OpenCV: Modules and Functions

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Outline

- Introduction
- Installation Guides
- OpenCV Modules
- Image processing Functions
    - Thresholding
    - Edge Detection
    - Hough Transform
    - Smoothing
    - Color Space

Introduction

- OpenCV is a C++ library for **image processing** and **computer vision**.
- It has hundreds of built-in functions.
- **Open Source and Free.**
- It runs on **Windows**, **Linux, and Mac.**
- There are also full interfaces of C, Python and JAVA.

Image Format in OpenCV

- Currently, the following file formats are supported:
  - Windows bitmaps - *.bmp, *.dib
  - JPEG files - *.jpeg, *.jpg, *.jpe
  - JPEG 2000 files - *.jp2
  - Portable Network Graphics - *.png
  - WebP - *.webp
  - Portable image format - *.pbm, *.pgm, *.ppm
  - Sun rasters - *.sr, *.ras
  - TIFF files - *.tiff, *.tif

Installation Guides for Different Platforms

- Windows:
  - http://docs.opencv.org/2.4/doc/tutorials/introduction/windows_install/windows_install.html
  - http://opencv-srf.blogspot.com/2013/05/installing-configuring-opencv-with-vs.html
- Linux:
  - http://docs.opencv.org/2.4/doc/tutorials/introduction/linux_install/linux_install.html
  - http://docs.opencv.org/2.4/doc/tutorials/introduction/linux_eclipse/linux_eclipse.html
- MAC:
  - http://blogs.wcode.org/2014/10/howto-install-build-and-use-opencv-macosx-10-10/
  - http://tilomitra.com/opencv-on-mac-osx/

OpenCV Modules

- OpenCV is a modular structure library.
- It has several modules, which include:
  - **core**: basic OpenCV data structures.
  - **highgui**: image I/O operations.
  - **imgproc**: image processing functions (e.g., filtering and thresholding).
  - ….. Other modules

OpenCV Modules

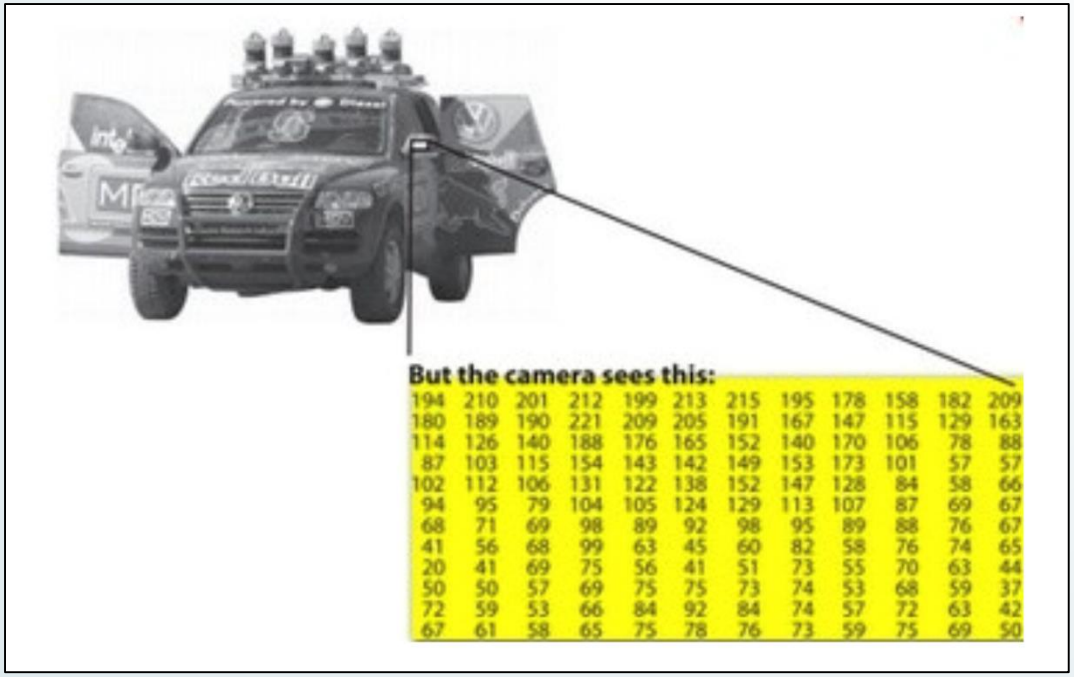
OpenCV Modules: core Module

- core module defines the basic OpenCV data structures.

- Basic data structures include:
  - **Point:** 2D point (x,y)
  - **Rect:** 2D rectangle object
  - **Vec**: row or column vector
  - **Mat:** Matrix object

Mat: The basic Image Container

- Mat is the primary data structure in OpenCV
- It is used to store an image as numerical matrix.
- Each cell of the matrix represents the intensity of a specific pixel.



Remember:

rows is your y coordinate
and
cols is your x coordinate

Mat Data Structure (cont.)

- **Functions:**
  - Mat.**at**<imagetype>(x, y)[channel] – returns the intensity of a pixel at x and y coordinates.
  - Mat.**channels**() - returns the image's number of channels.
  - Mat(**Rect** (x, y, sx, sy)) - returns sub image.
  - Mat.**size**() - returns the SIZE of an image.
  - Mat.**type**() - returns the TYPE of an image.

highgui Module: Image I/O Operations

- OpenCV provides simple and useful ways to read and write images.

- Examples

```
//Read an image
Mat image = imread( <filename>)

//Write an image
imwrite( <string filename> , image );

//Output image to window
imshow( <window name> , <image Mat to show> );

//pause program for input
key = waitKey( 0 );
```

Example Code

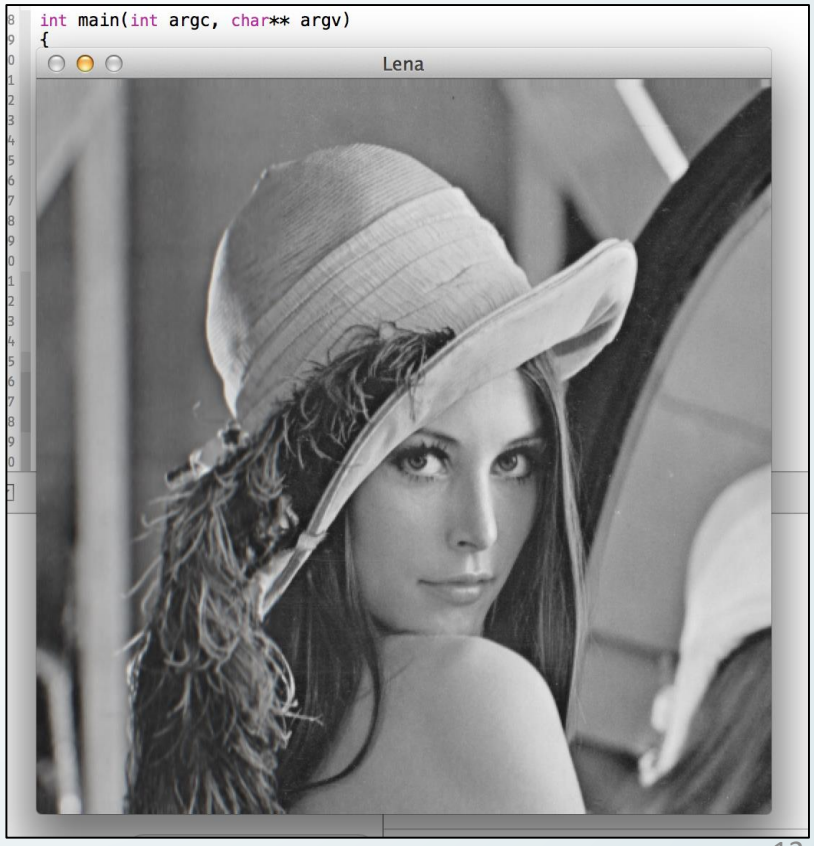
```
//header of modules
#include "opencv2/core/core.hpp“
#include "opencv2/highgui/highgui.hpp“

// OpenCV uses cv namespace
using namespace cv;

int main(int argc, char* argv[ ]){
   Mat image = imread(argv[1]);

   namedWindow(“Lena”);
   imshow(“Lena”,image);
   waitKey(0);
   return 0;
}
```

This program will load and show an image



imageproc Module

- Image processing module has many functions such as:
  - Thresholding
  - Image smoothing
  - Edge detections
  - Color space conversion
  - Hough Transform
  - Histogram modifications
  - and so on…

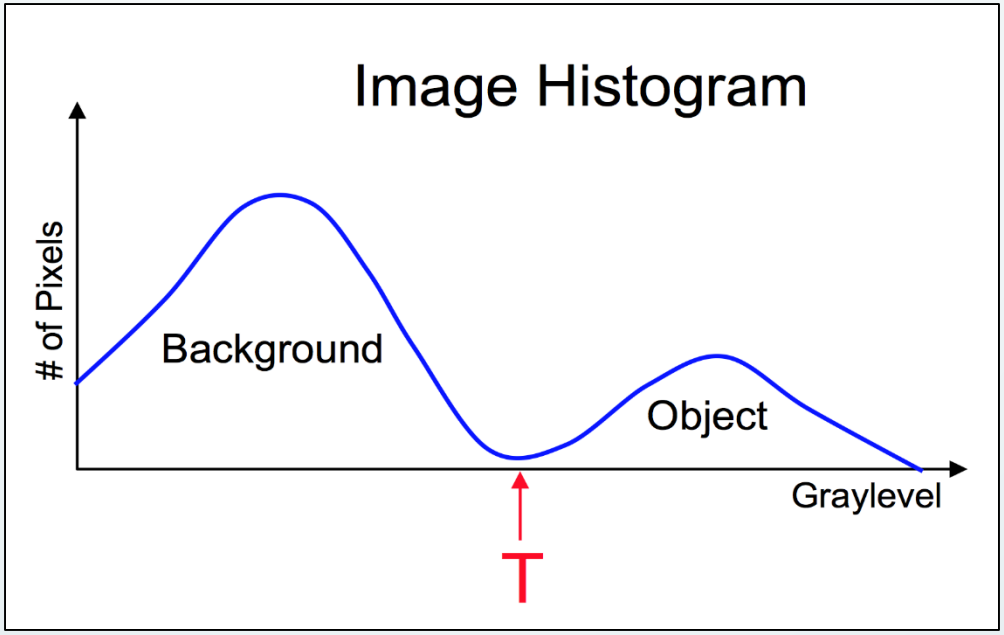
Thresholding

- Background:
  - It's a point operator.
  - The simplest method of segmentation.
  - Reject those pixels above or below some value (i.e., threshold) while keeping the others.

Thresholding (cont.)

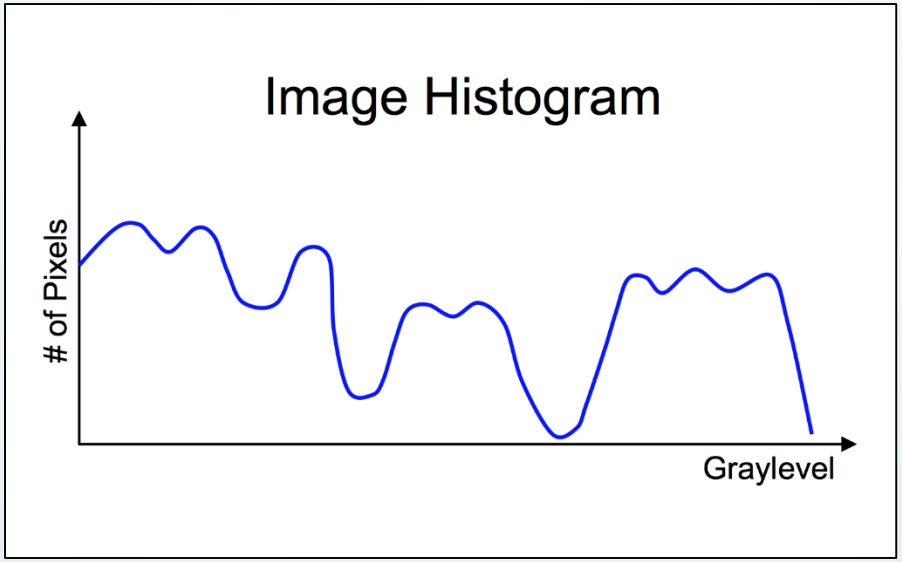
Global Thresholding =

Choose threshold **T** that separates object from background.



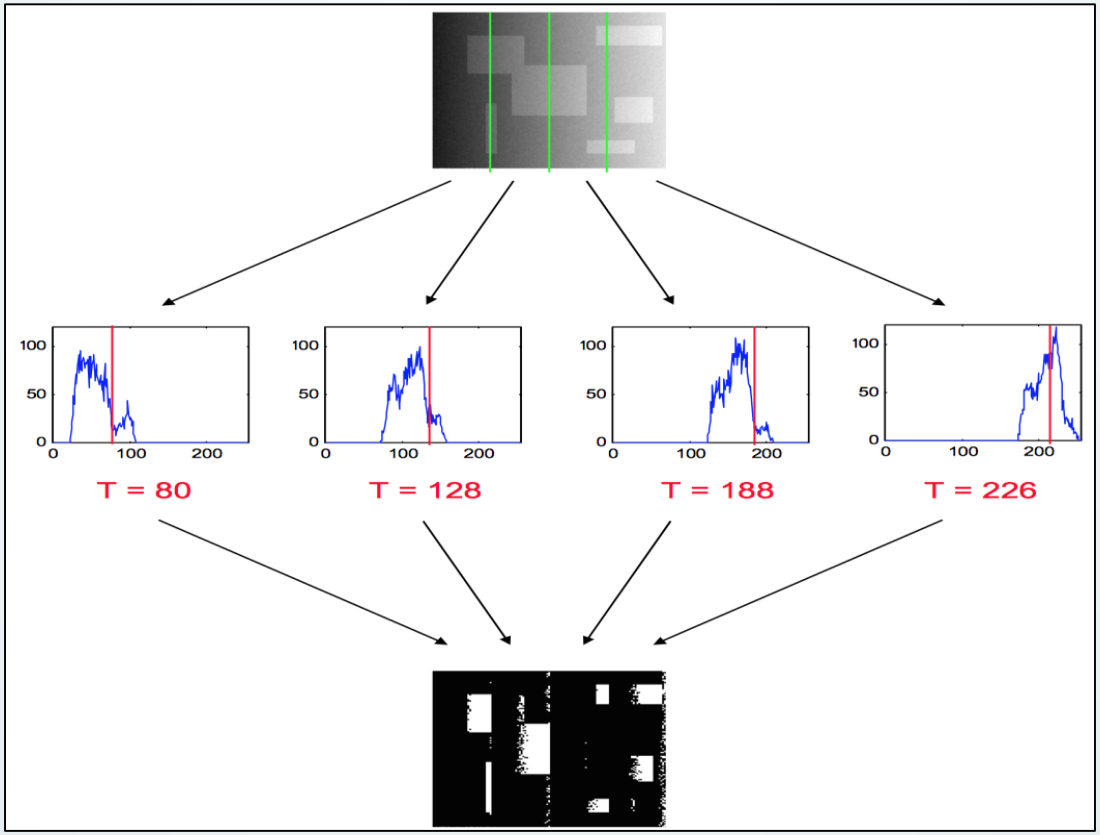
Thresholding (cont.)

- The Simple global thresholding is not always possible.
- What if the image histogram due to noise or large intensities variations looks like:



Thresholding (cont.)

- **Local thresholding:** divide the image into regions and perform thresholding in each region.



Thresholding (cont.)

- **Other Methods:**
  - Adaptive Thresholding.
  - Otsu's Thresholding.
  - Region growing
  - Graph cut
  - and so on…

OpenCV imageproc Module:
Threshold Function

- void threshold(src_img, dst_img, thresh, maxVal, thresold_type);

  Parameters:

  - **src** – source image.
  - **dst** – Destination image.
  - **thresh** - a user specified threshold.
  - **maxValue** – The new pixel intensity
  - **thresholdType** – Thresholding type.

Example:

```
threshold( src_gray, dst, 100, 255, THRESH_BINARY );
```

OpenCV imageproc Module: Threshold Function

- Below is a list of threshold_types in OpenCV:

- **THRESH_BINARY**

$$\texttt{dst}(x,y) = \begin{cases} \texttt{maxVal} & \text{if } \texttt{src}(x,y) > \texttt{thresh} \\ 0 & \text{otherwise} \end{cases}$$

- **THRESH_BINARY_INV**

$$\texttt{dst}(x,y) = \begin{cases} 0 & \text{if } \texttt{src}(x,y) > \texttt{thresh} \\ \texttt{maxVal} & \text{otherwise} \end{cases}$$

- **THRESH_TRUNC**

$$\texttt{dst}(x,y) = \begin{cases} \texttt{threshold} & \text{if } \texttt{src}(x,y) > \texttt{thresh} \\ \texttt{src}(x,y) & \text{otherwise} \end{cases}$$

- **THRESH_TOZERO**

$$\texttt{dst}(x,y) = \begin{cases} \texttt{src}(x,y) & \text{if } \texttt{src}(x,y) > \texttt{thresh} \\ 0 & \text{otherwise} \end{cases}$$

- **THRESH_TOZERO_INV**

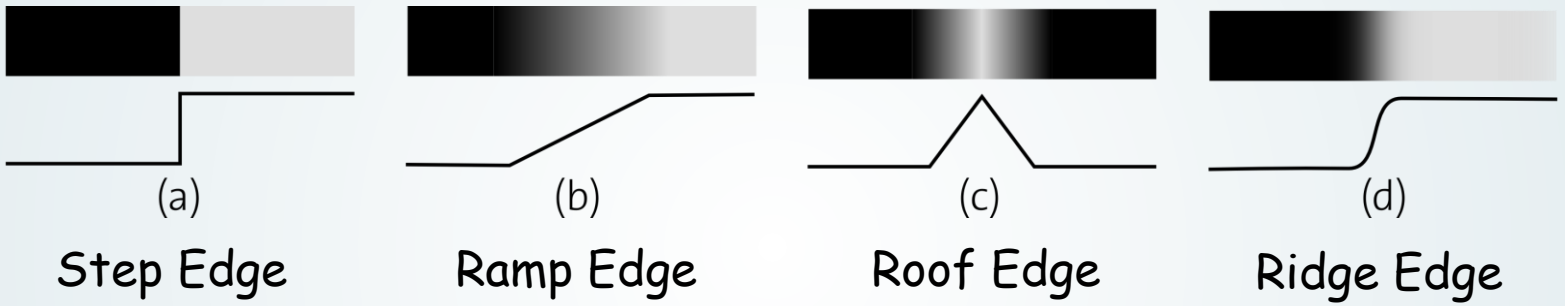
$$\texttt{dst}(x,y) = \begin{cases} 0 & \text{if } \texttt{src}(x,y) > \texttt{thresh} \\ \texttt{src}(x,y) & \text{otherwise} \end{cases}$$

Edge Detections

- Another way for image segmentation.
- Convert a 2D image into a set of curves (i.e., edges) and background.
- Edges are significant local changes of intensity in an image.
- Edge Types include: step edge, ramp edge, ridge edge, and roof edge.

Edge Detections

- Examples of edge types:

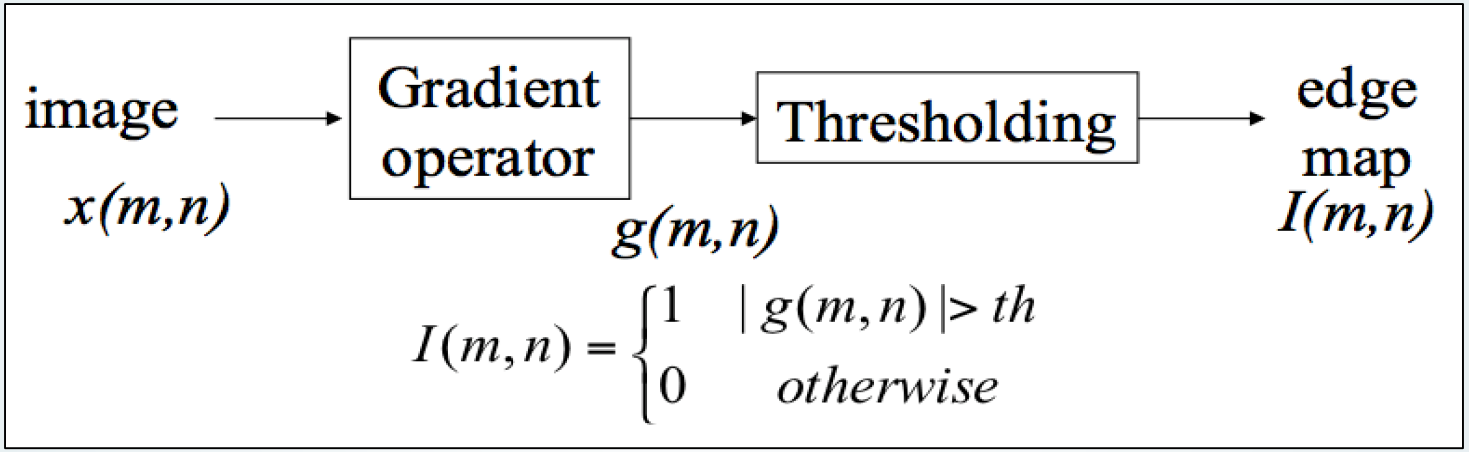


- Gradient Operators to detect edges.

change in the pixel value ⟶ large gradient

Edge Detections

- Gradient Operator:



- The gradient of the image at every point is computed using:

$g_1(m,n) = x(m,n) * H_1(-m, -n) \rightarrow g_x$

$g_2(m,n) = x(m,n) * H_2(-m, -n) \rightarrow g_y$

Edge Detections

Where x(m,n) denote an arbitrary image location and H_1 and H_2 are masks (i.e., gradient operators) to measure the gradient of the image in two orthogonal directions

- Then, we compute the gradient magnitude:

$$g(m,n) = \sqrt{g_x^2(m,n) + g^2_y(m,n)}$$

- Examples of gradient operators or masks:

$$\text{Sobel} : H_1 = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} \qquad H_2 = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix}$$

Edge Detections

$$\text{Prewitt}: \quad H_1 = \begin{bmatrix} -1 & 0 & 1 \\ -1 & 0 & 1 \\ -1 & 0 & 1 \end{bmatrix} \qquad H_2 = \begin{bmatrix} -1 & -1 & -1 \\ 0 & 0 & 0 \\ 1 & 1 & 1 \end{bmatrix}$$

$$\text{Roberts}: \quad H_1 = \begin{bmatrix} 0 & 1 \\ -1 & 0 \end{bmatrix} \qquad H_2 = \begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix}$$

OpenCV imageproc Module:
Edge Detections

- void **Sobel**(src, dst, xorder, yorder ksize)

  Parameters:

  - **src** – input image.
  - **dst** – output image.
  - **xorder & yorder** – x direction or y direction.
  - **ksize** – size of the Sobel kernel (H); it must be 1, 3, 5, or 7.

- OpenCV has similar functions for other gradient operators.

OpenCV imageproc Module:
Edge Detections

- Example:

Original Image

Horizontal Edge

Vertical Edge

Sobel operator (*th=48*)

Hough Transform

- It is a transform for direct object recognition (e.g., lines, circles).
- Applied on detected edges image.
- Key Idea: edges VOTE for the possible model

Parameter Space

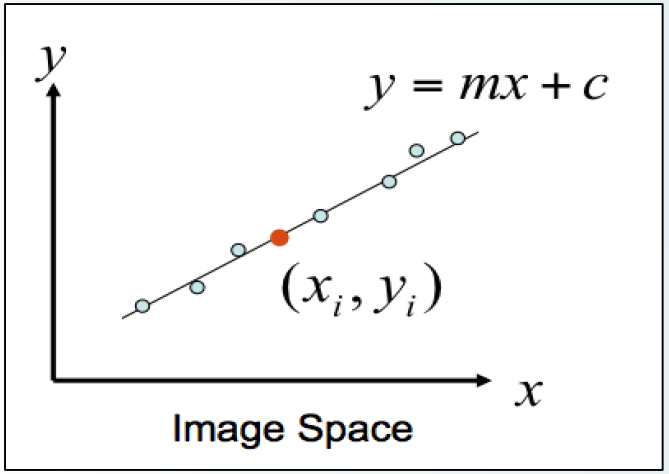
Equation of Line: $y = mx + c$

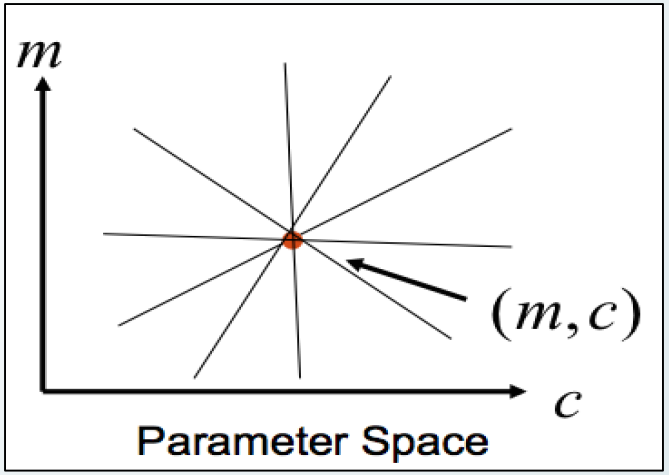
Find: (m,c)

Consider point: (x_i , y_i)

$y_i = mx_i + c$ or $c = -mx_i + y_i$

Parameter space also called Hough Space





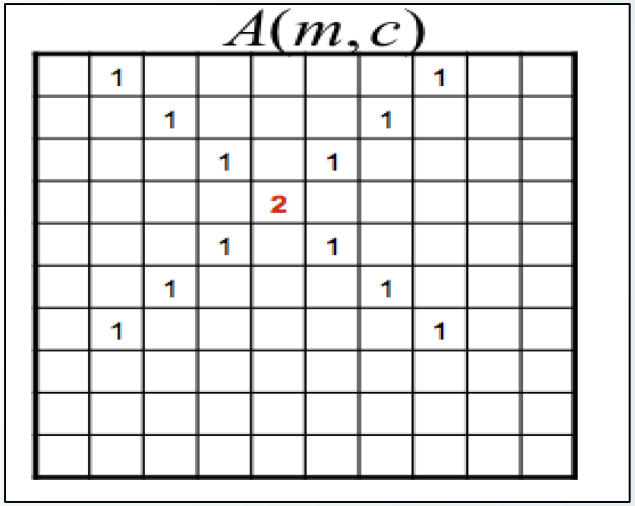
Line Detection

Algorithm:

- Quantize Parameter Space **(m,c)**
- Create Accumulator Array **A(m,c)**
- Set **A(m,c) = 0** for all m,c
- For each image edge **(x_i, y_i)** increment:

  A(m,c) = A(m,c) + 1
- If **(m,c)** lies on the line:

  $c = -x_i + y_i$
- Find local maxima in **A(m,c)**



OpenCV imageproc Module: Hough Transform – Lines

- void **HoughLines**(src, put_lines, rho, theta, thresh)

  Parameters:

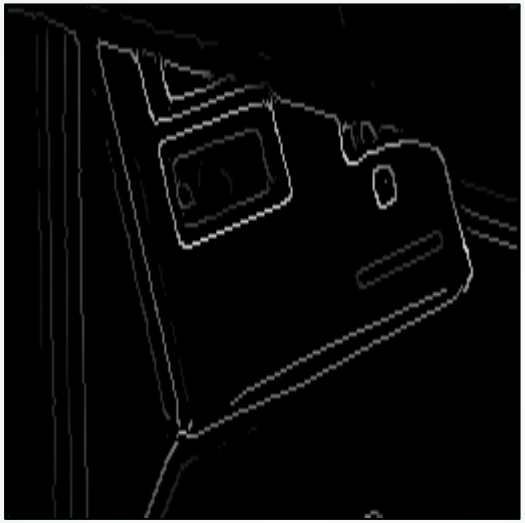
  - **src** – input image.
  - **out_lines** – output vector of lines.
  - **rho** – distance resolution of the accumulator in pixels.
  - **theta**– angle resolution of the accumulator in radians.
  - **thresh** – accumulator threshold parameter. Only those lines are returned that get enough votes (> thresh).

- Example:

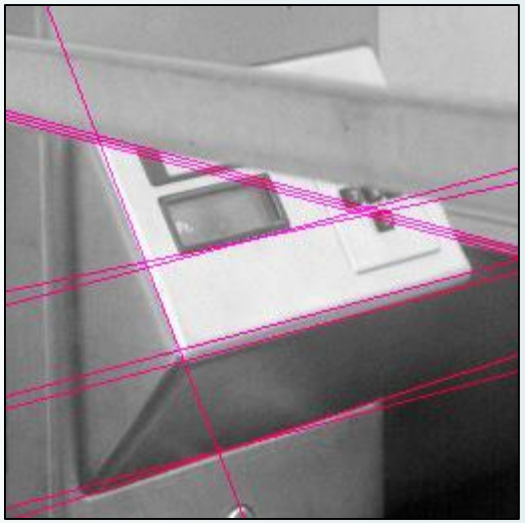
  HoughLines(src, lines, 1, CV_PI/180, 100);

Example

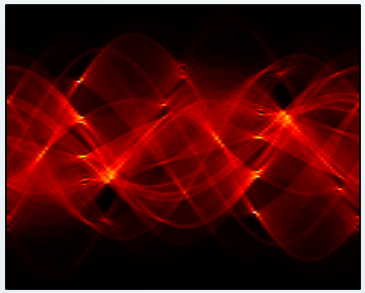
Original



Edge Detection



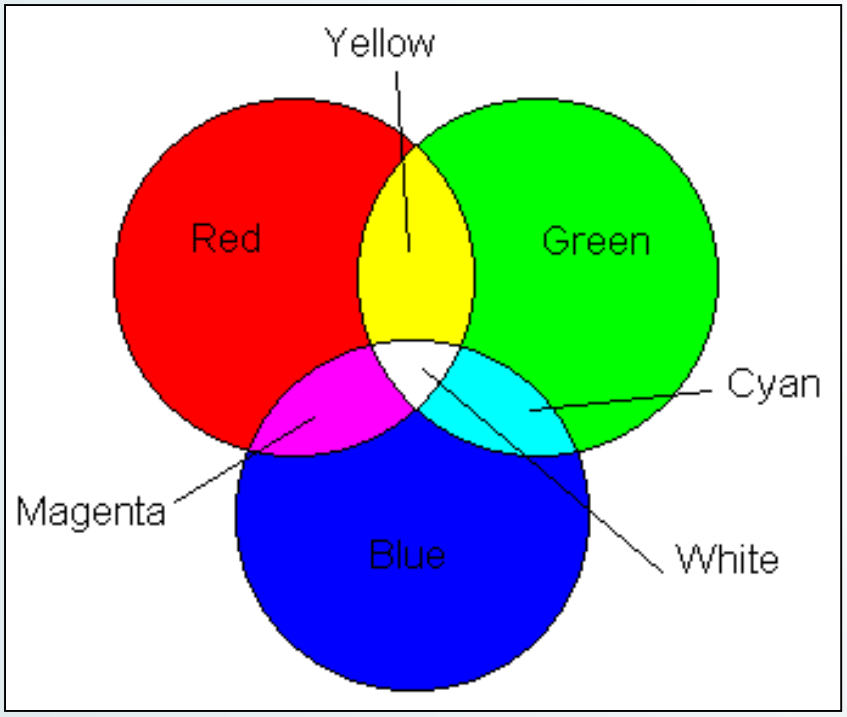
Found Lines

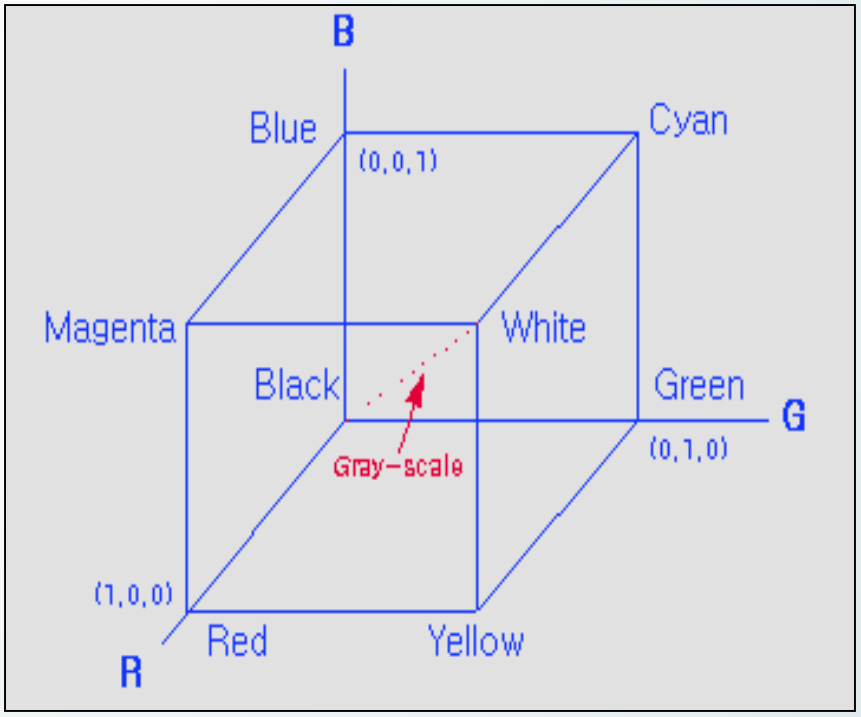


Parameter Space

Color Space

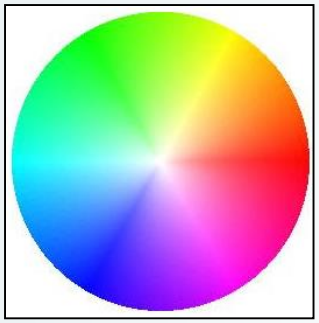
RGB:

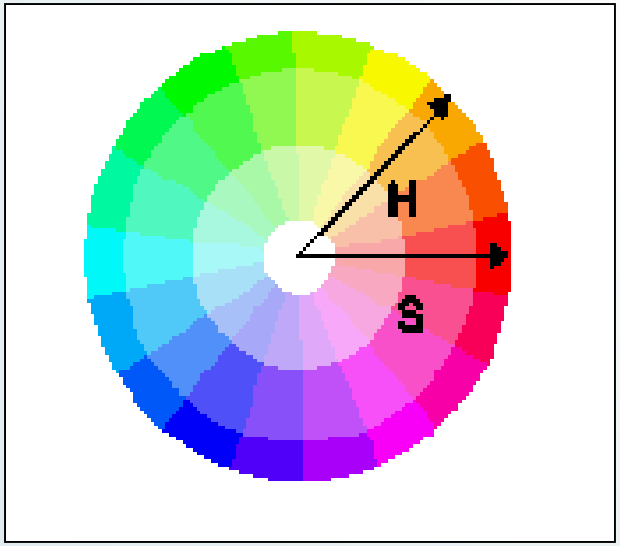


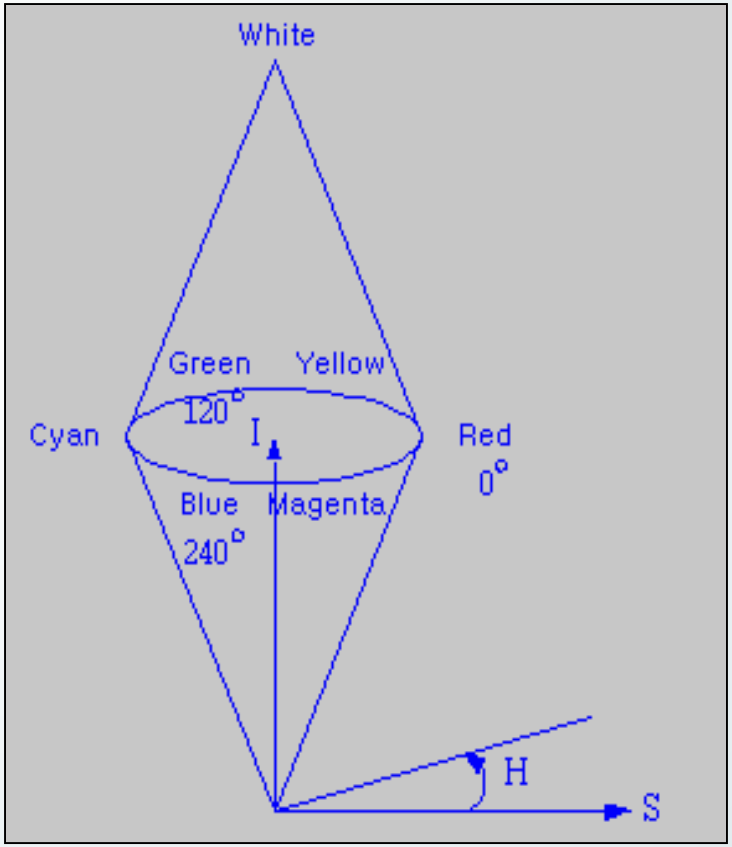


Color Space

HSI:







Color Spaces in OpenCV

- Examples of color spaces in OpenCV:
  - **BGR (i.e., RGB)** - 3 channels color (blue, green, red).
  - **HSV** – Hue, Saturation, and Value; 3 channels.
  - **GRAYSCALE** - Single channel.
- Each channel ranges from 0 to 255.

Color Spaces in OpenCV

- OpenCV function: void **cvtColor**(**src**, **dst**, **code**)
  - Parameters:
    - **src**: input image.
    - **dst**: output image.
    - **Code:** color space conversion code (e.g., CV_BGR2GRAY, CV_BGR2HSV)
- Example:
  - cvtColor(src, bwsrc, CV_BGR2GRAY);
  - cvtColor(src, bwsrc, CV_BGR2HSV);

Example

RGB

HSV

Gray

Image Smoothing

- Image smoothing is used to suppress image noise or undesired image fluctuations.

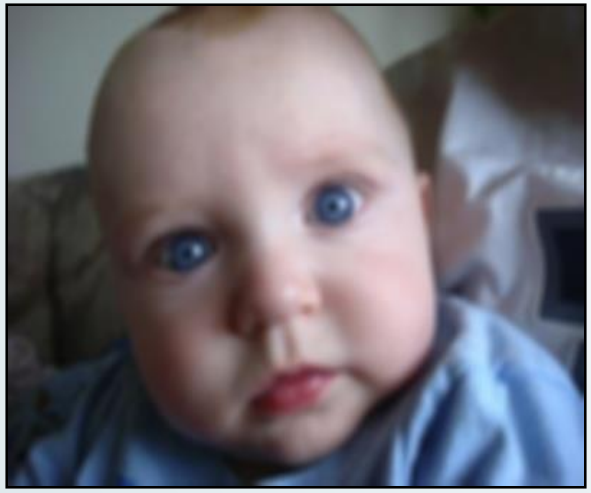
- OpenCV Fuction:
  - void **cvSmooth** (src, dst, **smooth_type**, param1, param2, param3)

  Parameters:
  - **src** – input image.
  - **dst**– output vector of lines.
  - **Smooth_type** –
    - CV_GUSSIAN
    - CV_MEDIAN
    - CV_BLUR
  - ***param1 and param2*** *- the filter window's width and height.*
  - ***param3*** *- Sigma value (only for Gaussian).*
- *Example:*

  cvSmooth(src, dst, CV_BLUR, 3, 3);

Example

Original



medianBlur

GussianBlur

Other Modules & Functions

- Tutorials and examples of other modules and their functions can be found in OpenCV documentation, See:
  - http://docs.opencv.org/2.4/doc/tutorials/tutorials.html
  - http://docs.opencv.org/3.0.0/modules.html
- Other useful blogs:
  - http://www.shervinemami.info/openCV.html
  - http://opencv-srf.blogspot.com
  - http://www.learnopencv.com

Thanks!

Please feel free to email as if you have questions?!

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