
oldFrame = cv2.blur(oldFrame, (5, 5))

# Read until video is completed
while(cap.isOpened()):
  # Capture frame-by-frame
  ret, newFrame = cap.read()

  if ret == True:
    # Display the resulting frame
    newFrame = cv2.blur(newFrame, (5, 5))
    cv2.imshow('Video', newFrame-oldFrame)
    outRGB.write(newFrame-oldFrame)

    oldFrame = newFrame.copy()
    # Press Q on keyboard to  exit
    k = cv2.waitKey(25)
    if k == ord('q'):
      break
  else:
    break

# When everything done, release the video capture object
cap.release()
outRGB.release()

# Closes all the frames
cv2.destroyAllWindows()
```

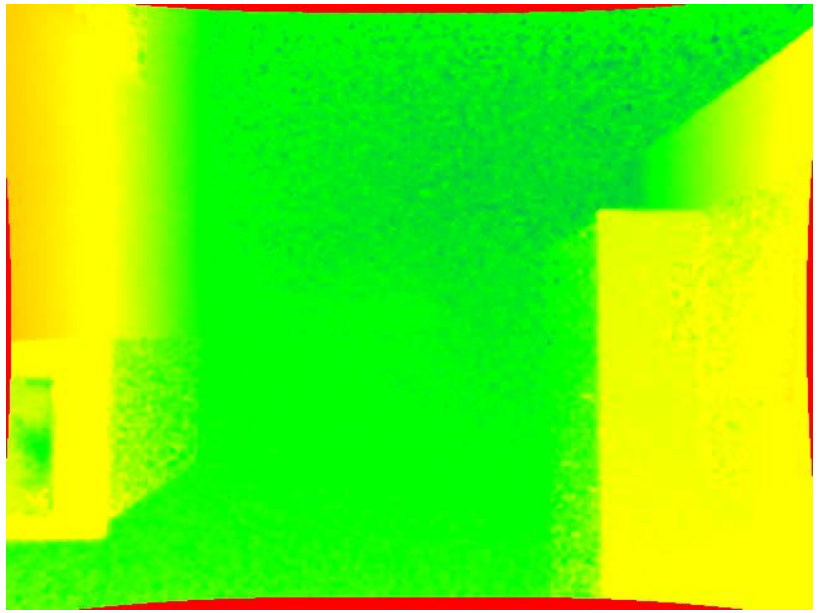
- GaussianBlur and medianBlur can also help…



3) TYPES OF IMAGES

- Depending on your camera sensors and needs, you can use many types of cameras:

DEPTH



INFRARED

RGB

LIDAR, MEDICAL, MULTISPECTRAL, AERIAL, SATELITE IMAGES…

4) COLOR IMAGES OR NOT…

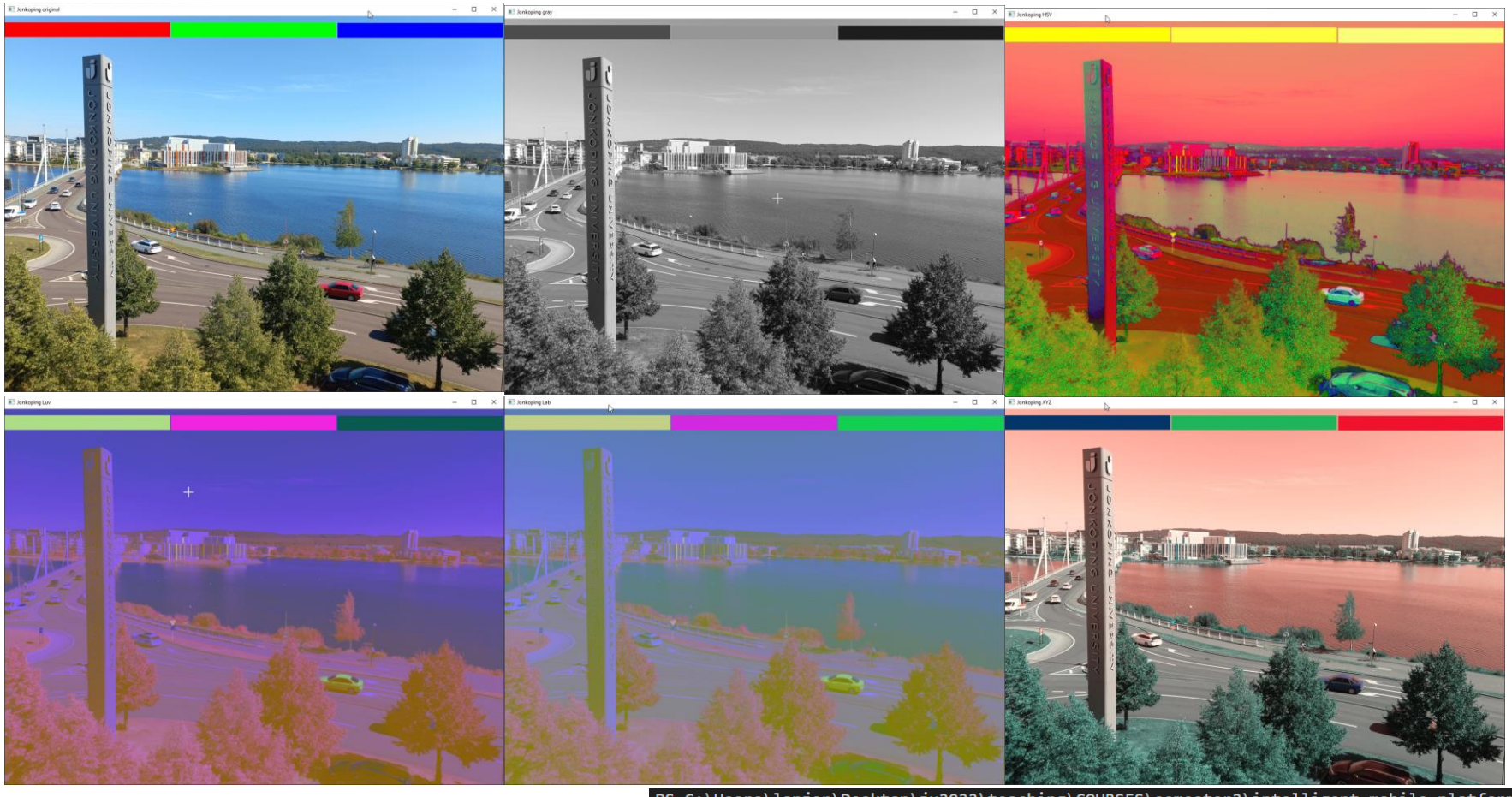
- RGB, Grayscale, HSV, HSL, XYZ, Lab, Luv… colorspaces

improc-0040.py > ...

```python
# we import all libraries used in our program
import cv2
import numpy

# we read an image from disk to memory
img = cv2.imread('img/jonkoping-01.jpg')
imgGray = cv2.cvtColor(img, cv2.COLOR_BGR2GRAY)
imgHSV = cv2.cvtColor(img, cv2.COLOR_BGR2HSV)
imgLab = cv2.cvtColor(img, cv2.COLOR_BGR2LAB)
imgLuv = cv2.cvtColor(img, cv2.COLOR_BGR2LUV)
imgXYZ = cv2.cvtColor(img, cv2.COLOR_BGR2XYZ)
print("---> Stats:")
print("shape, (min, max, avg) RGB: ", img.shape, ', ', numpy.min(img), numpy.max(img), numpy.mean(img))
print("shape, (min, max, avg) Gray: ", imgGray.shape, ', ', numpy.min(imgGray), numpy.max(imgGray), numpy.mean(imgGray))
print("shape, (min, max, avg) HSV: ", imgHSV.shape, ', ', numpy.min(imgHSV), numpy.max(imgHSV), numpy.mean(imgHSV))
print("shape, (min, max, avg) Lab: ", imgLab.shape, ', ', numpy.min(imgLab), numpy.max(imgLab), numpy.mean(imgLab))
print("shape, (min, max, avg) Luv: ", imgLuv.shape, ', ', numpy.min(imgLuv), numpy.max(imgLuv), numpy.mean(imgLuv))
print("shape, (min, max, avg) XYZ: ", imgXYZ.shape, ', ', numpy.min(imgXYZ), numpy.max(imgXYZ), numpy.mean(imgXYZ))
# we show the image and wait for a key to be pressed
cv2.imshow('Jonkoping original', img)
cv2.imshow('Jonkoping gray', imgGray)
cv2.imshow('Jonkoping Lab', imgLab)
cv2.imshow('Jonkoping HSV', imgHSV)
cv2.imshow('Jonkoping Luv', imgLuv)
cv2.imshow('Jonkoping XYZ', imgXYZ)
key = cv2.waitKey(0)

cv2.destroyAllWindows()

```

OpenCV docs: https://docs.opencv.org/4.7.0/d8/d01/group__imgproc__color__conversions.html

4) COLOR IMAGES OR NOT…



```
PS C:\Users\lanjer\Desktop\ju2022\teaching\COURSES\semester2\intelligent-mobile-platform\cours-jerome\code> python .\improc-0040.py
---> Stats:
shape, (min, max, avg) RGB:  (867, 1156, 3) ,  0 255 133.69111128405498
shape, (min, max, avg) Gray:  (867, 1156) ,  4 255 132.29723762087778
shape, (min, max, avg) HSV:  (867, 1156, 3) ,  0 255 114.5795405413675
shape, (min, max, avg) Lab:  (867, 1156, 3) ,  2 255 130.53138565284314
shape, (min, max, avg) Luv:  (867, 1156, 3) ,  3 255 119.25149164082487
shape, (min, max, avg) XYZ:  (867, 1156, 3) ,  1 255 137.87846236941076
```

5) BACKGROUND REMOVAL

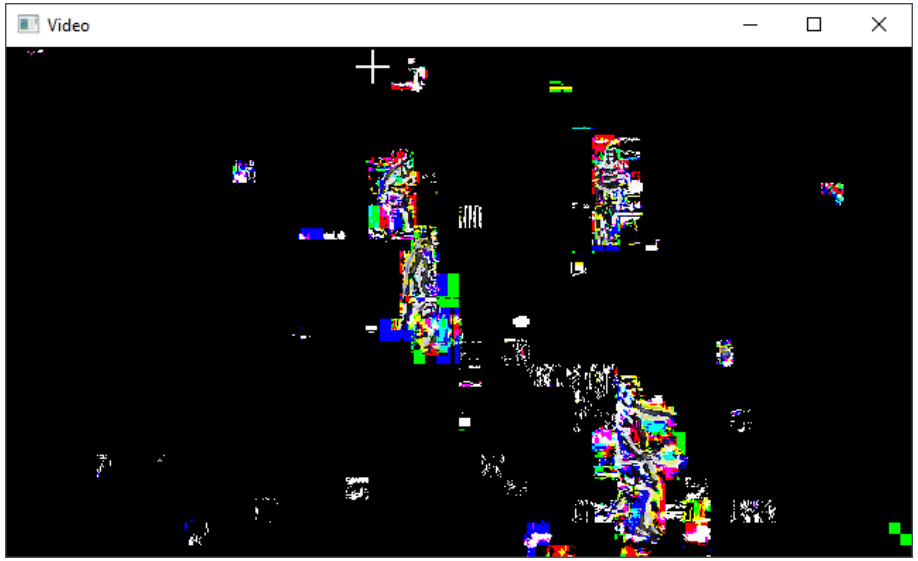
- In order to study the moving parts in a video (here th players and the ball), we can try to guess the background of the image and see what have moved by a simple difference (bgImg-CurrentImg)
- How to get the background of a video?

Source video: https://www.youtube.com/watch?v=P6yfa7rfc6o
YT2MP4 Converter: https://wave.video/convert/youtube-to-mp4-85

5) BACKGROUND REMOVAL

improc-0050.py > ...

```python
import cv2
import numpy as np

#source: https://learnopencv.com/read-write-and-display-a-video-using-opencv-cpp-python/
cap = cv2.VideoCapture('padelpoint.mp4')
# Check if camera opened successfully
if (cap.isOpened()== False):
  print("Error opening video stream or file")
ret, oldFrame = cap.read()
# Read until video is completed
while(cap.isOpened()):
  # Capture frame-by-frame
  ret, newFrame = cap.read()
  if ret == True:
    # Display the resulting frame
    cv2.imshow('Video', oldFrame-newFrame)
    oldFrame = newFrame.copy()
    # Press Q on keyboard to  exit
    k = cv2.waitKey(25)
    if k == ord('q'):
      break
  else:
    break

# When everything done, release the video capture object
cap.release()
# Closes all the frames
cv2.destroyAllWindows()

```



5) BACKGROUND REMOVAL (1ST TRY)

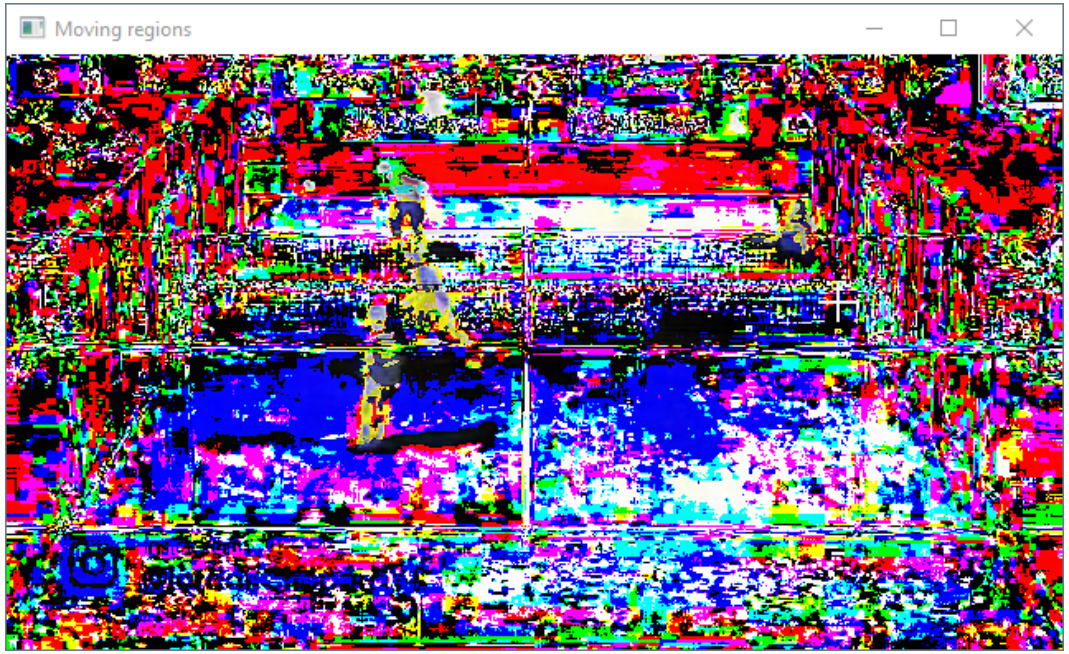
improc-0051.py > ...

```python
import cv2
import numpy

#source: https://learnopencv.com/read-write-and-display-a-video-using-opencv-cpp-python/
cap = cv2.VideoCapture('padelpoint.mp4')
# Check if camera opened successfully
if (cap.isOpened()== False):
  print("Error opening video stream or file")
ret, frame = cap.read()
sumImages = numpy.zeros(frame.shape)
nb = 0

# Read until video is completed
while(cap.isOpened()):
  # Capture frame-by-frame
  ret, frame = cap.read()
  if ret == True:
    # add the image to the sum
    sumImages += frame
    nb += 1
  else:
    break

avgImages = sumImages / nb
avgImages = avgImages.astype(numpy.uint8)
cv2.imshow('sumImages', avgImages)
key = cv2.waitKey(0)

# When everything done, release the video capture object
cap.release()
# Closes all the frames
cv2.destroyAllWindows()
```

5) BACKGROUND REMOVAL (2ND TRY)

improc-0052.py > ...

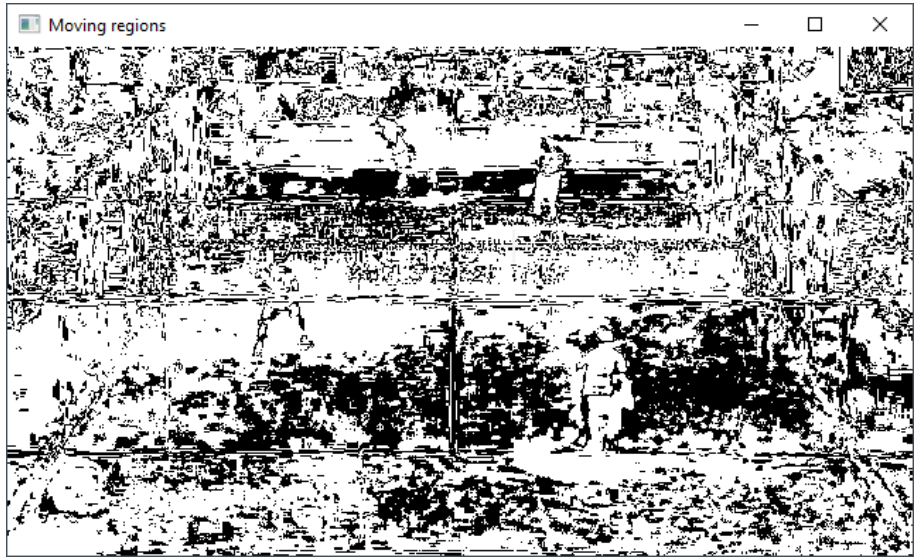
```
        # add the image to the sum
        sumImages += frame
        nb += 1
    else:
        break

avgImages = sumImages / nb
avgImages = avgImages.astype(numpy.uint8)
cv2.imshow('sumImages', avgImages)
key = cv2.waitKey(0)

backgroundImage = avgImages.copy()
# When everything done, release the video capture object
cap.release()

cap = cv2.VideoCapture('padelpoint.mp4')
# Check if camera opened successfully
if (cap.isOpened()== False):
  print("Error opening video stream or file")
ret, frame = cap.read()
sumImages = numpy.zeros(frame.shape)
nb = 0

# Read until video is completed
while(cap.isOpened()):
  # Capture frame-by-frame
  ret, frame = cap.read()
  cv2.imshow('Moving regions', backgroundImage-frame)
  key = cv2.waitKey(10)
  if key == ord('q'):
    break

# When everything done, release the video capture object
cap.release()
# Closes all the frames
cv2.destroyAllWindows()
```



5) BACKGROUND REMOVAL (3RD TRY)

improc-0053.py > ...

```
      sumImages += cv2.cvtColor(frame, cv2.COLOR_BGR2GRAY)
      nb += 1
    else:
      break

avgImages = sumImages / nb
avgImages = avgImages.astype(numpy.uint8)
cv2.imshow('sumImages', avgImages)
key = cv2.waitKey(0)

backgroundImage = avgImages.copy()
# When everything done, release the video capture object
cap.release()

cap = cv2.VideoCapture('padelpoint.mp4')
# Check if camera opened successfully
if (cap.isOpened()== False):
  print("Error opening video stream or file")
ret, frame = cap.read()
sumImages = numpy.zeros(frame.shape)
nb = 0

# Read until video is completed
while(cap.isOpened()):
  # Capture frame-by-frame
  ret, frame = cap.read()
  diff = (((backgroundImage-cv2.cvtColor(frame, cv2.COLOR_BGR2GRAY))<200)*255).astype(numpy.uint8)
  print(diff)
  cv2.imshow('Moving regions', diff)
  key = cv2.waitKey(10)
  if key == ord('q'):
    break

# When everything done, release the video capture object
cap.release()
# Closes all the frames
cv2.destroyAllWindows()
```



5) BACKGROUND REMOVAL

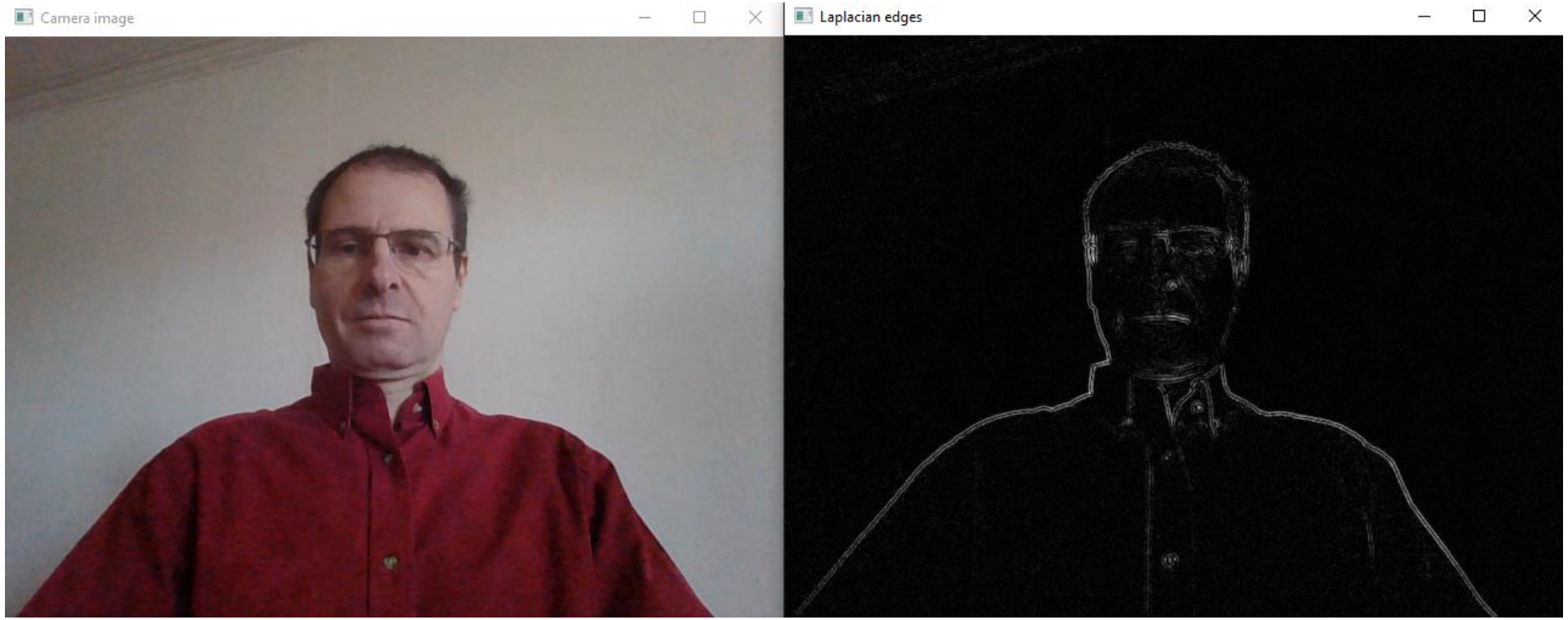
5) BACKGROUND REMOVAL

improc-0054.py > ...

```
23      break
24
25  avgImages = sumImages / nb
26  avgImages = avgImages.astype(numpy.uint8)
27  cv2.imshow('sumImages', avgImages)
28  key = cv2.waitKey(0)
29
30  backgroundImage = avgImages.copy()
31  # When everything done, release the video capture object
32  cap.release()
33
34  cap = cv2.VideoCapture('bridgeRGB2023414161111.avi')
35  # Check if camera opened successfully
36  if (cap.isOpened()== False):
37    print("Error opening video stream or file")
38  ret, frame = cap.read()
39  sumImages = numpy.zeros(frame.shape)
40  nb = 0
41
42  # Read until video is completed
43  while(cap.isOpened()):
44    # Capture frame-by-frame
45    ret, frame = cap.read()
46    diff = (((backgroundImage-cv2.cvtColor(frame, cv2.COLOR_BGR2GRAY))<200)*255).astype(numpy.uint8)
47    print(diff)
48    cv2.imshow('Moving regions', diff)
49    key = cv2.waitKey(10)
50    if key == ord('q'):
51      break
52
53  # When everything done, release the video capture object
54  cap.release()
55  # Closes all the frames
56  cv2.destroyAllWindows()
57
```

6) EDGES AND REGIONS

- In many applications of Image Processing, you need to find **edges** and **regions** in an image.



6) EDGES AND REGIONS

improc-0060.py > ...

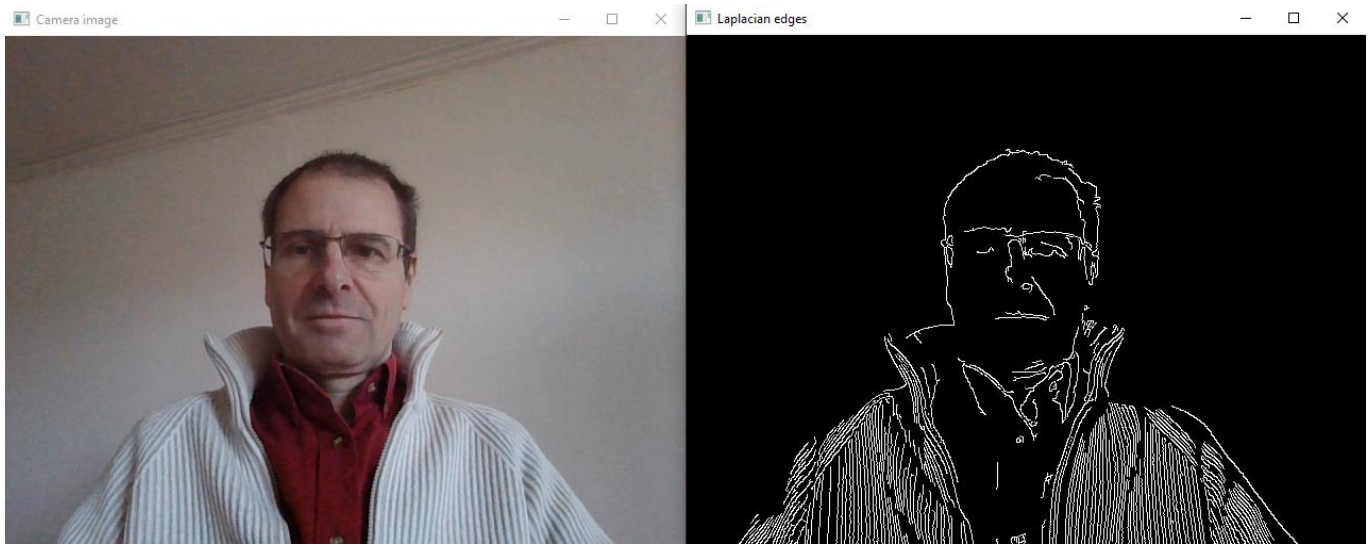
```python
# we import all libraries used in our program
import cv2

# Initialize Camera
cap = cv2.VideoCapture(0)

# infinite loop
while True:
    # we read an image from the camera
    ret, frame = cap.read()
    # there is an image
    if ret:
        frame = cv2.flip(frame, flipCode = 1)
        frameBlur = cv2.GaussianBlur(frame, (3, 3), 0)
        frameGray = cv2.cvtColor(frameBlur, cv2.COLOR_BGR2GRAY)
        frameEdges = cv2.Laplacian(frameGray, cv2.CV_16S, ksize=3)
        frameFinalEdges = cv2.convertScaleAbs(frameEdges)
        # we display it
        cv2.imshow('Camera image', frame)
        cv2.imshow('Laplacian edges', frameFinalEdges)
        # we wait for a key pressed
        k = cv2.waitKey(10)
        # if it is 'q', we quit
        if k == ord('q'):
            break
    # there is no image
    else:
        print('ERROR ---> Camera not found!')

# we close all windows
cv2.destroyAllWindows()
```

Laplacian filter

6) EDGES AND REGIONS

improc-0061.py > ...

```python
# we import all libraries used in our program
import cv2

# Initialize Camera
cap = cv2.VideoCapture(0)

# infinite loop
while True:
    # we read an image from the camera
    ret, frame = cap.read()
    # there is an image
    if ret:
        frame = cv2.flip(frame, flipCode = 1)
        frameEdges = cv2.Canny(frame, 100, 200)
        # we display it
        cv2.imshow('Camera image', frame)
        cv2.imshow('Laplacian edges', frameEdges)
        # we wait for a key pressed
        k = cv2.waitKey(10)
        # if it is 'q', we quit
        if k == ord('q'):
            break
    # there is no image
    else:
        print('ERROR ---> Camera not found!')

# we close all windows
cv2.destroyAllWindows()
```

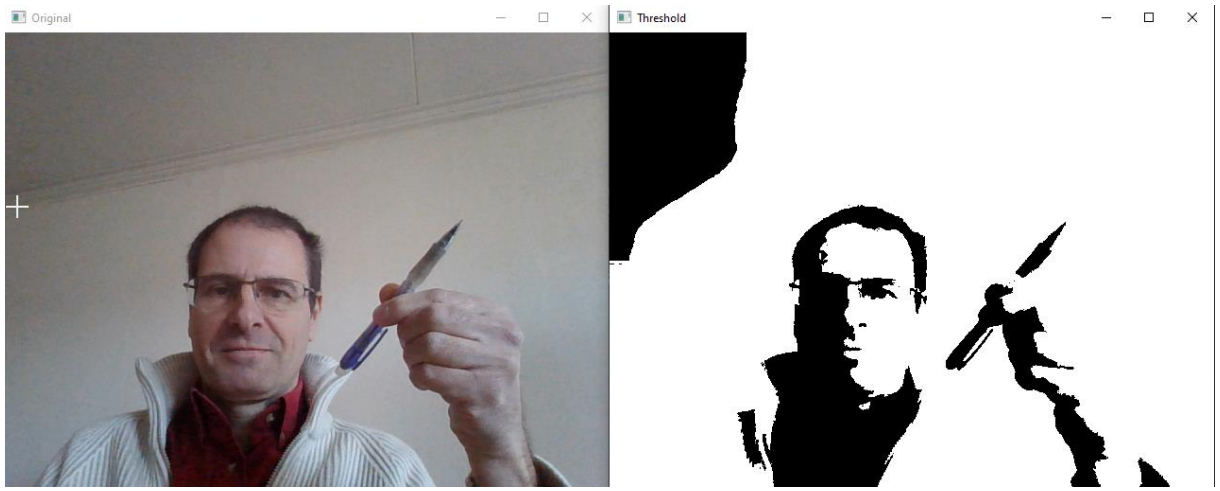


Canny Edge Detector

6) EDGES AND REGIONS

improc-0062.py > ...

```python
# we import all libraries used in our program
import cv2
# Initialize Camera
cap = cv2.VideoCapture(0)
# infinite loop
while True:
    # we read an image from the camera
    ret, frame = cap.read()
    # there is an image
    if ret:
        frame = cv2.flip(frame, flipCode = 1)
        #Edge-based segmentation
        #source: https://pyimagesearch.com/2015/11/02/watershed-opencv/
        shifted = cv2.pyrMeanShiftFiltering(frame, 21, 51)
        # convert the mean shift image to grayscale, then apply
        # Otsu's thresholding
        gray = cv2.cvtColor(shifted, cv2.COLOR_BGR2GRAY)
        thresh = cv2.threshold(gray, 0, 255,
            cv2.THRESH_BINARY | cv2.THRESH_OTSU)[1]
        # we display it
        cv2.imshow("Original", frame)
        cv2.imshow("Threshold", thresh)

        # we wait for a key pressed
        k = cv2.waitKey(10)
        # if it is 'q', we quit
        if k == ord('q'):
            break

# we close all windows
cv2.destroyAllWindows()

```



Watershed algorithm

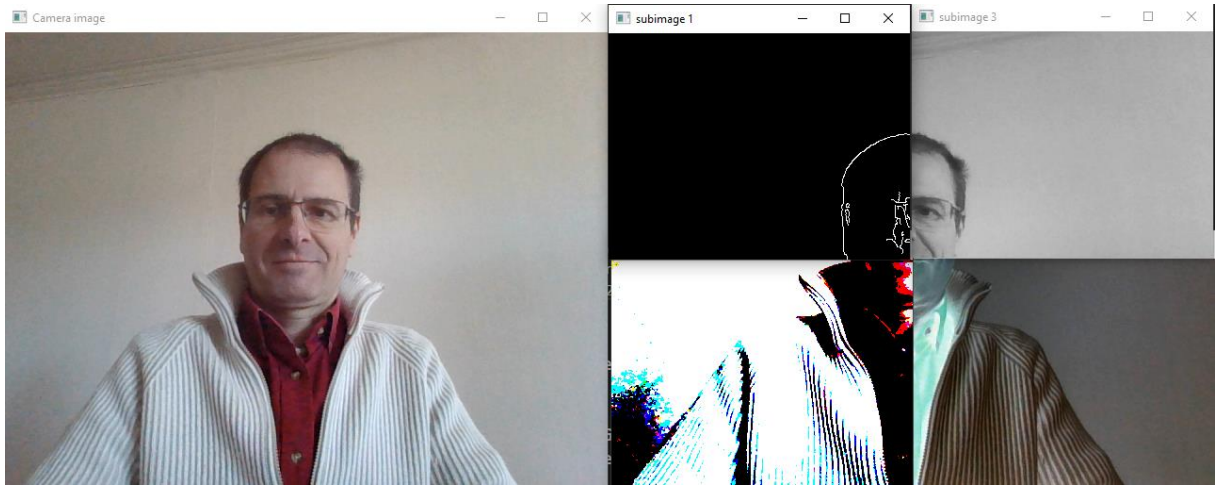
7) REGION OF INTEREST

- When working on an image, we can choose to work only in a sub-image:
  - The interest thing happens only in a small part of the image so it is unnecessary to work on the whole image
  - It saves computing time to work only on a small part of the image

7) REGION OF INTEREST

improc-0070.py > ...

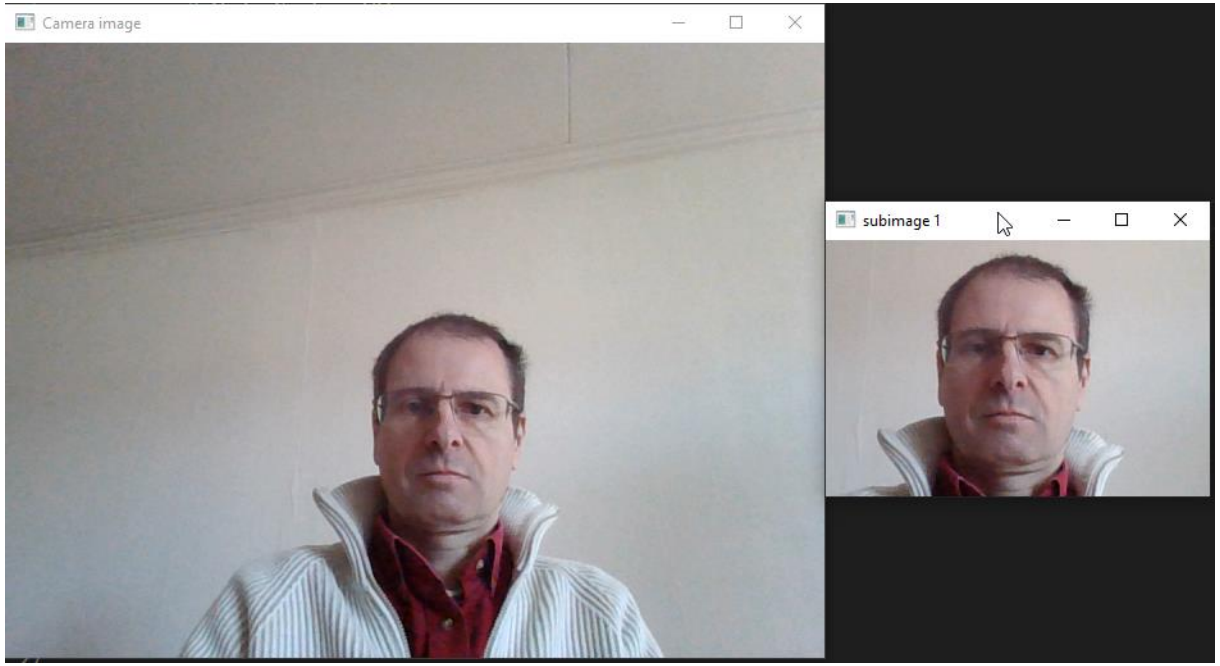
```python
# we import all libraries used in our program
import cv2
import numpy
# Initialize Camera
cap = cv2.VideoCapture(0)
ret, frame = cap.read()
print("Shape: ", frame.shape)
nb = 0
# infinite loop
while True:
    ret, frame = cap.read()
    if ret:
        frame = cv2.flip(frame, flipCode = 1)
        frame1 = frame[0:frame.shape[0]//2, 0:frame.shape[1]//2]
        frame2 = frame[frame.shape[0]//2:frame.shape[0], 0:frame.shape[1]//2]
        frame3 = frame[0:frame.shape[0]//2, frame.shape[1]//2:frame.shape[1]]
        frame4 = frame[frame.shape[0]//2:frame.shape[0], frame.shape[1]//2:frame.shape[1]]
        if nb==0:
            print("shapes 1,2,3,4: ", frame1.shape, frame2.shape, frame3.shape, frame4.shape)
        nb += 1
        frame1 = cv2.Canny(frame1, 100, 200)
        frame2 = ((frame2>127)*255).astype(numpy.uint8)
        frame3 = cv2.cvtColor(frame3, cv2.COLOR_BGR2GRAY)
        frame4 = 255 - frame4
        # we display it
        cv2.imshow('Camera image', frame)
        cv2.imshow('subimage 1', frame1)
        cv2.imshow('subimage 2', frame2)
        cv2.imshow('subimage 3', frame3)
        cv2.imshow('subimage 4', frame4)
        # we wait for a key pressed
        k = cv2.waitKey(10)
        # if it is 'q', we quit
        if k == ord('q'):
            break
    # there is no image
    else:
        print('ERROR ---> Camera not found!')

```



7) REGION OF INTEREST

improc-0071.py > ...

```python
# we import all libraries used in our program
import cv2
import numpy
# Initialize Camera
cap = cv2.VideoCapture(0)
ret, frame = cap.read()
# infinite loop
while True:
    ret, frame = cap.read()
    if ret:
        frame = cv2.flip(frame, flipCode = 1)
        frame1 = frame[200:400, 200:500]
        # we display it
        cv2.imshow('Camera image', frame)
        cv2.imshow('subimage 1', frame1)
        # we wait for a key pressed
        k = cv2.waitKey(10)
        # if it is 'q', we quit
        if k == ord('q'):
            break
    # there is no image
    else:
        print('ERROR ---> Camera not found!')

# we close all windows
cv2.destroyAllWindows()
```



8) EXTRACT INFORMATION

- You can extract statistics from images to get information about the whole image and/or regions, …
- Among all possible tools, the histogram of the image gives information about the distribution of colors in the image

8) EXTRACT INFORMATION

improc-0080.py > ...

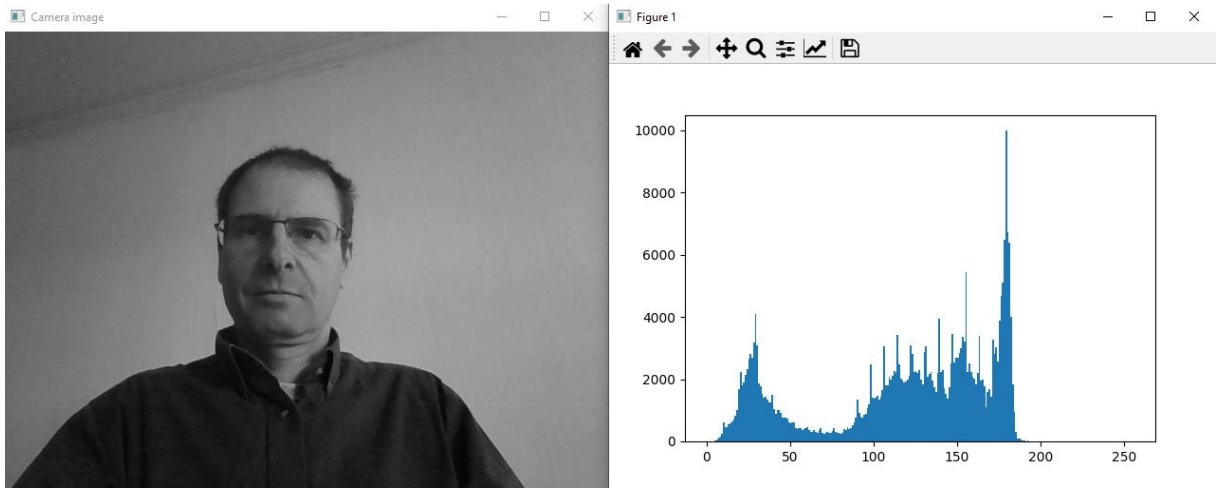
```python
# we import all libraries used in our program
import cv2
import numpy
# Initialize Camera
cap = cv2.VideoCapture(0)
ret, frame = cap.read()
# infinite loop
while True:
    ret, frame = cap.read()
    if ret:
        frame = cv2.flip(frame, flipCode = 1)
        mean = numpy.mean(frame)
        min = numpy.min(frame)
        max = numpy.max(frame)
        stddev = numpy.std(frame)
        print('Statistics: min, max, mean, stddev ---> ', min, max, mean, stddev)
        # we display it
        cv2.imshow('Camera image', frame)
        # we wait for a key pressed
        k = cv2.waitKey(10)
        # if it is 'q', we quit
        if k == ord('q'):
            break
    # there is no image
    else:
        print('ERROR ---> Camera not found!')

# we close all windows
cv2.destroyAllWindows()
```

```
Statistics: min, max, mean, stddev --->  0 221 121.81957139756945 33.391712692708815
Statistics: min, max, mean, stddev --->  0 217 121.92159505208333 33.3514742402933
Statistics: min, max, mean, stddev --->  0 221 121.96024848090278 33.34492241090537
Statistics: min, max, mean, stddev --->  0 217 121.95812825520834 33.36773861152294
Statistics: min, max, mean, stddev --->  0 223 121.9390603298611 33.327133106727736
```

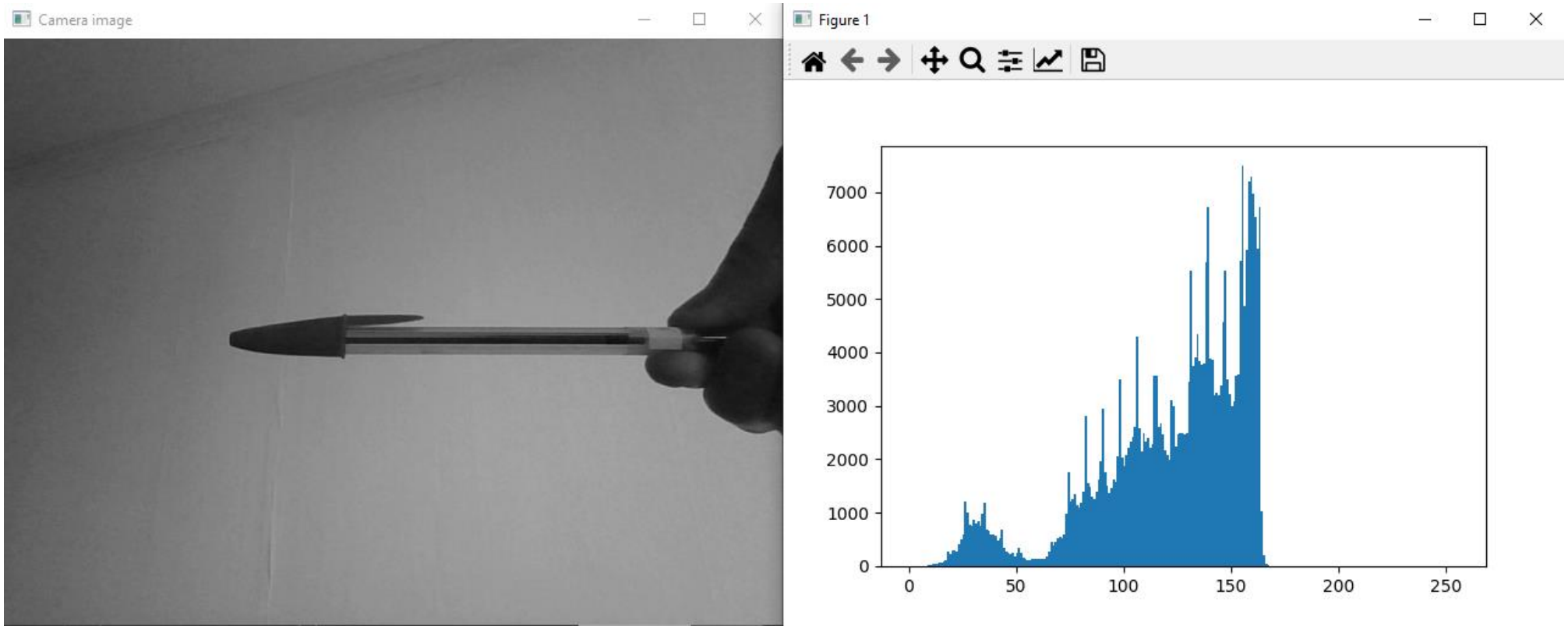
8) EXTRACT INFORMATION

improc-0081.py > ...

```python
# we import all libraries used in our program
import cv2
import numpy
from matplotlib import pyplot as plt
# Initialize Camera
cap = cv2.VideoCapture(0)
ret, frame = cap.read()
# infinite loop
while True:
    ret, frame = cap.read()
    if ret:
        frame = cv2.flip(frame, flipCode = 1)
        frame = cv2.cvtColor(frame, cv2.COLOR_BGR2GRAY)
        plt.hist(frame.ravel(),256,[0,256])
        plt.show()
        # we display it
        cv2.imshow('Camera image', frame)
        # we wait for a key pressed
        k = cv2.waitKey(10)
        # if it is 'q', we quit
        if k == ord('q'):
            break
    # there is no image
    else:
        print('ERROR ---> Camera not found!')

# we close all windows
cv2.destroyAllWindows()
```



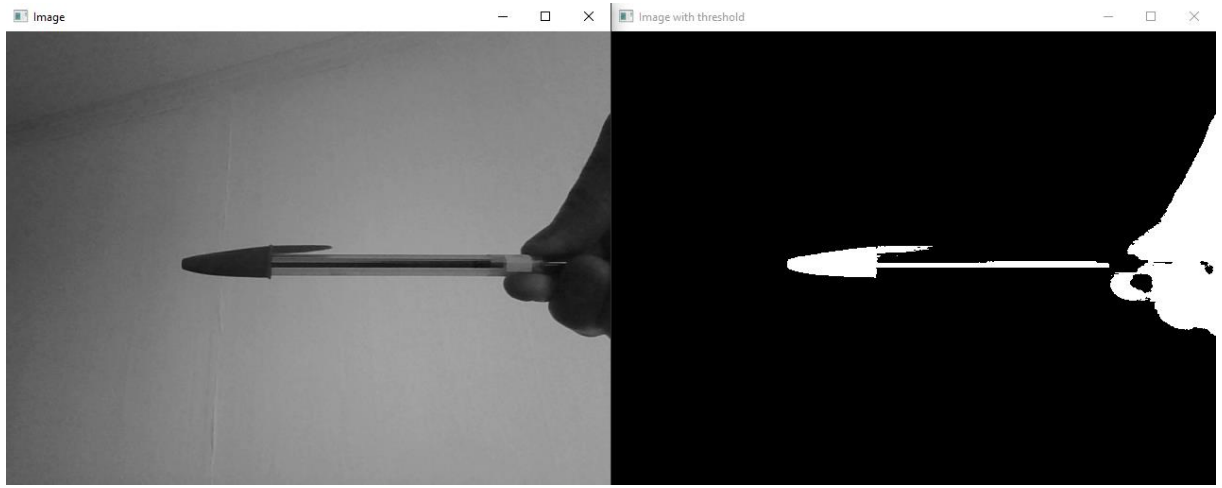
8) EXTRACT INFORMATION



8) EXTRACT INFORMATION

improc-0082.py > ...

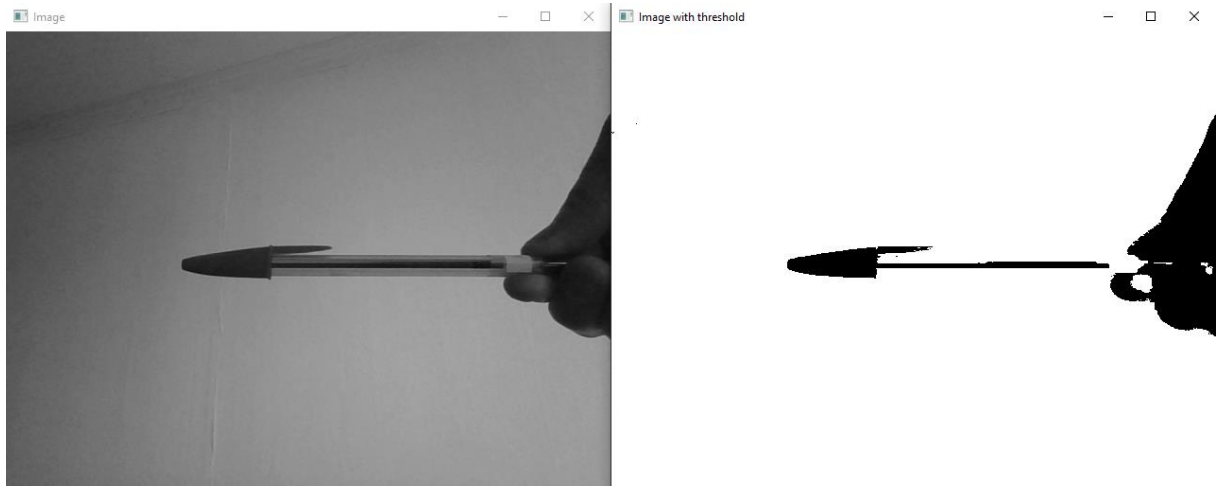
```
5    # we load the image
6    img = cv2.imread('penna.bmp')
7    print('Shape: ', img.shape)
8    # infinite loop
9    frame = cv2.cvtColor(img, cv2.COLOR_BGR2GRAY)
10   plt.hist(frame.ravel(),256,[0,256])
11   plt.show()
12
13   frameThreshold = ((frame<56).astype(numpy.uint8))*255
14   print(frameThreshold)
15   # we display it
16   cv2.imshow('Image', frame)
17   cv2.imshow('Image with threshold', frameThreshold)
18
19   # we wait for a key pressed
20   k = cv2.waitKey(0)
21
22   # we close all windows
23   cv2.destroyAllWindows()
24
```



8) EXTRACT INFORMATION

improc-0083.py > ...

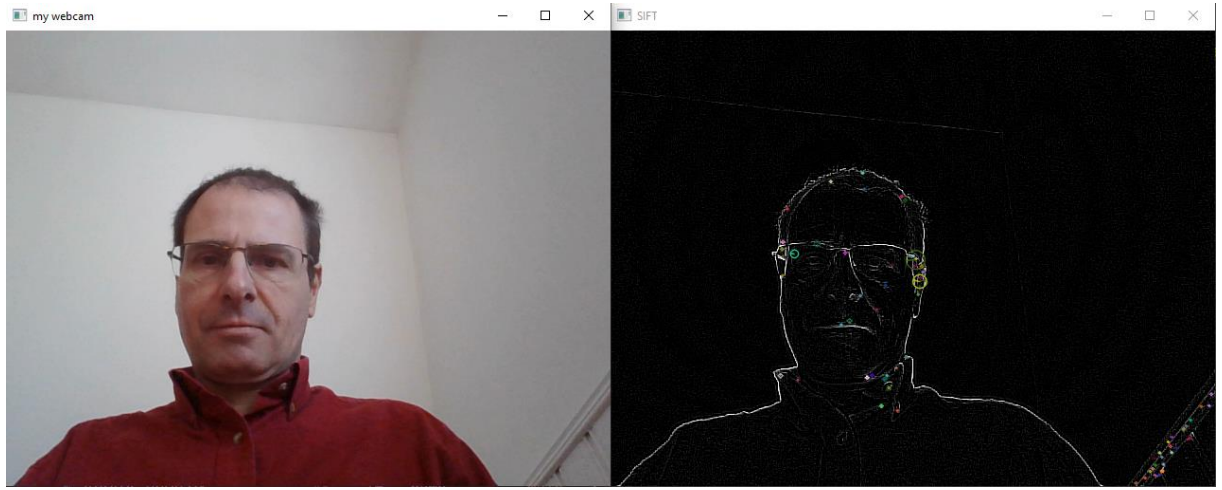
```python
# we import all libraries used in our program
import cv2
import numpy
from matplotlib import pyplot as plt
# we load the image
img = cv2.imread('penna.bmp')
print('Shape: ', img.shape)
# infinite loop
frame = cv2.cvtColor(img, cv2.COLOR_BGR2GRAY)
plt.hist(frame.ravel(),256,[0,256])
plt.show()

frameThreshold = ((frame>56).astype(numpy.uint8))*255
print(frameThreshold)
# we display it
cv2.imshow('Image', frame)
cv2.imshow('Image with threshold', frameThreshold)

# we wait for a key pressed
k = cv2.waitKey(0)

# we close all windows
cv2.destroyAllWindows()

```



8) EXTRACT INFORMATION

improc-0110.py > show_webcam

```python
import cv2
import numpy
def show_webcam(mirror=False):
    ddepth = cv2.CV_8U
    kernel_size = 3
    cam = cv2.VideoCapture(0)
    while True:
        ret_val, img = cam.read()
        imgSift = img.copy()
        gray = cv2.cvtColor(img,cv2.COLOR_BGR2GRAY)
        grayLaplace = cv2.Laplacian(gray, ddepth, ksize=kernel_size)

        # Applying SIFT detector
        sift = cv2.SIFT_create()
        kp, descriptor = sift.detectAndCompute(grayLaplace, None)

        # Marking the keypoint on the image using circles
        imgSift=cv2.drawKeypoints(grayLaplace,
                                  kp ,
                                  imgSift,
                                  flags=cv2.DRAW_MATCHES_FLAGS_DRAW_RICH_KEYPOINTS)
        if mirror:
            img = cv2.flip(img, 1)
            imgSift = cv2.flip(imgSift, 1)
        cv2.imshow('my webcam', img)
        cv2.imshow('SIFT', imgSift)
        if cv2.waitKey(1) == 27:
            break  # esc to quit
    cv2.destroyAllWindows()
def main():
    show_webcam(mirror=True)
if __name__ == '__main__':
    main()
```



8) EXTRACT INFORMATION

improc-0111.py > ...

```python
import cv2
def show_webcam(mirror=False):
    cam = cv2.VideoCapture(0)
    while True:
        ret_val, img = cam.read()
        imgSift = img.copy()
        gray= cv2.cvtColor(img,cv2.COLOR_BGR2GRAY)
        # Applying SIFT detector
        sift = cv2.SIFT_create()
        kp = sift.detect(gray, None)
        # Marking the keypoint on the image using circles
        imgSift=cv2.drawKeypoints(gray,
                                  kp,
                                  imgSift,
                                  flags=cv2.DRAW_MATCHES_FLAGS_DRAW_RICH_KEYPOINTS)
        if mirror:
            img = cv2.flip(img, 1)
            imgSift = cv2.flip(imgSift, 1)
        cv2.imshow('my webcam', img)
        cv2.imshow('SIFT', imgSift)
        if cv2.waitKey(1) == 27:
            break  # esc to quit
    cv2.destroyAllWindows()
def main():
    show_webcam(mirror=True)
if __name__ == '__main__':
    main()

```

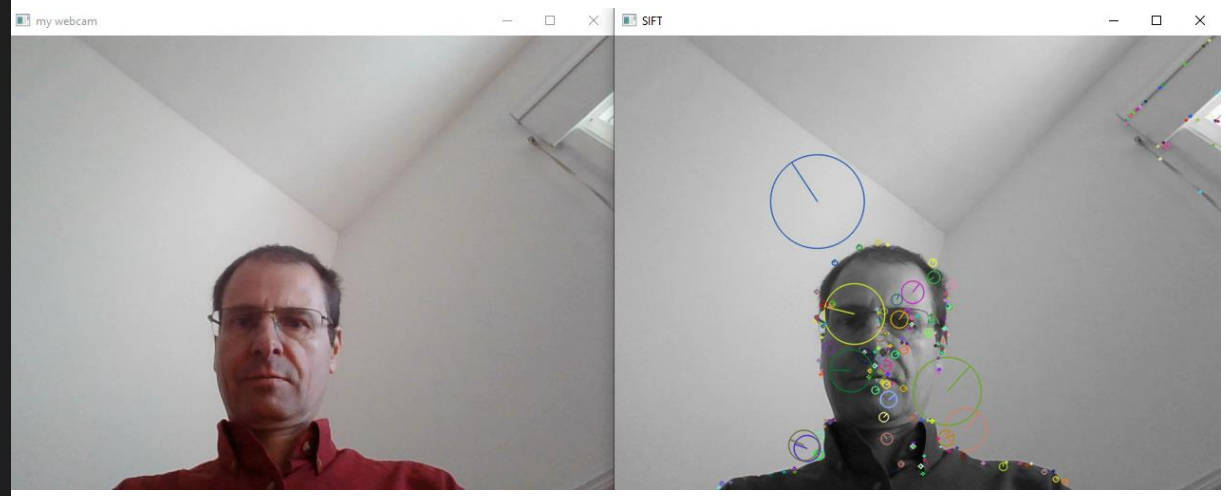


Image registration:
https://learnopencv.com/image-alignment-feature-based-using-opencv-c-python/

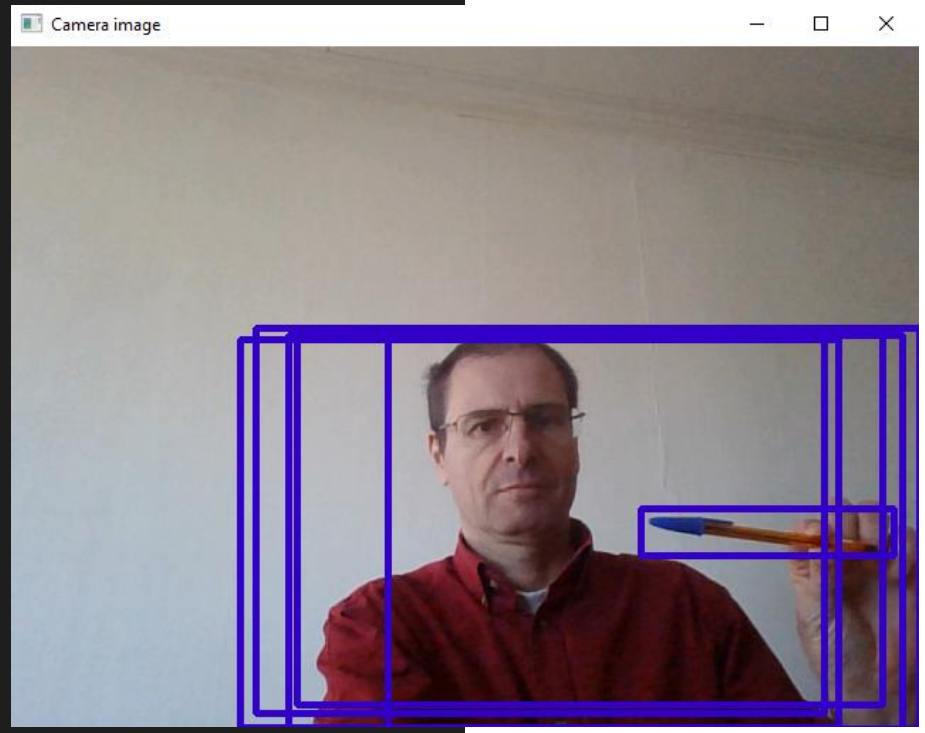
9) MACHINE LEARNING

- In order to find objects in images, you can use pre-trained machine learning algorithms (or train them yourself)
- To use these tools, you must have a powerful computer (GPU processing)
- In order to boost performances, you must program in C++ instead of Python

9) MACHINE LEARNING

improc-0099-model.py > ...

```python
import cv2
# OpenCV DNN
#source: https://github.com/patrick013/Object-Detection---Yolov3/blob/master/model/yolov3.weights
#another source: https://learnopencv.com/deep-learning-based-object-detection-using-yolov3-with-opencv-python-c/
net = cv2.dnn.readNet('model/yolov3.weights', 'model/yolov3.cfg')
net.setPreferableBackend(cv2.dnn.DNN_BACKEND_CUDA)
net.setPreferableTarget(cv2.dnn.DNN_TARGET_CUDA_FP16)
model = cv2.dnn_DetectionModel(net)
model.setInputParams(size=(320, 320), scale=1/255, swapRB=True)
# Initialize Camera
cap = cv2.VideoCapture(0)
while True:
    ret, frame = cap.read()
    if ret:
        (class_ids, scores, bboxes) = model.detect(frame)
        for class_id, score, bbox in zip(class_ids, scores, bboxes):
            (x, y, w, h) = bbox
            cv2.rectangle(frame, (x, y), (x+w, y+h), (200, 0, 50), 3)
        cv2.imshow('Camera image', frame)
        k = cv2.waitKey(100)
        if k==ord('q'):
            break
    else:
        print('ERROR ---> Camera not found!')

cv2.destroyAllWindows()
```



10) USEFUL TOOLS

- You can get important information about your OpenCV version
- You can also use keys and mouse events onto your images

10) USEFUL TOOLS

improc-0100.py > ...

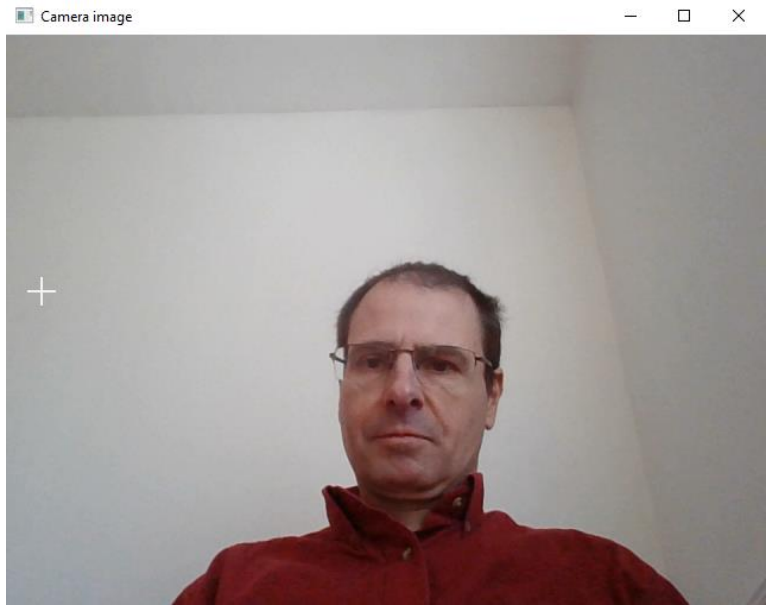
```python
# we import all libraries used in our program
import cv2
import datetime
print("---> OpenCV version : {0}".format(cv2.__version__))
# Initialize Camera
cap = cv2.VideoCapture(0)
# infinite loop
while True:
    # we read an image from the camera
    ret, frame = cap.read()
    # there is an image
    if ret:
        frame = cv2.flip(frame, flipCode = 1)
        # we display it
        cv2.imshow('Camera image', frame)
        # we wait for a key pressed
        k = cv2.waitKey(10)
        # if it is 'q', we quit
        if k == ord('q'):
            break
        if k == ord('s'):
            x = datetime.datetime.now()
            filenameRGB = 'outRGB'+str(x.year)+str(x.month)+
            str(x.day)+str(x.hour)+str(x.minute)+str(x.second)+'.png'
            cv2.imwrite(filenameRGB, frame)
            print('Image ', filenameRGB, ' saved...')
    # there is no image
    else:
        print('ERROR ---> Camera not found!')

# we close all windows
cv2.destroyAllWindows()
```

```
PS C:\Users\lanjer\Desktop\ju2022\teaching\COURSES\semester2\intelligent-mobile-platform\cours-jerome\code> python .\improc
-0100.py
---> OpenCV version : 4.7.0
Image  outRGB202341714158.png  saved...
Image  outRGB20234171420.png  saved...
Image  outRGB20234171422.png  saved...
PS C:\Users\lanjer\Desktop\ju2022\teaching\COURSES\semester2\intelligent-mobile-platform\cours-jerome\code>
```

10) USEFUL TOOLS

improc-0101.py > ...

```python
import cv2
import datetime
print("---> OpenCV version : {0}".format(cv2.__version__))
#source: https://thinkinfi.com/detect-mouse-click-events-with-python-opencv/
listPoints = []
def mousePoints(event,x,y,flags,params):
    global listPoints
    # Left button mouse click event opencv
    if event == cv2.EVENT_LBUTTONDOWN:
        listPoints.append([x, y])
        print(listPoints)
# Initialize Camera
cap = cv2.VideoCapture(0)
# infinite loop
while True:
    ret, frame = cap.read()
    if ret:
        frame = cv2.flip(frame, flipCode = 1)
        cv2.imshow('Camera image', frame)
        cv2.setMouseCallback("Camera image", mousePoints)
        k = cv2.waitKey(10)
        if k == ord('q'):
            break
        if k == ord('s'):
            x = datetime.datetime.now()
            filenameRGB = 'outRGB'+str(x.year)+str(x.month)+str(x.day)+str(x.hour)+str(x.minute)+str(x.second)+'.png'
            cv2.imwrite(filenameRGB, frame)
            print('Image ', filenameRGB, ' saved...')
    # there is no image
    else:
        print('ERROR ---> Camera not found!')
# we close all windows
cv2.destroyAllWindows()
```




```
---> OpenCV version : 4.7.0
[[217, 160]]
[[217, 160], [476, 229]]
[[217, 160], [476, 229], [515, 337]]
[[217, 160], [476, 229], [515, 337], [187, 395]]
[[217, 160], [476, 229], [515, 337], [187, 395], [30, 216]]
```

MORE INFORMATION

- Official OpenCV documentation: https://docs.opencv.org/
- GeeksforGeeks OpenCV Python tutorial: https://www.geeksforgeeks.org/opencv-python-tutorial/
- Learn OpenCV: https://learnopencv.com
- PyImageSearch: https://pyimagesearch.com/

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