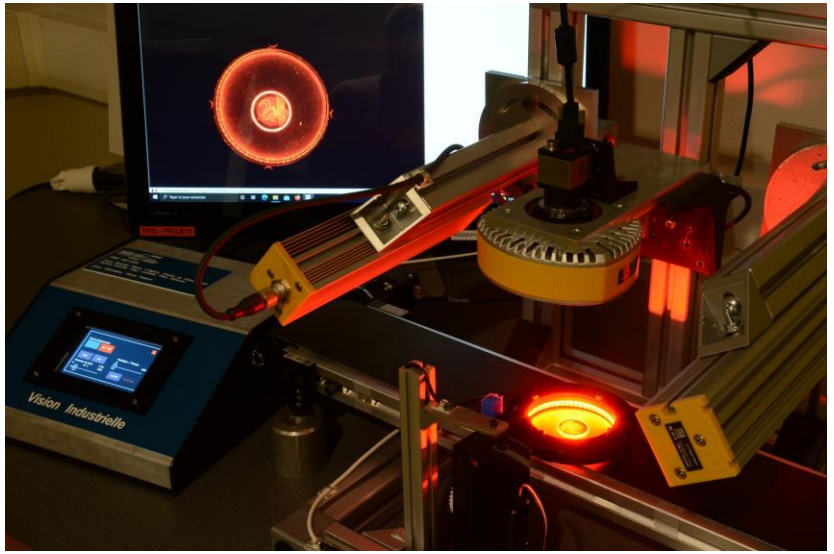
INSTITUT d'OPTIQUE GRADUATE SCHOOL | Continuing Education

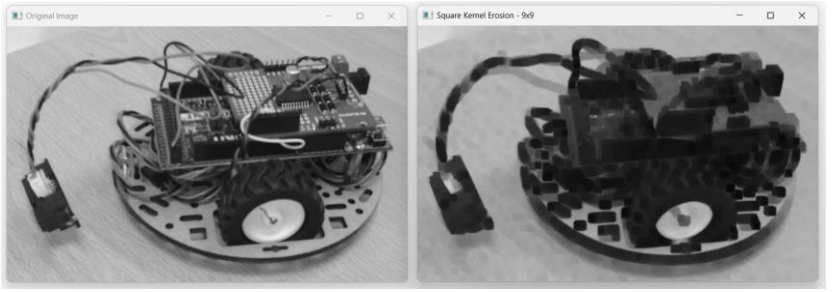
Formation Continue

SC 19 – Machine Vision

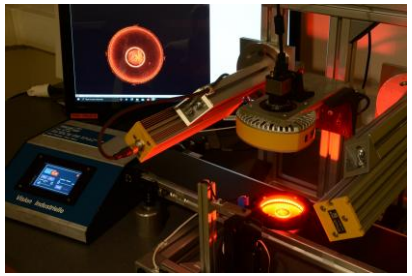
Image Processing

Julien VILLEMEJANE





INSTITUT d'OPTIQUE GRADUATE SCHOOL | Continuing Education | Formation Continue



SC19 – Image Processing

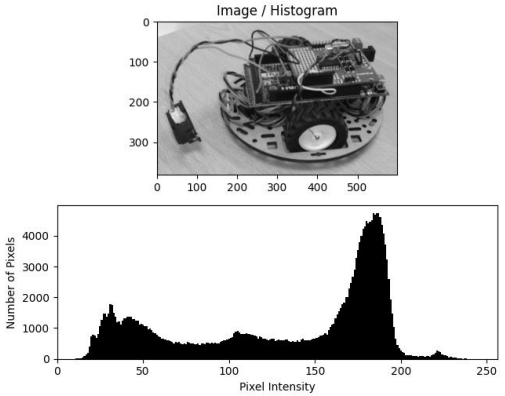
- At the end of this training, the learners will be able to:

Use basic building blocks of OpenCV

Open an image
Create the histogram of an image

Apply basic transforms on images
- blur, filters
- erosion, dilation, opening, closing

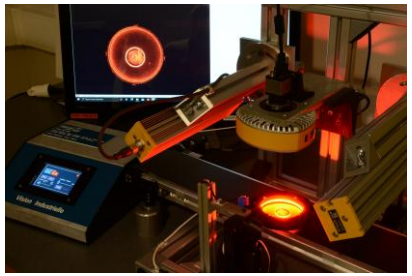
Display the contour of objects



LEnsE.TECH

https://iogs-lense-training.github.io/image-processing/

INSTITUT d'OPTIQUE GRADUATE SCHOOL | Continuing Education | Formation Continue



SC19 – Image Processing

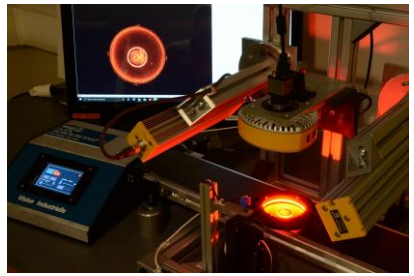
What is image processing for ?

Why is image processing required in a machine vision chain ?
For industrial inspection applications ?

What are the **main processes** ?
What is the goal of each of them ?
What is the ideal **workflow** ?

https://www.youtube.com/@firstprinciplesofcomputerv3258

INSTITUT d'OPTIQUE GRADUATE SCHOOL | Continuing Education | Formation Continue



SC19 – Image Processing

Goal of processing an image

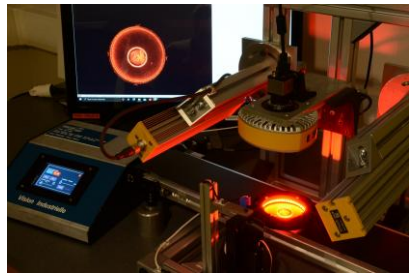
Image from the camera

- **Noise**
- Bad contrast
- Inhomogeneous Lighting
- …

Desired image with objects with **well-defined contours**

- Homogeneous zones
- Transition zones

INSTITUT d'OPTIQUE GRADUATE SCHOOL | Continuing Education | Formation Continue



SC19 – Image Processing

Steps for processing an image

Acquisition

Light, Camera…

Pre Processing

Noise Reduction / Filtering
Contrast Enhancement
Normalization

Ensuring clarity and reducing unwanted information
Making features of interest stand out
Standardizing the image scale or intensity

Segmentation

Thresholding
Edge Detection
Region of Interest Selection

Isolating objects of ROI / Separating product from background
Identifying boundaries and contours
Focusing only on relevant portions of the image

Feature Extraction

Geometric Features
Texture Analysis
Color Analysis

Extracting measurements (size, shape, position…)
Recognizing patterns, symbols, points of interest

Classification

Object detection
Template Matching
Classification

Identifying and labelling objects
Checking correct shape, size or orientation
Categorizing objects to specific groups (defective or non-def.)

Decision

Tolerances, pass/fail, real-time feedback…

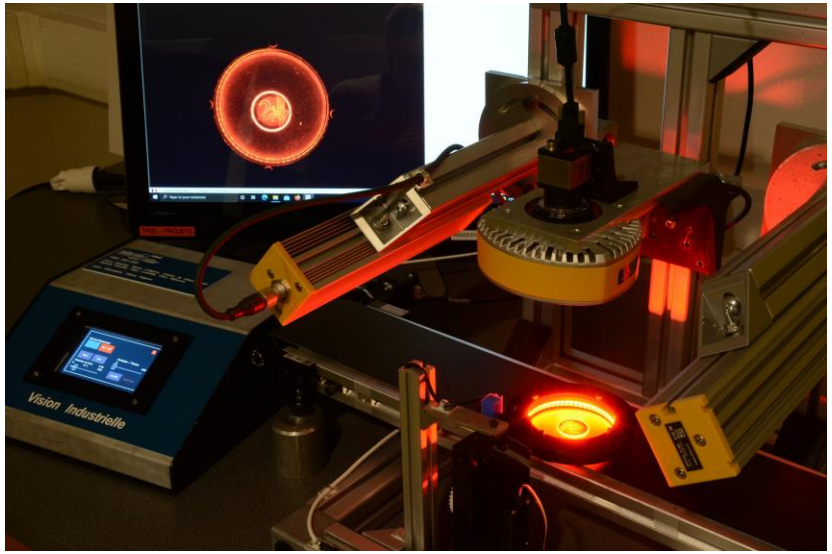
INSTITUT d'OPTIQUE GRADUATE SCHOOL | Continuing Education
Formation Continue

OpenCV

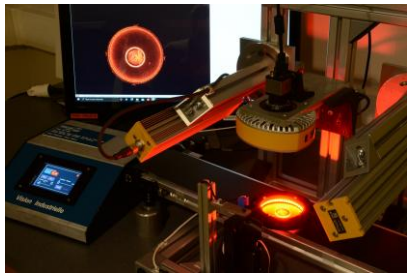
SC 19 – Machine Vision

Image Processing
with OpenCV

Julien VILLEMEJANE



INSTITUT d'OPTIQUE GRADUATE SCHOOL | Continuing Education | Formation Continue



SC19 – Image Processing

What is OpenCV ?

Open Source Computer Vision Library

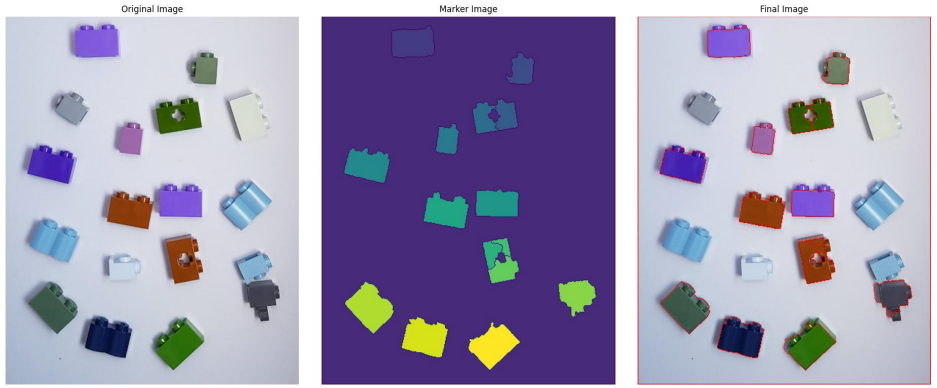
An open source **computer vision** and machine learning software **library**

supporting multiple programming languages such as Python, C++, Java, and MATLAB

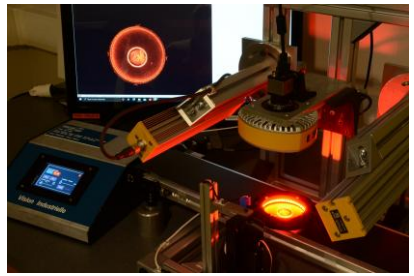
OpenCV

https://opencv.org

Image Processing	*Filtering, Edge detection, Image transformations…*
Object Recognition	*Detecting objects in images and videos*
CV Algorithms	*Motion tracking, 3D reconstruction, Augmented reality*
Machine Learning	*Image classification, Pattern recognition, Scene Understanding*



INSTITUT d'OPTIQUE GRADUATE SCHOOL | Continuing Education | Formation Continue



SC19 – Image Processing

Installation of OpenCV

Installing OpenCV for Python 3

```
pip install opencv-python
```

Testing OpenCV importation in a script

```
import cv2
Cv2.__version__
```

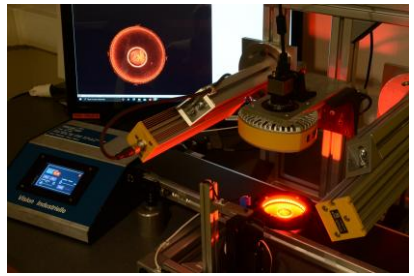
OpenCV

https://opencv.org

LEnsE.TECH

https://iogs-lense-training.github.io/image-processing/

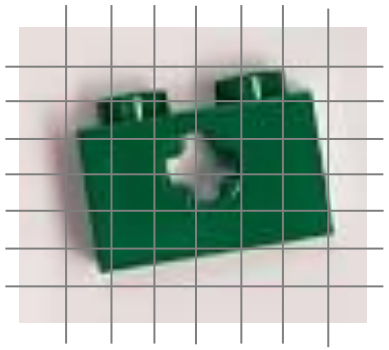
INSTITUT d'OPTIQUE GRADUATE SCHOOL | Continuing Education | Formation Continue



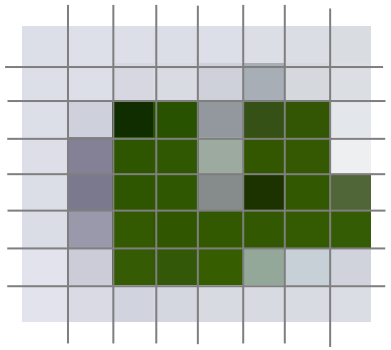
SC19 – Image Processing

Digital Images

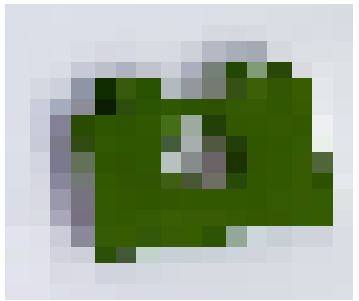
Continuous image



Digital image : projection of the continuous image



8 x 8 grid



16 x 16 grid

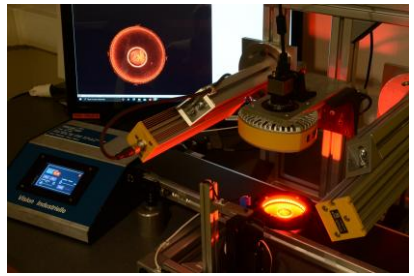
32 x 32 grid

Digital Image

Picture represented in **numerical form**

*so that it can be **stored**, **processed**, and **displayed** by a computer or digital device.*

INSTITUT d'OPTIQUE GRADUATE SCHOOL | Continuing Education | Formation Continue

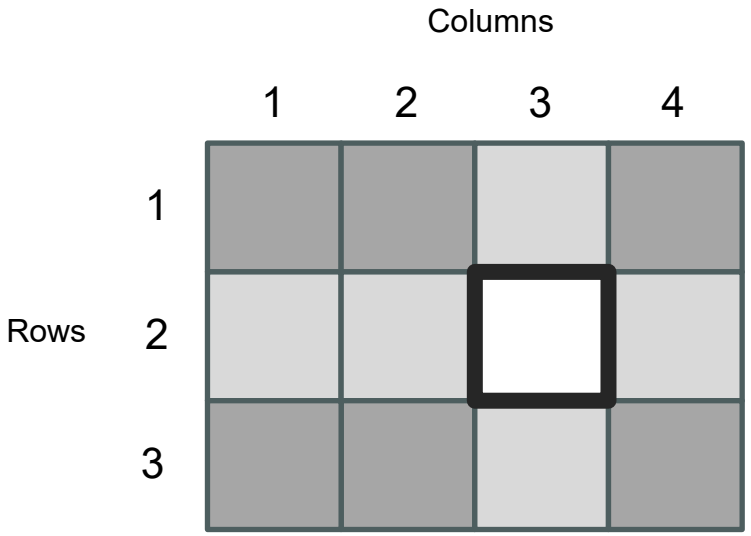


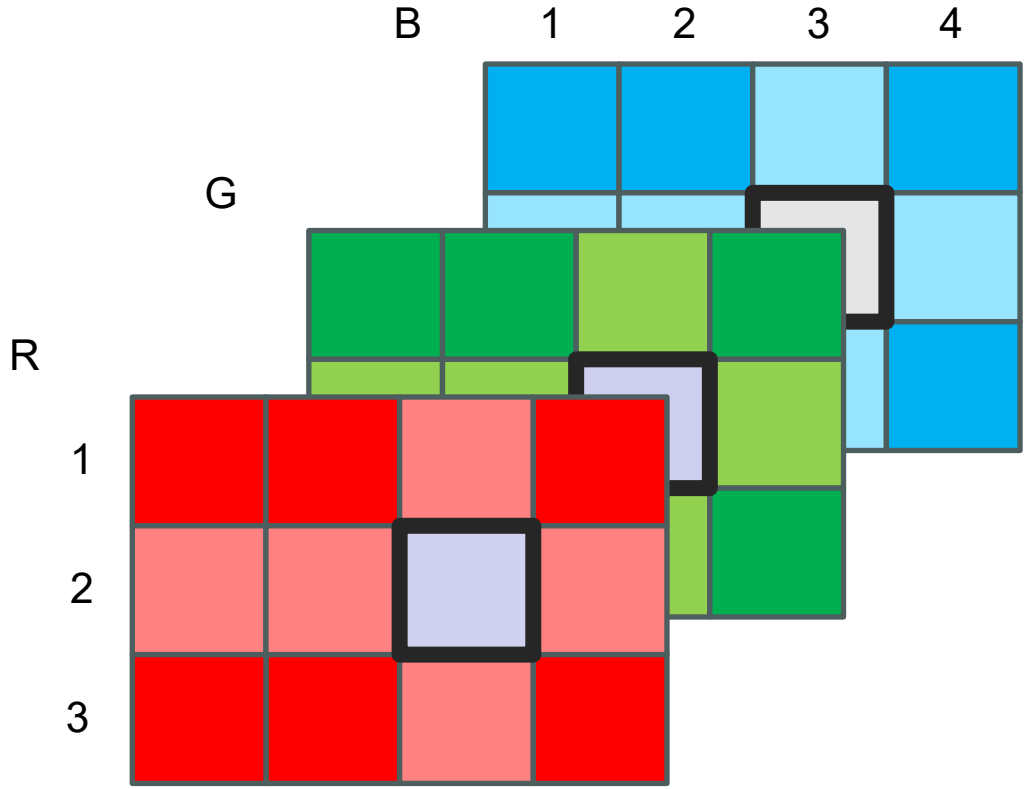
SC19 – Image Processing

Digital Images

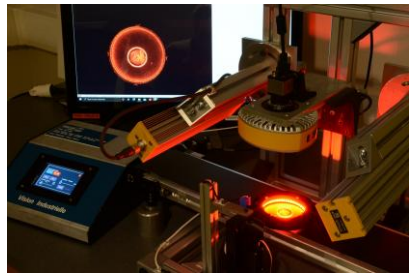
Nb of pixels = h x v

GrayScale





INSTITUT d'OPTIQUE GRADUATE SCHOOL | Continuing Education | Formation Continue

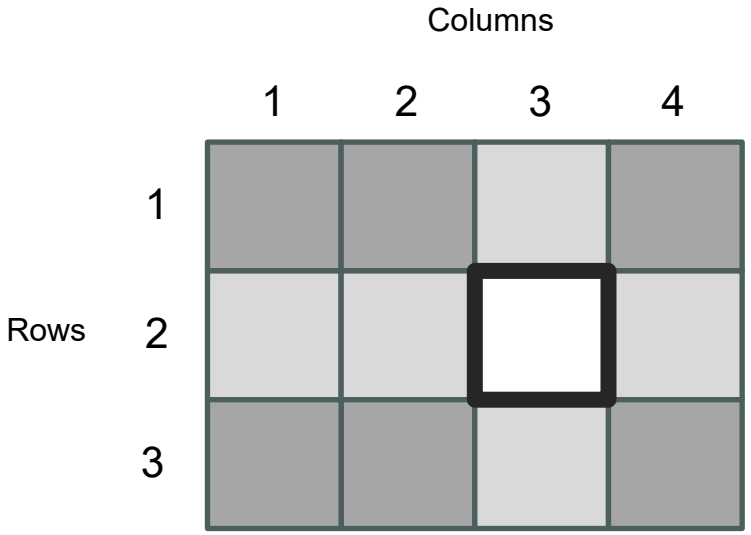


SC19 – Image Processing

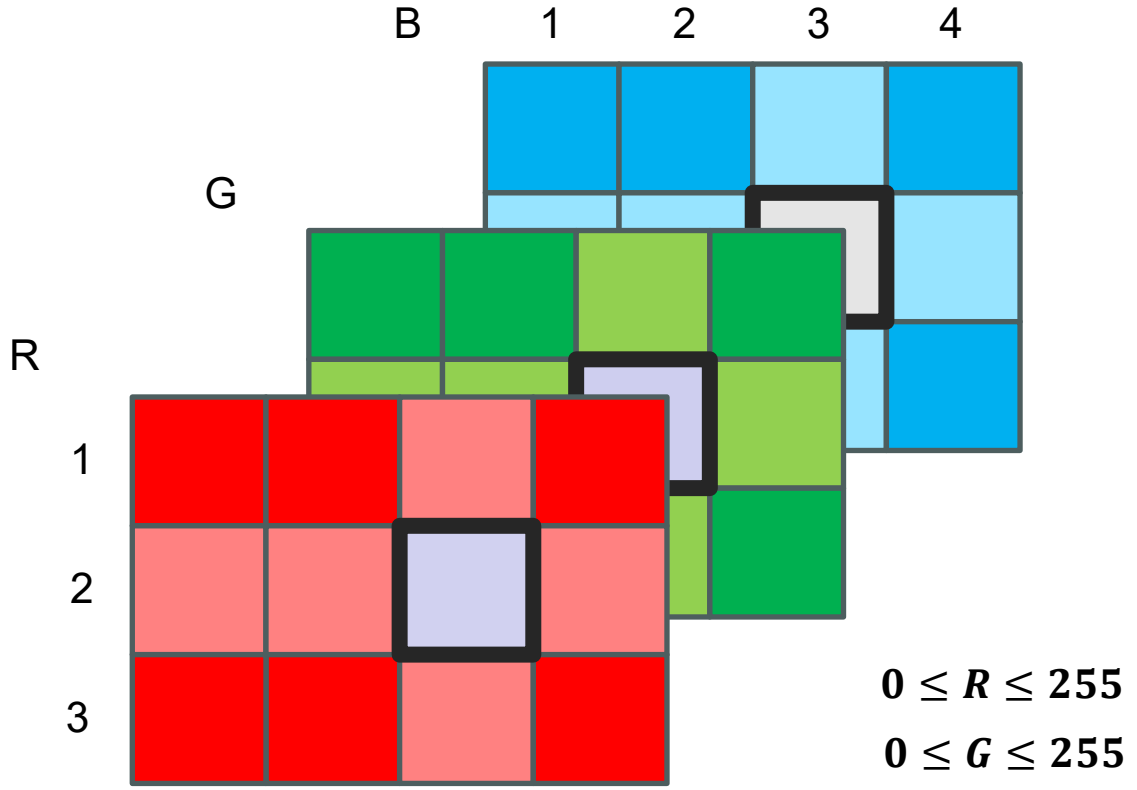
Digital Images / RGB

Nb of pixels = h x v

GrayScale



Each pixel is converted into **n bits**.

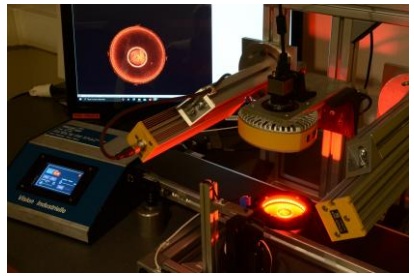


RGB : 3 channels of 8 bits

$$0 \leq R \leq 255$$
$$0 \leq G \leq 255$$
$$0 \leq B \leq 255$$

R=200, G=100, G=50

INSTITUT d'OPTIQUE GRADUATE SCHOOL | Continuing Education | Formation Continue

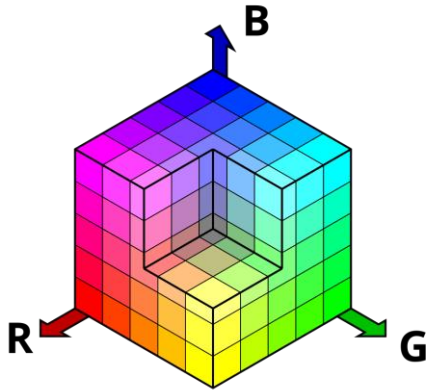


SC19 – Image Processing

Digital Images / Color spaces

RGB

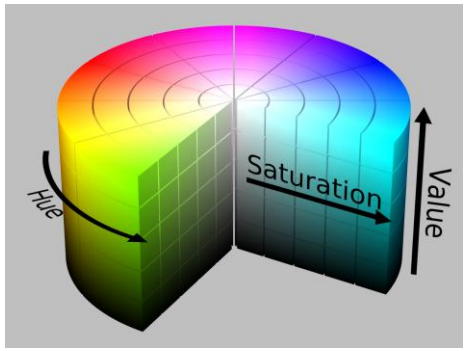
Used primarily in **electronic displays** like computer screens, cameras, and scanners. The combination of these three primary colors at various intensities can produce any color.



HSV

Used in **image editing**. It separates image's color from its brightness.

Hue : type of color
Saturation : intensity of the color
Value : Brightness of the color



CMYK

LAB

YUV

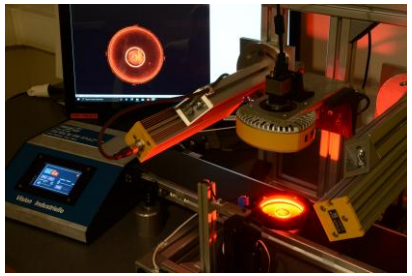
Color Space

Model for **representing colors** in a consistent and reproducible way

Each color space uses a different method for organizing and describing color, depending on the purpose or application

Images Source : Wikipedia

INSTITUT d'OPTIQUE GRADUATE SCHOOL | Continuing Education | Formation Continue



SC19 – Image Processing

Digital Images / Color spaces

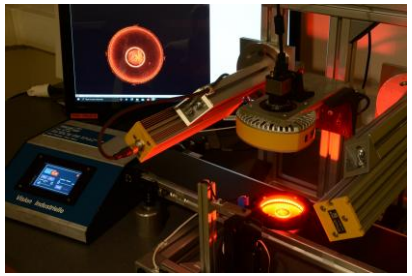
Table 9 from
Segmentation of Images by Color Features: A Survey - Scientific Figure on ResearchGate. Available from: https://www.researchgate.net/figure/Advantages-and-disadvantages-of-color-spaces_tbl7_323632019 [accessed 10 Oct 2024]

Color Space

Model for **representing colors** in a consistent and reproducible way

Color space	Advantages	Disadvantages
RGB	Convenient for image acquisition and displaying;	Non-uniform illumination sensitive; Differences between colors is not linear
HSV, HSI	Based on human color perception; Robust before non-uniform illumination; The chromaticity is decoupled from the intensity	Non removable singularities
L*a*b*, L*u*v*	Efficient in measuring small color difference; The chromaticity is decoupled from the intensity;	Singularity problem as other nonlinear transformations
YUV, YCbCr	Efficient coding color information for TV signal.	Due to the linear transformation, correlation between the component channels exists, although not as high as the RGB space

INSTITUT d'OPTIQUE GRADUATE SCHOOL | Continuing Education — Formation Continue



SC19 – Image Processing

OpenCV / Open and display an image

Acquisition

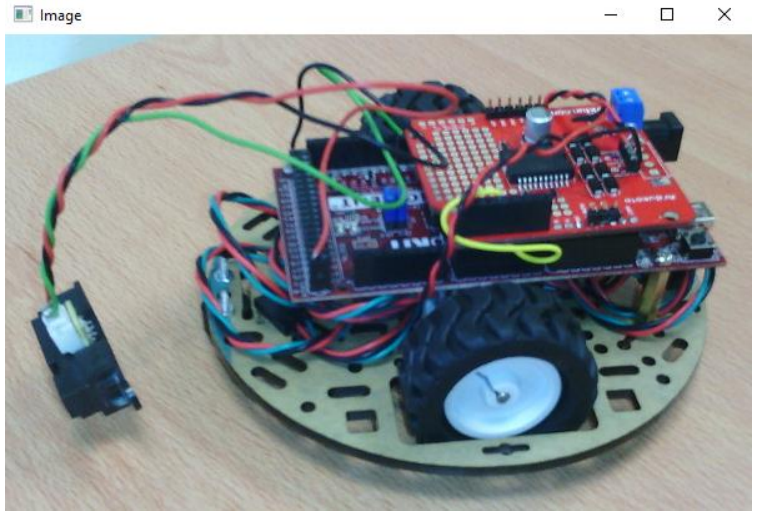
```
import cv2

image_rgb = cv2.imread('path/to/image.png')
image_gray = cv2.imread('path/to/image.png', cv2.IMREAD_GRAYSCALE)
```

```
image = cv2.imread("../../_data/robot.pgm")
print(type(image))
```

```
<class 'numpy.ndarray'>
```

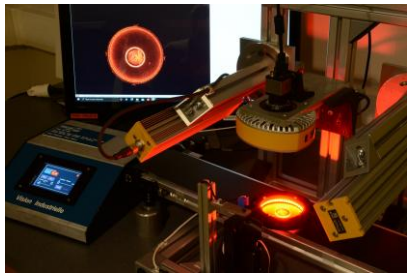
```
print(image.shape)
```

```
(382, 600, 3)
```




```
cv2.imshow('Image ', image_rgb)
cv2.waitKey(0)
```

INSTITUT d'OPTIQUE GRADUATE SCHOOL | Continuing Education | Formation Continue



SC19 – Image Processing

Pre-processing

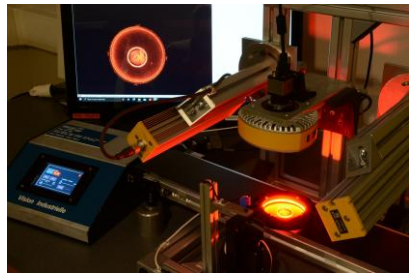
Acquisition

Pre Processing

Noise Reduction / Filtering
Contrast Enhancement
Normalization

Ensuring clarity and reducing unwanted information
Making features of interest stand out
Standardizing the image scale or intensity

INSTITUT d'OPTIQUE GRADUATE SCHOOL | Continuing Education — Formation Continue

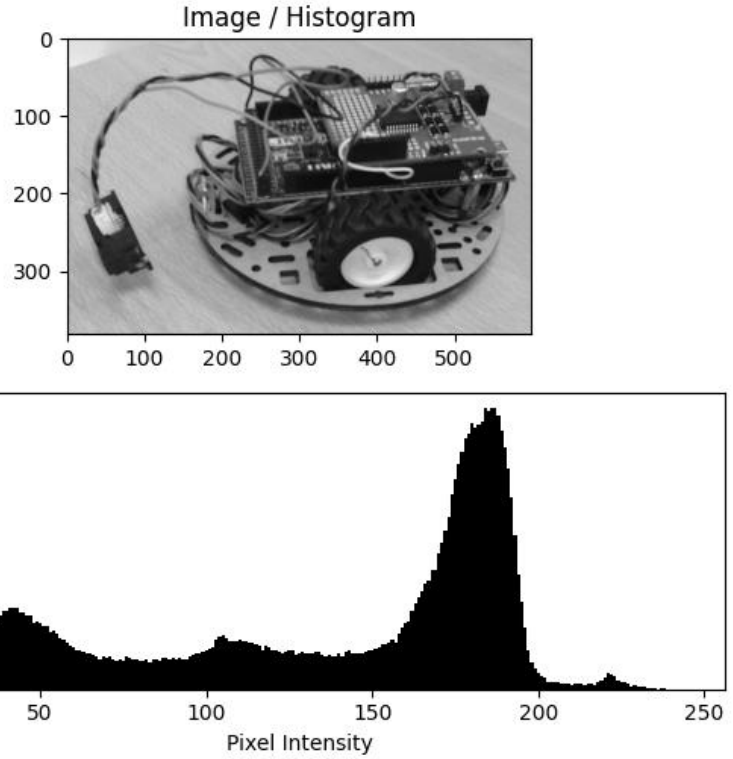


SC19 – Image Processing

OpenCV / Histogram of an image

Acquisition

Pre Processing



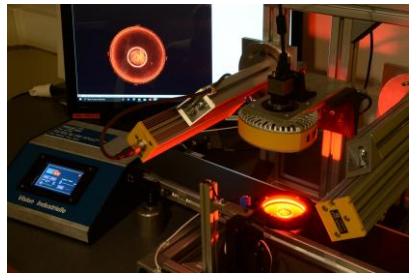
Histogram

Graphical representation that shows the **distribution of pixel intensity values** in an image

cv2.**calcHist**([image], [chan], Mask, [bins_nb], [min, max])

```
histogram = cv2.calcHist([image], [0], None, [256], [0, 256])
```

INSTITUT d'OPTIQUE GRADUATE SCHOOL | Continuing Education | Formation Continue

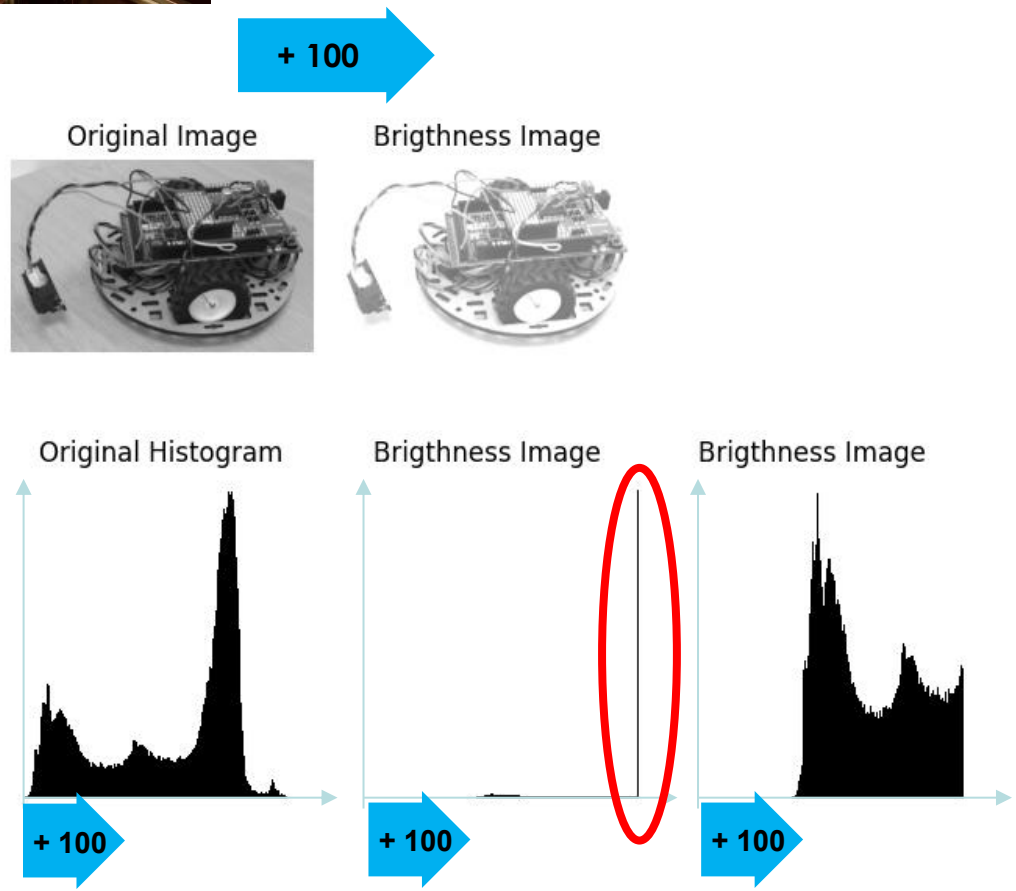


SC19 – Image Processing

OpenCV / Contrast and Brightness

Acquisition

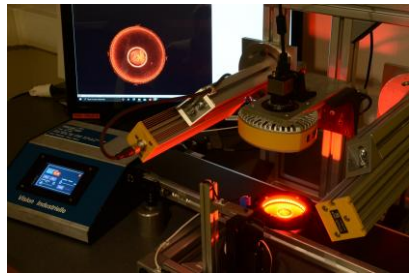
Pre Processing




```
new_img = cv2.convertScaleAbs(image, beta=100)
```

INSTITUT d'OPTIQUE GRADUATE SCHOOL | Continuing Education

Formation Continue



SC19 – Image Processing

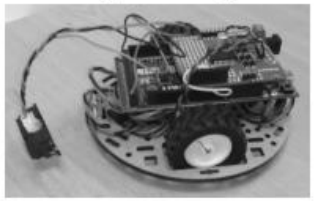
OpenCV / Contrast and Brightness

Acquisition

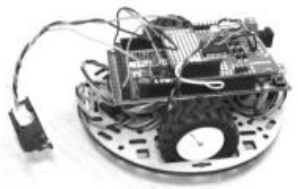
Pre Processing

x 1.5

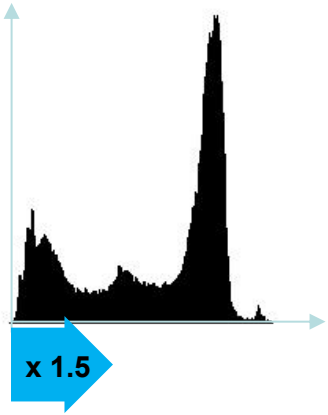
Original Image



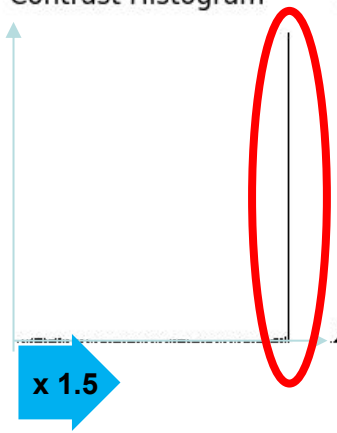
Contrast Image



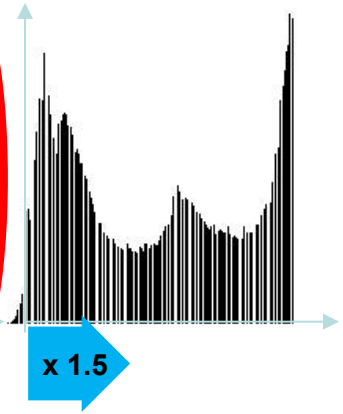
Original Histogram



Contrast Histogram

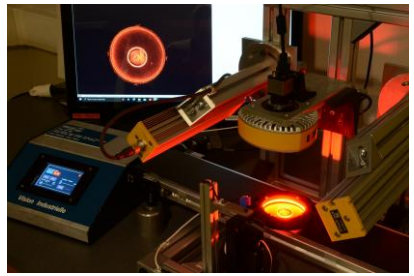


Contrast Histogram




```
new_img = cv2.convertScaleAbs(image, alpha=1.5)
```

INSTITUT d'OPTIQUE GRADUATE SCHOOL | Continuing Education | Formation Continue



SC19 – Image Processing

OpenCV / Convolution

Acquisition

Pre Processing

Convolution (filter)

kernel

-1	0	-2
1	5	1
-2	0	-1

original image

5	8	4	2	3	1	5
9	5	1	8	7	6	2
5	7	1	5	6	8	7
5	8	2	8	4	3	3
5	6	6	7	2	5	1

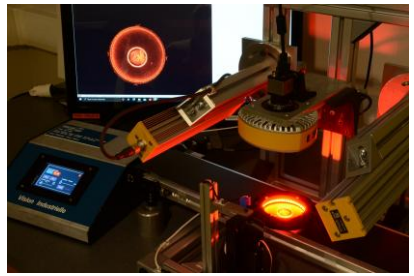
5	8	4	2	3	1	5
9	5	1	8 x -1	7 x 0	6 x -2	2
5	7	1	5 x 1	6 x 5	8 x 1	7
5	8	2	8 x -2	4 x 0	3 x -1	3
5	6	6	7	2	5	1

R = -8 + 0 – 12 + 5 + 30 + 8 – 16 + 0 – 3
R = 4

filtered image

				4		

INSTITUT d'OPTIQUE GRADUATE SCHOOL | Continuing Education Formation Continue



SC19 – Image Processing

OpenCV / Convolution Kernel

Acquisition

Pre Processing

kernel = cv2.***getStructuringElement***(cv2.MORPH_xx, (M,N))

Cross Kernel

0	0	1	0	0
0	0	1	0	0
1	1	1	1	1
0	0	1	0	0
0	0	1	0	0

cv2.**MORPH_CROSS**

Rect Kernel

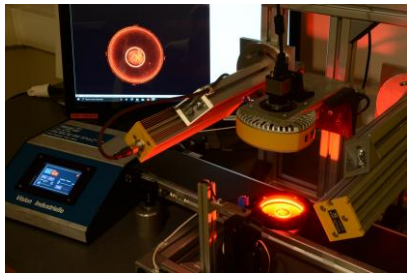
1	1	1	1	1
1	1	1	1	1
1	1	1	1	1
1	1	1	1	1
1	1	1	1	1

cv2.**MORPH_RECT**

INSTITUT d'OPTIQUE GRADUATE SCHOOL | Continuing Education | Formation Continue

SC19 – Image Processing

OpenCV / Erosion and Dilation

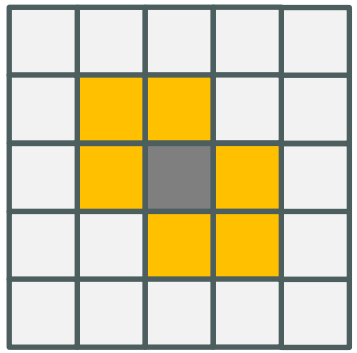


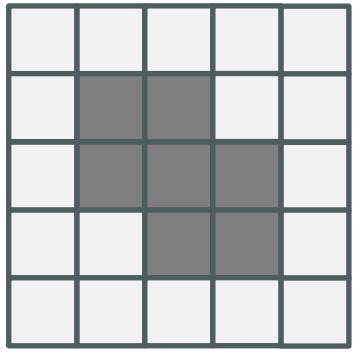
Acquisition

Pre Processing

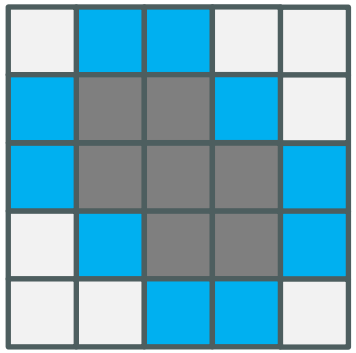
Original pixels

Removed pixels





Added pixels



kernel

0	1	0
1	1	1
0	1	0

Erosion

Shrinking the foreground by **removing pixels** to the boundaries of objects

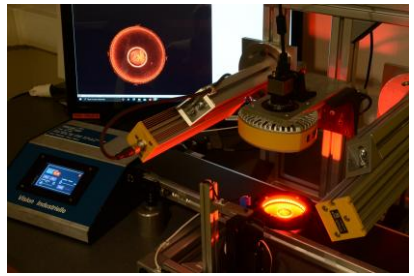
https://www.youtube.com/watch?v=fmyE7DiaIYQ

Dilation

Enlarging the foreground by **adding pixels** to the boundaries of objects

https://www.youtube.com/watch?v=xO3ED27rMHs

INSTITUT d'OPTIQUE GRADUATE SCHOOL | Continuing Education | Formation Continue



SC19 – Image Processing

OpenCV / Erosion and Dilation

Acquisition

Pre Processing

kernel

0	1	0
1	1	1
0	1	0

Erosion

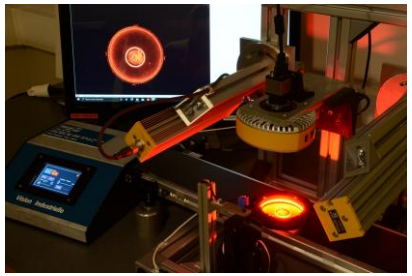
Shrinking the foreground by **removing pixels** to the boundaries of objects

Dilation

Enlarging the foreground by **adding pixels** to the boundaries of objects

```
eroded_image = cv2.erode(image, kernel, iterations=1)
dilated_image = cv2.dilate(image, kernel, iterations=1)
```

INSTITUT d'OPTIQUE GRADUATE SCHOOL | Continuing Education | Formation Continue



SC19 – Image Processing

OpenCV / Opening and Closing

morphological transforms

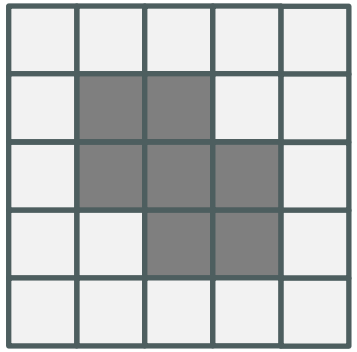
Acquisition

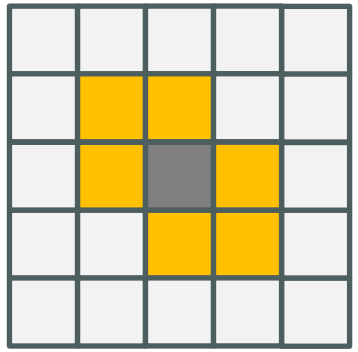
Pre Processing

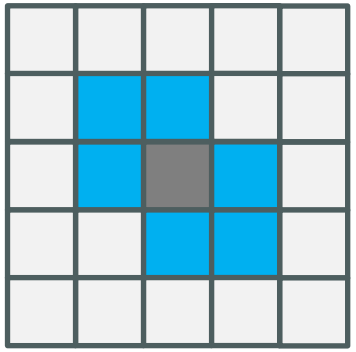
Original pixels

Removed pixels

Added pixels







kernel

0	1	0
1	1	1
0	1	0

Opening

Erosion then **Dilation**

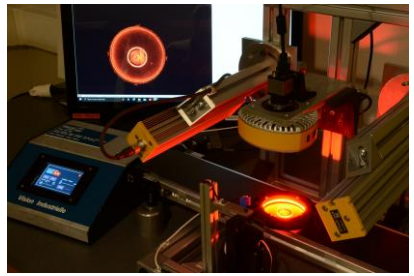
Removing small objects

Closing

Dilation then **Erosion**

Filling in small holes

INSTITUT d'OPTIQUE GRADUATE SCHOOL | Continuing Education | Formation Continue



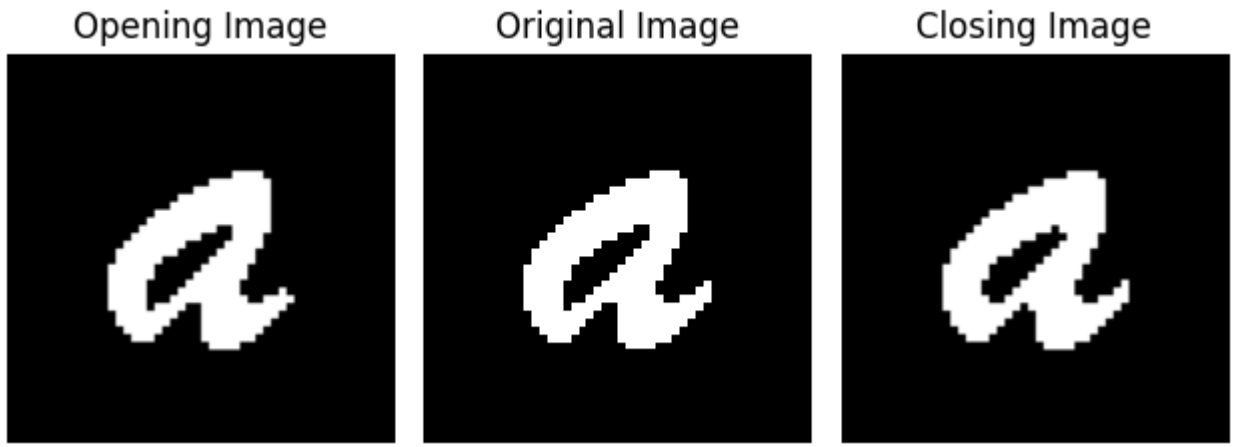
SC19 – Image Processing

OpenCV / Opening and Closing

morphological transforms

Acquisition

Pre Processing



kernel

0	1	0
1	1	1
0	1	0

Opening

Erosion then **Dilation**

Removing small objects

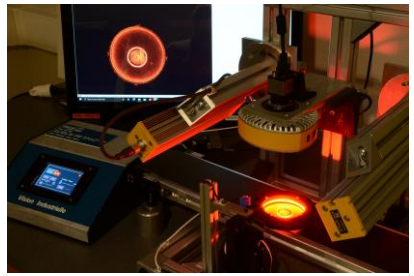
Closing

Dilation then **Erosion**

Filling in small holes

```
opening_image = cv2.morphologyEx(image, cv2.MORPH_OPEN, kernel)
closing_image = cv2.morphologyEx(image, cv2.MORPH_CLOSE, kernel)
```

INSTITUT d'OPTIQUE GRADUATE SCHOOL | Continuing Education | Formation Continue



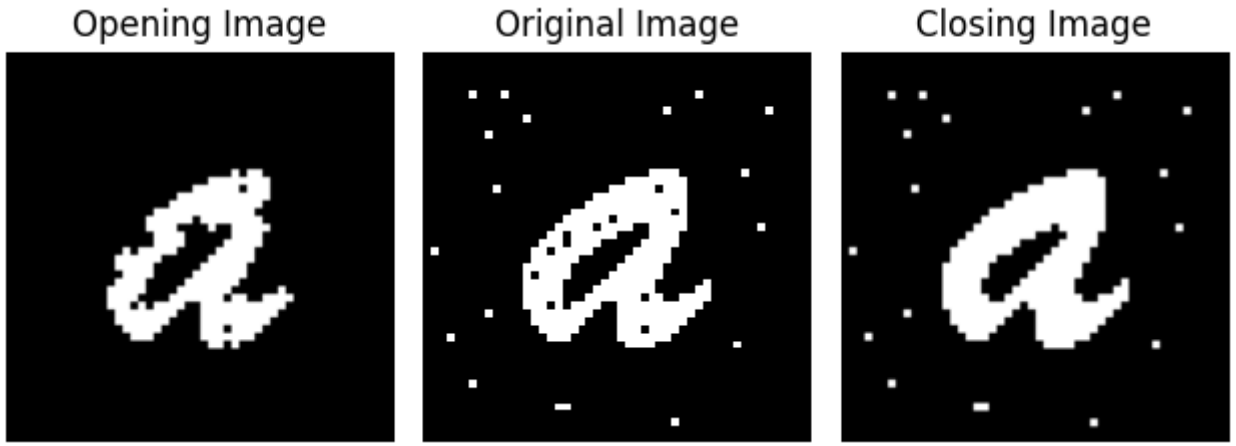
SC19 – Image Processing

OpenCV / Opening and Closing

morphological transforms

Acquisition

Pre Processing



kernel

0	1	0
1	1	1
0	1	0

Opening

Erosion then **Dilation**

Removing small objects, in the background

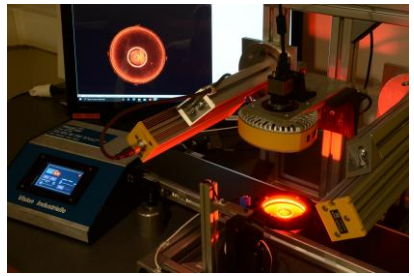
Closing

Dilation then **Erosion**

Filling in small holes in the foreground

```
opening_image = cv2.morphologyEx(image, cv2.MORPH_OPEN, kernel)
closing_image = cv2.morphologyEx(image, cv2.MORPH_CLOSE, kernel)
```

INSTITUT d'OPTIQUE GRADUATE SCHOOL | Continuing Education — Formation Continue



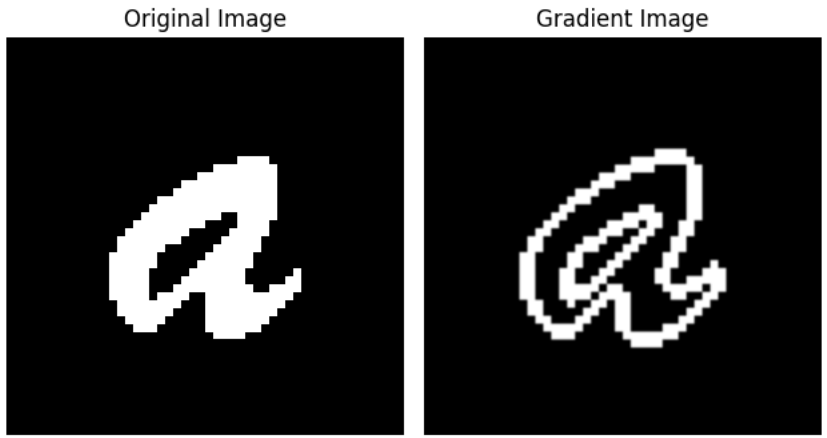
SC19 – Image Processing

OpenCV / Gradient

morphological transforms

Acquisition

Pre Processing



kernel

0	1	0
1	1	1
0	1	0

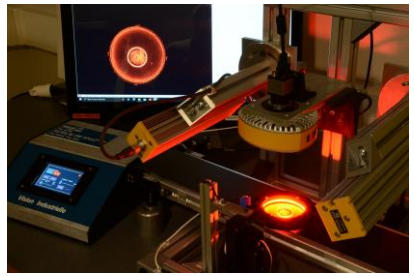
Gradient

Difference between a **dilation** and an **erosion**

Unknown pixels classification : background or foreground ?

gradient_image = cv2.**morphologyEx**(image, ***cv2.MORPH_GRADIENT***, kernel)

INSTITUT d'OPTIQUE GRADUATE SCHOOL | Continuing Education — Formation Continue



SC19 – Image Processing

OpenCV / Blur and Mean

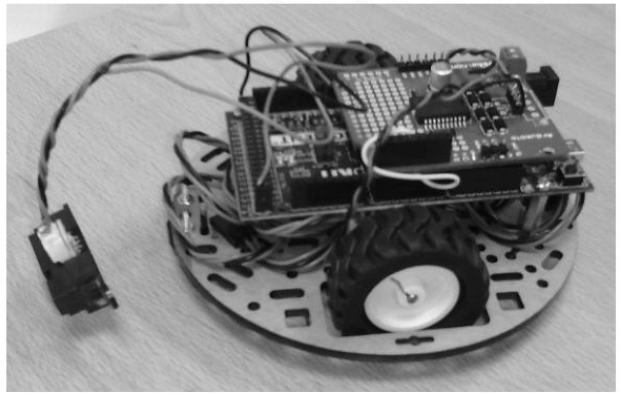
morphological transforms

Acquisition

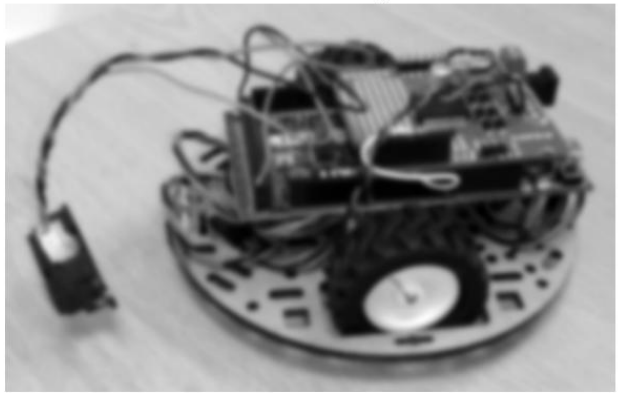
Pre Processing

```
kernel_size = (N,M)

blurred_image_gauss = cv2.GaussianBlur(image, kernel_size, 0)
blurred_image_box = cv2.blur(image, kernel_size)
```

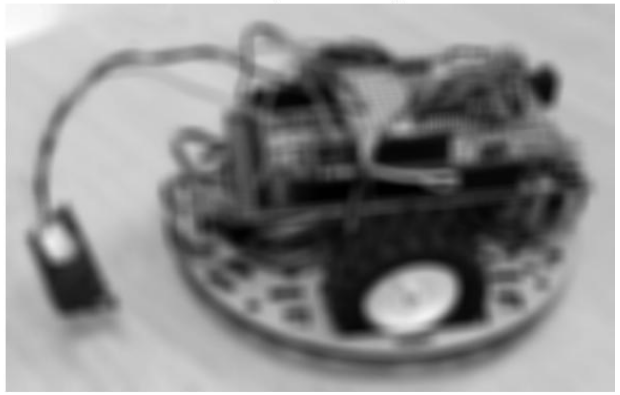
Original Image



Gaussian Blur Image



Median/Box Blur Image



1	4	7	4	1
4	16	26	16	4
7	26	41	26	7
4	16	26	16	4
1	4	7	4	1

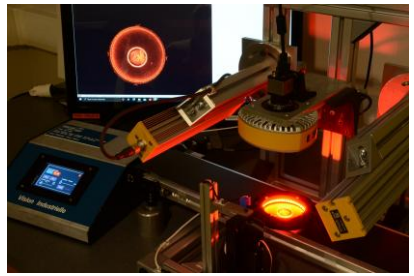
Gaussian Kernel
(x 1/273)

Mean Kernel (x 1/(N*M))

1/9	1/9	1/9
1/9	1/9	1/9
1/9	1/9	1/9

Removing irrelevant details

INSTITUT d'OPTIQUE GRADUATE SCHOOL | Continuing Education Formation Continue



SC19 – Image Processing

OpenCV / Sobel

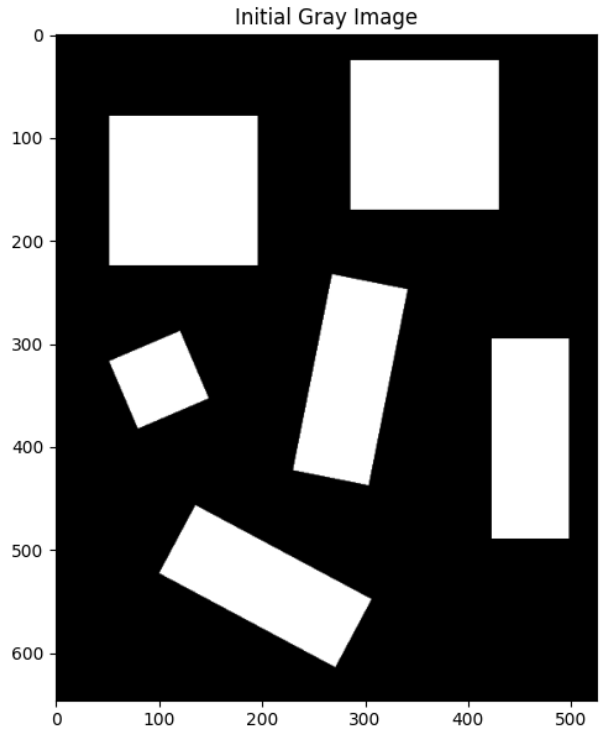
Acquisition

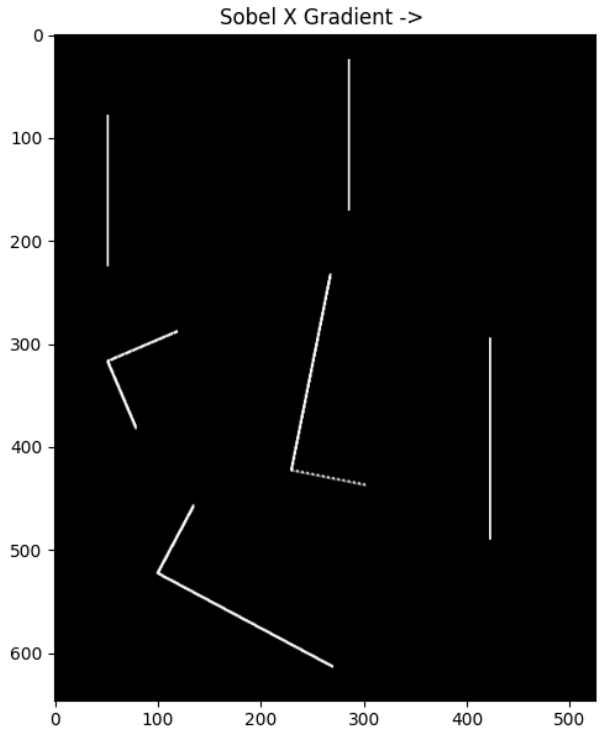
Pre Processing

```
sobel_kernel_x1 = np.array([[-1, 0, 1], [-2, 0, 2], [-1, 0, 1]])

sobelx_1 = cv2.filter2D(image, -1, sobel_kernel_x1)
```

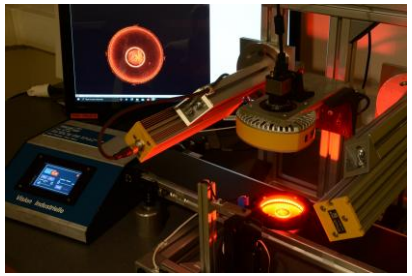
kernel

-1	0	1
-2	0	2
-1	0	1





INSTITUT d'OPTIQUE GRADUATE SCHOOL | Continuing Education | Formation Continue



SC19 – Image Processing

OpenCV / Sobel

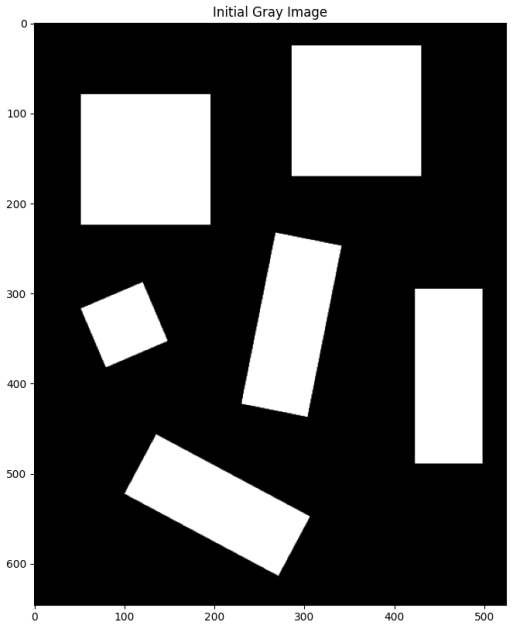
Acquisition

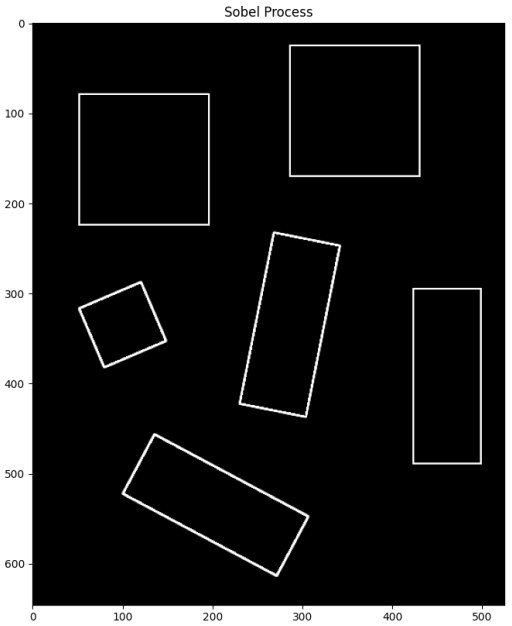
Pre Processing

```
sobelx = cv2.Sobel(image_gray, cv2.CV_64F, 1, 0, ksize=3)
sobely = cv2.Sobel(image_gray, cv2.CV_64F, 0, 1, ksize=3)

magnitude = cv2.magnitude(sobelx, sobely)
magnitude = cv2.convertScaleAbs(magnitude)
```

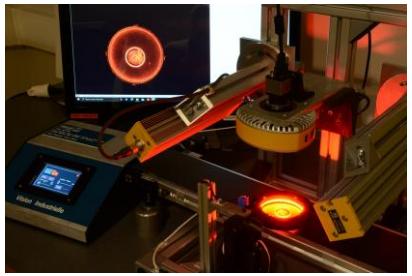
kernel

-1	0	1
-2	0	2
-1	0	1





INSTITUT d'OPTIQUE GRADUATE SCHOOL | Continuing Education | Formation Continue



SC19 – Image Processing

Goal of processing an image

Acquisition

Pre Processing

Segmentation

Thresholding
Edge Detection
Region of Interest Selection

Isolating objects of ROI / Separating product from background
Identifying boundaries and contours
Focusing only on relevant portions of the image

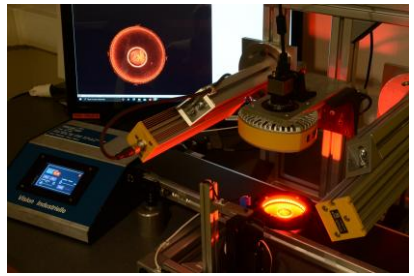
Feature Extraction

Geometric Features
Texture Analysis
Color Analysis

Extracting measurements (size, shape, position…)
Recognizing patterns, symbols, points of interest

https://docs.opencv.org/4.x/d3/db4/tutorial_py_watershed.html

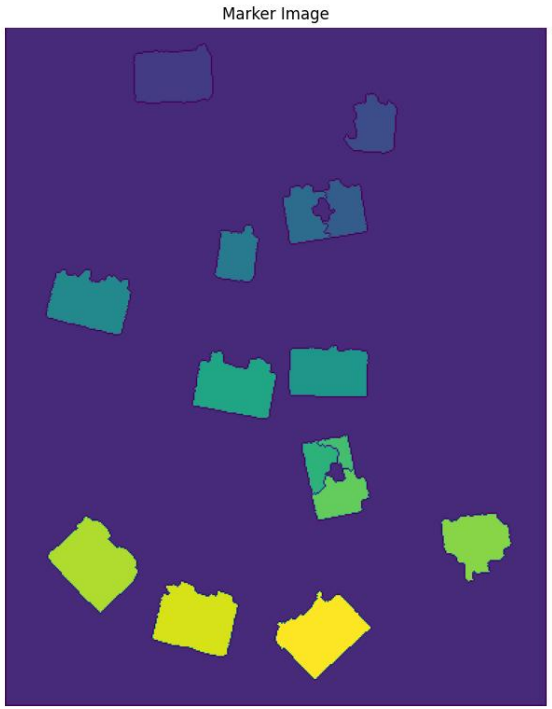
INSTITUT d'OPTIQUE GRADUATE SCHOOL | Continuing Education | Formation Continue



SC19 – Image Processing

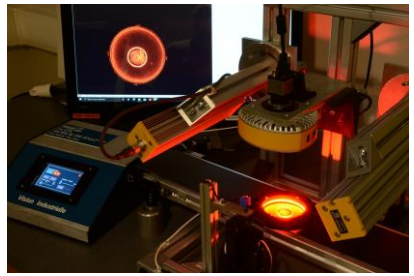
Segmentation and Feature extraction

- Acquisition
- Pre Processing
- Segmentation
- Feature Extraction



Watershed method

INSTITUT d'OPTIQUE GRADUATE SCHOOL | Continuing Education | Formation Continue



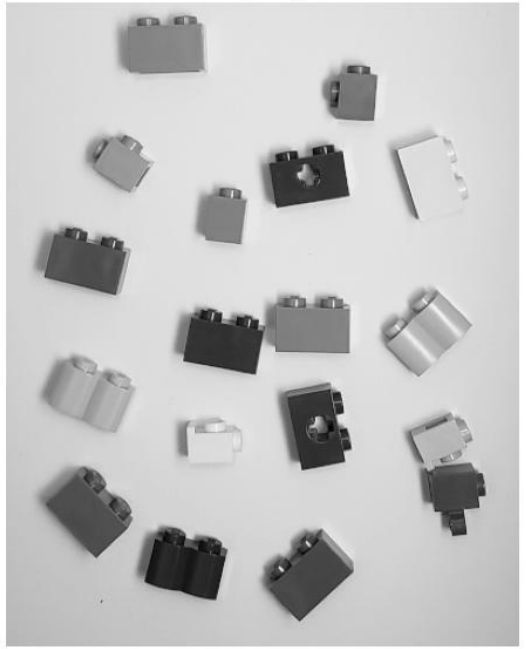
SC19 – Image Processing

Segmentation and Feature extraction

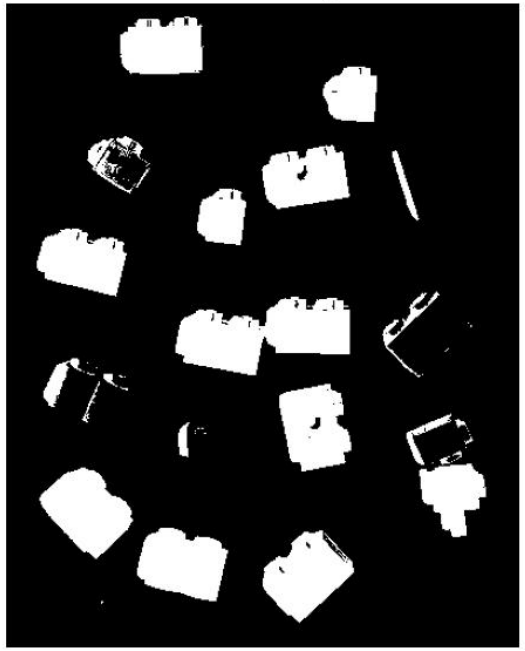
- Acquisition
- Pre Processing
- Segmentation
- Feature Extraction

Original RGB Image

Gray Image

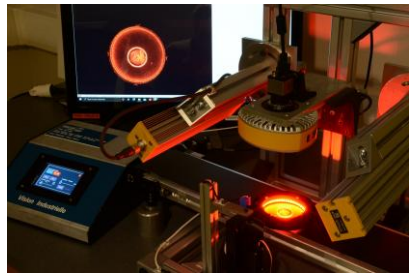


Threshold Image



Watershed method / First step - Thresholding

INSTITUT d'OPTIQUE GRADUATE SCHOOL | Continuing Education | Formation Continue



SC19 – Image Processing

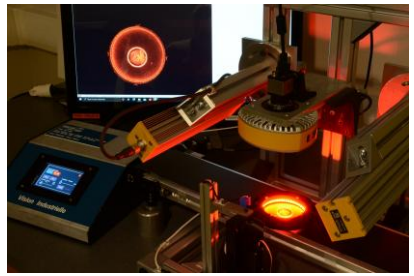
Segmentation and Feature extraction

- Acquisition
- Pre Processing
- Segmentation
- Feature Extraction

Watershed method / Second step – Sure BG/FG image

Watershed method / Third step – Labelling

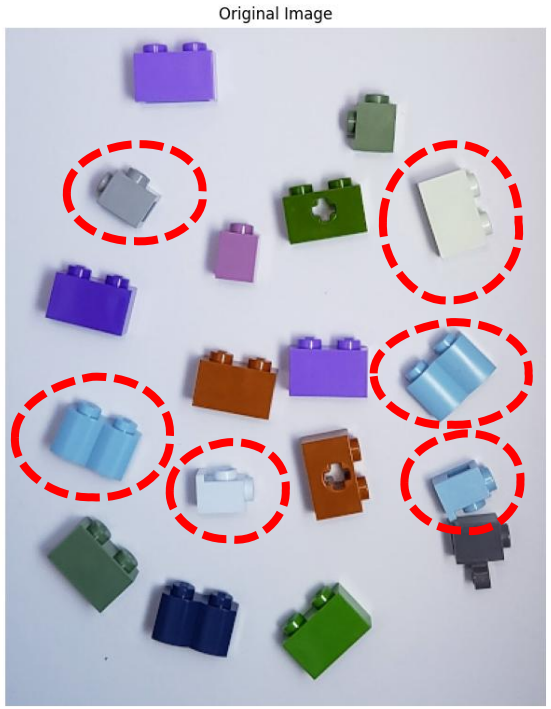
INSTITUT d'OPTIQUE GRADUATE SCHOOL | Continuing Education | Formation Continue

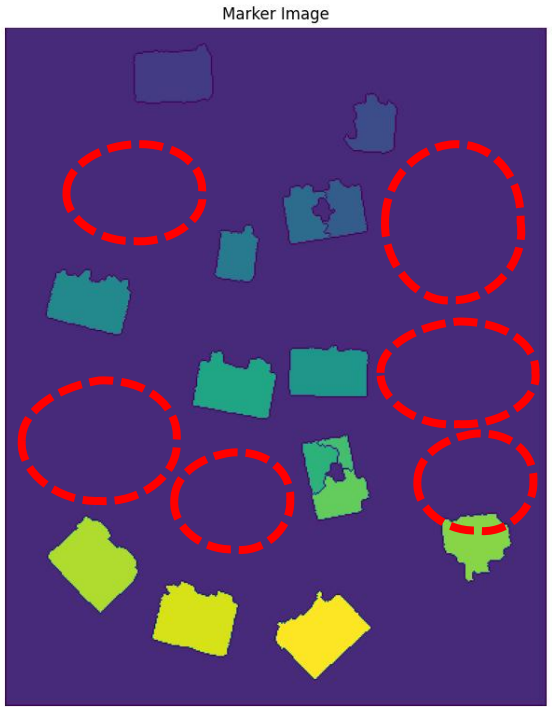


SC19 – Image Processing

Segmentation and Feature extraction

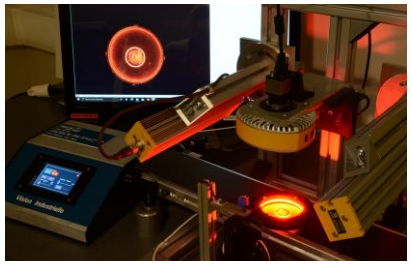
- Acquisition
- Pre Processing
- Segmentation
- Feature Extraction





Watershed method

INSTITUT d'OPTIQUE GRADUATE SCHOOL | Continuing Education | Formation Continue



SC19 – Image Processing

Fourier Transform and Filtering

- Acquisition
- Pre Processing
- Segmentation
- Feature Extraction