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Practical work of Image Processing

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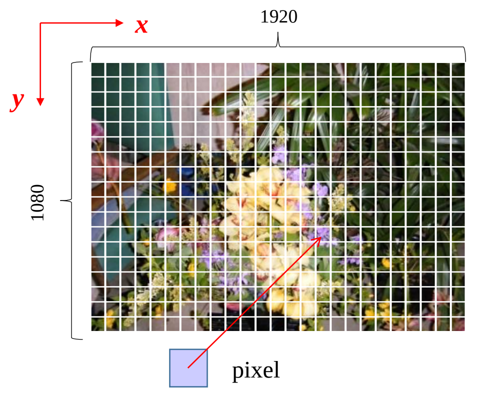
Disciplinary Background

1. Linear Algebra
2. Signals and Systems
3. Digital Signal Processing
4. Probability Theory and Random Process
5. C/C++, Python Programming Skill, Matlab

Computational Intelligence
Machine Learning
Data Science .....

Description of Image Data

Image Size: 1920 × 1080, 1280 × 720, 640 × 480, 320 × 240 .....



When you take a picture using a digital camera or a mobile phone, the image size is described such as 1280x720 and 1920x1080. It means that the image taken by the camera consists of the 1920x1080 picture elements. A picture is divided into 1920x1080 small pixels.

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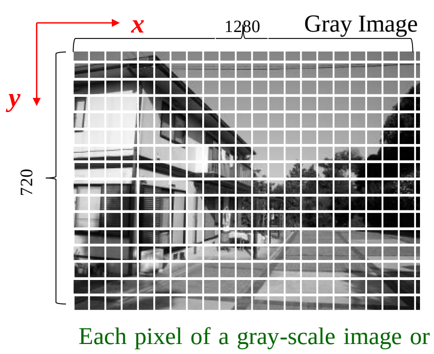
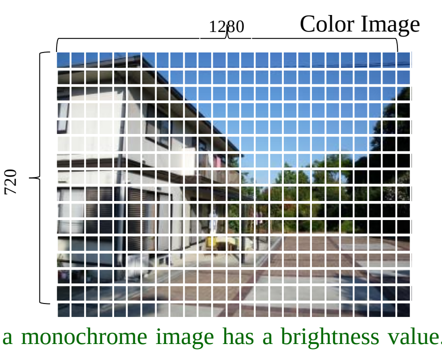
Description of Image Data





Each pixel of a gray-scale image or a monochrome image has a brightness value. In a computer, the brightness value is expressed by an integer from 0 to 255, where 0 is black and 255 is white.

In a color image, each pixel consists of 3 data. There are different ways to express color data, however RGB expression is widely used. R means red color, G means green color and B means blue color, which are the three primary colors of light. The three values of RGB colors are expressed also by the number from 0 to 255. Any color that can be displayed in a color display is expressed by the combination of RGB data.

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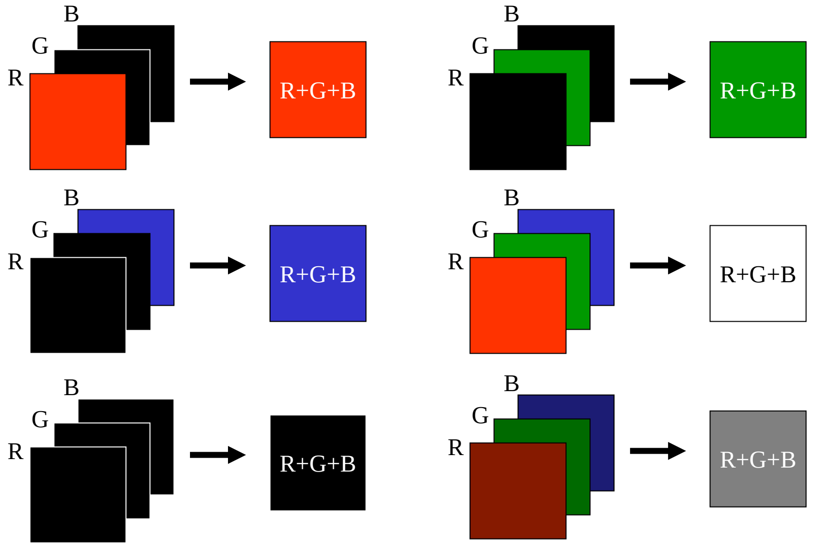
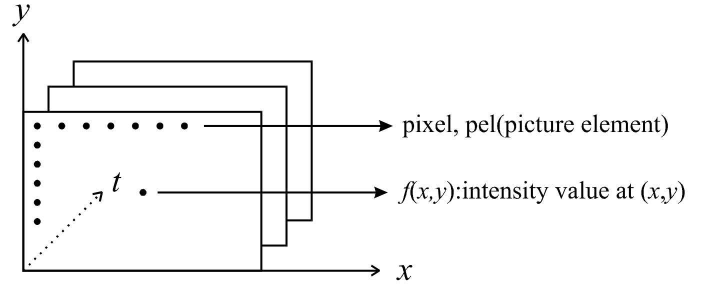
Expression of Color Image Data



Description of Image Data



picture size $\Rightarrow$ picture resolution ; 640×480, 1980×1080

$0 \leq f(x, y) \leq L\ (= 255)$; gray level, 8bit/pixel

(x, y) ; spatial coordinate

t ; temporal coordinate

Algebraic Description

$$f(x,y)=\begin{bmatrix} f(0,0) & f(0,1) & \cdots & f(0,N-1) \\ f(1,0) & f(1,1) & \cdots & f(1,N-1) \\ \vdots & & & \\ f(M-1,0) & \cdots & \cdots & f(M-1,N-1) \end{bmatrix} \qquad M \times N \text{ matrix}$$

$$\mathbf{A}=\begin{bmatrix} a_{00} & a_{01} & \cdots & a_{0,N-1} \\ \vdots & & & \\ \vdots & & & \\ a_{M-1,0} & \cdots & \cdots & a_{M-1,N-1} \end{bmatrix} \qquad a_{ij}= f\,(x=i,\, y=j)$$

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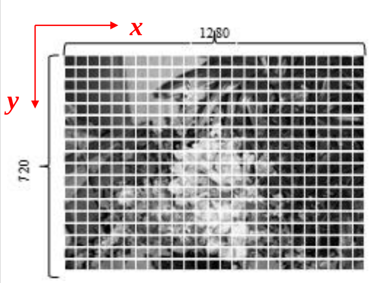
Image Description in C-program

Image data are described as 2 dimensional array, which elements have values from 0 to 255. As a gray image, typical expression is as follows;

unsigned char image-name[y-pixel-size][x-pixel-size];



Left image presents 1280x720 pixels picture in gray scale values, and the description of the image is;

unsigned char flower[720][1280];

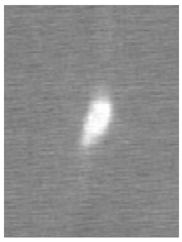
or

unsigned char image_name[HEIGHT][WIDTH];

where HEIGHT is 720 and WIDTH is 1280.

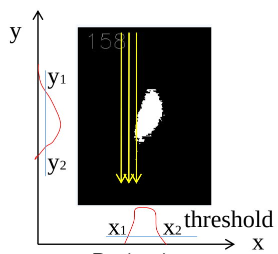
For color images, each pixel consists of three colors, which are R, G and B that represent Red, Green and Blue, respectively.

Projection for the Localization of an Object



Original image

Binarized image



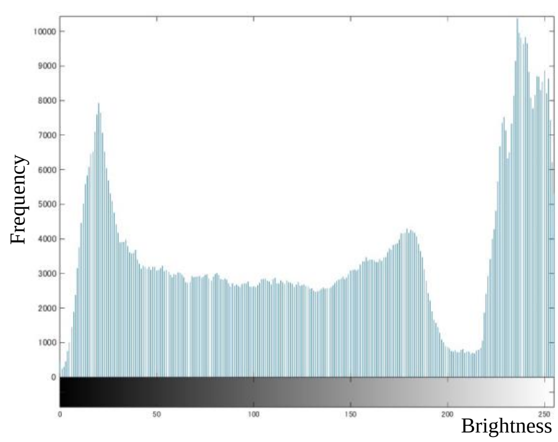
Projection

"Projection" is the operation to count white pixels along x-axis and y-axis. The counting result shows the distribution of white pixels. The area that exceeds a certain threshold should be the position, or the region of the white blob.

We can say that a white blob exists in the area between (x1 and x2) and (y1 and y2).

Histogram

I = imread("Temple.jpg");
imshow(I);



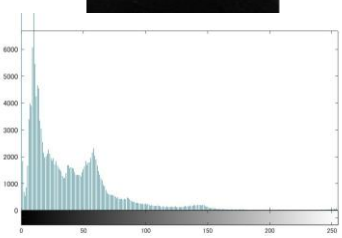
imhist(I);

imwrite(I, "Histogram.png")

Adjusting Image Contrast

imadjust(gs);

Non-linear adjustment



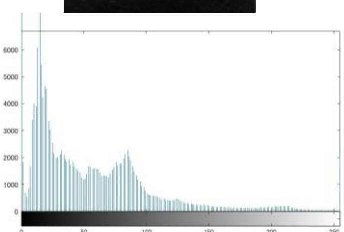


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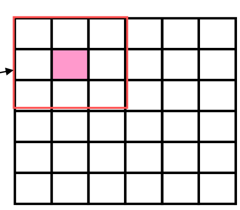
Image Filtering by Convolutional Operations

Averaging/Smoothing/Uniform filter

$$h = \begin{bmatrix} 1/9 & 1/9 & 1/9 \\ 1/9 & 1/9 & 1/9 \\ 1/9 & 1/9 & 1/9 \end{bmatrix} = \frac{1}{9}\begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix}$$



H = fspecial("average", 3)

Image data

$W_{mn}=$

$W_{-1,-1}$	$W_{0,-1}$	$W_{+1,-1}$
$W_{-1,0}$	$W_{0,0}$	$W_{+1,0}$
$W_{-1,+1}$	$W_{0,+1}$	$W_{+1,+1}$

Kernel

$$F_{ij} = \sum_{m=-k}^{+k} \sum_{n=-k}^{+k} W_{mn} * f_{i+m,j+n}$$

Operation

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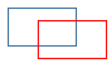
Geometric translation

$$\begin{pmatrix} x' \\ y' \\ 1 \end{pmatrix} = \begin{pmatrix} S_{11} & S_{12} & S_{13} \\ S_{21} & S_{22} & S_{23} \\ S_{31} & S_{32} & S_{33} \end{pmatrix} \begin{pmatrix} x \\ y \\ 1 \end{pmatrix}$$

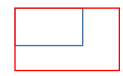
Shift in *x*- or *y*-direction

$$\begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ t_x & t_y & 1 \end{pmatrix}$$



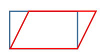
Scale translation

$$\begin{pmatrix} S_x & 0 & 0 \\ 0 & S_y & 0 \\ 0 & 0 & 1 \end{pmatrix}$$



Shear deformation

$$\begin{pmatrix} 1 & \tan\theta_y & 0 \\ \tan\theta_x & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix}$$



Rotation

$$\begin{pmatrix} \cos\theta & \sin\theta & 0 \\ -\sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

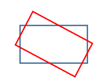
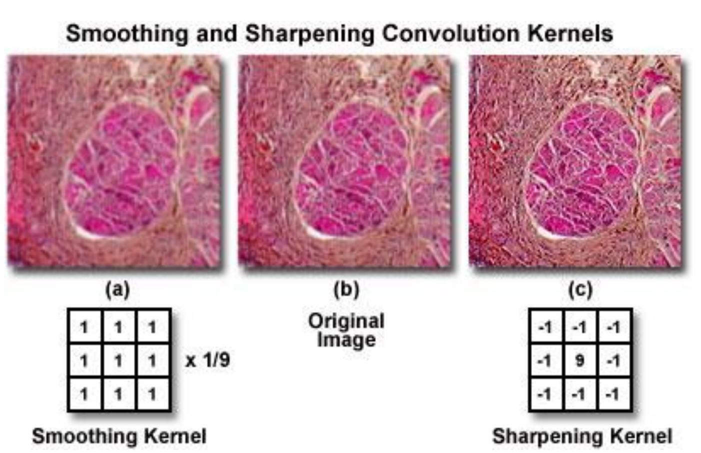


Image Filtering by Convolutional Operations



microscopy.fsu.edu

Edge Detection

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Sobel operator

$$h_x = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix}$$

$$h_y = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix}$$

$$h_{xy} = \left(h_x^2 + h_y^2\right)^{\frac{1}{2}}$$

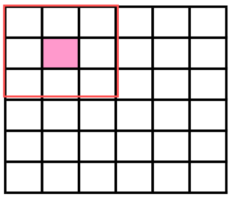

Image data

H = fspecial(“sobel”)

Edge Detection

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$$h_x = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} \quad h_y = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix}$$

10	10	10	50	50	50
10	10	10	50	50	50
10	10	10	50	50	50
10	10	10	50	50	50
10	10	10	50	50	50
10	10	10	50	50	50

$$h_x = \begin{array}{l} -1*10 + 0*10 + 1*10 \\ +(-2*10) + 0*10 + 2*10 \\ -1*10 + 0*10 + 1*10 \end{array}$$

$$h_x = \begin{array}{l} -1*10 + 0*10 + 1*50 \\ +(-2*10) + 0*10 + 2*50 \\ -1*10 + 0*10 + 1*50 \end{array}$$

$$h_{xy} = \left(h_x^2 + h_y^2\right)^{\frac{1}{2}}$$

0	160	160	0
0	160	160	0
0	160	160	0
0	160	160	0
0	160	160	0
0	160	160	0

h_x

EdgeDetect = imfilter(GrayImage, H);

Edge Detection

$$h_x = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} \quad h_y = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix}$$

10	10	10	50	50	50
10	10	10	50	50	50
10	10	10	50	50	50
10	10	10	50	50	50
10	10	10	50	50	50
10	10	10	50	50	50

$$h_x = \begin{array}{l} -1*10+0*10+1*10 \\ +(-2*10)+0*10+2*10 \\ -1*10+0*10+1*10 \end{array}$$

$$h_x = \begin{array}{l} -1*10+0*10+1*50 \\ +(-2*10)+0*10+2*50 \\ -1*10+0*10+1*50 \end{array}$$

$$h_{xy} = \left(h_x^2 + h_y^2\right)^{\frac{1}{2}}$$

0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0

h_y

EdgeDetect = imfilter(GrayImage, H);

Edge Detection

Original picture

Grayscale

Edge detection

Practical work with Matlab

Image Processing Toolbox
Statistics and Machine Learning Toolbox

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https://www.mathworks.com/products.html

Physics, Informatics and Robotics

(A) Find the location of an object in a picture.

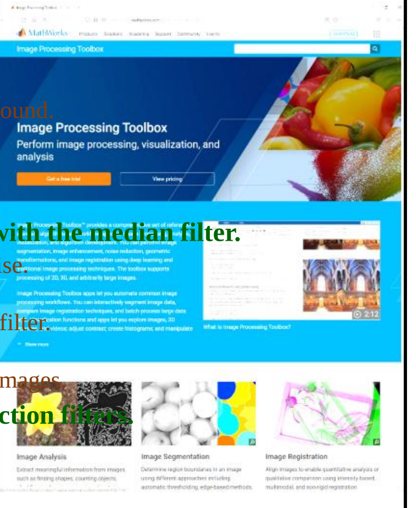
1) Take a picture of some object using your camera.
2) Send the picture to the programing environment.
3) Set a threshold to separate the object from background.
4) Binarize the image.
5) Execute the projection to x- and y- direction.
6) Calculate the center coordinate of the object.

(B) Compare the effect of the averaging filter with the median filter.

1) Take a picture of some texture or with spiking noise.
2) Send the picture to the programing environment.
3) Find the averaging/uniform filter and the median filter.
4) Apply the filters to the picture.
5) Examine the difference between the two filtered images.

(C) Examine the effects of different edge-extraction filters.

1) Take a picture of some objects having textures.
2) Send the picture to Matlab.
3) Find different edge-detection filters.
4) Apply the filters to the picture.
5) Examine the difference among the filtered images.



Practical work with Matlab

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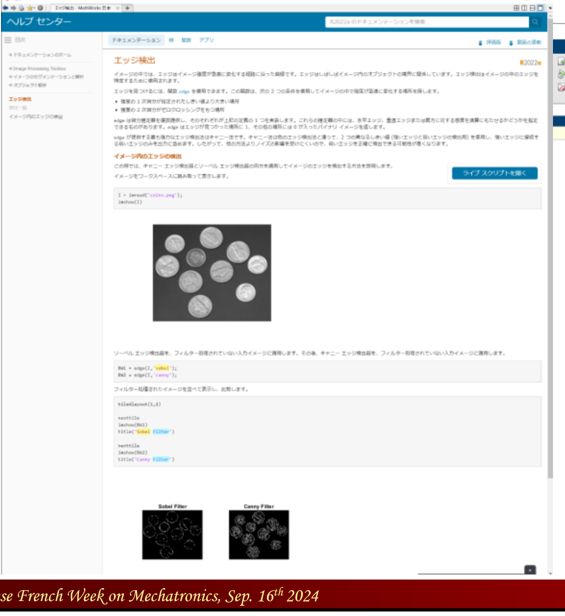
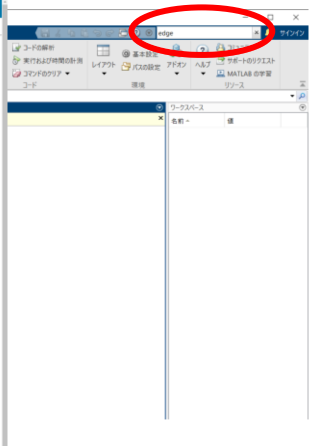
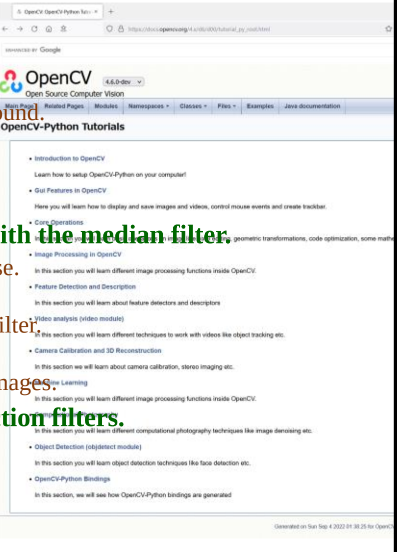
Physics, Informatics and Robotics





Practical work with OpenCV-Python

https://docs.opencv.org/4.x/d6/d00/tutorial_py_root.html



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Presented by
Hideyuki Sawada Laboratory
Waseda University