Introduction to Image Processing

upGrad knowledgehut

Learning Objectives

- Describe image processing
- Explain digital image processing
- Demonstrate the types of images
- Describe coordinate scheme and RGB
- Explain other color schemes
- Classify histogram and statistics
- Explain intensity transformations
- Describe blending
- Execute edge detection
- Discuss morphological filters

Introduction to Image Processing

Image Processing

Application of algorithmic, mathematical or statistical operations to an image for:

1. Enhancing an image

2. Extracting information

3. Classifying it within a given category

Overview

Digital image = image stored/viewed on computers

Digital images representation: matrix of numbers

Grayscale has a range of numeric values:

- 8-bit representation: 0 is black 255 is white
- 16-bit representation: 0 is black 65,535 is white

Digital Image Processing

History

Digital image Processing started in the 1960s, when computers were quite different from where they are today.

It started at several different major research laboratories, including Bell Laboratory, the Jet Propulsion Laboratory (JPL), and the Massachusetts Institute of Technology, also known as MIT.

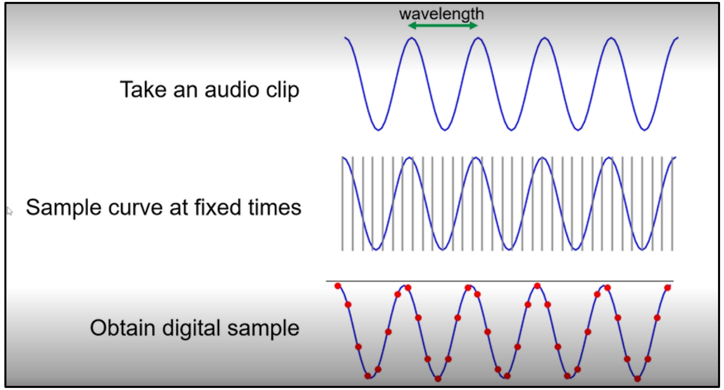
The success story came from NASA, the space detector arranger seven, flew in 1964. It took several different images of the moon at that time, and it sent back over 4000 different images.

Digital Sampling for sound

Sound travels as a waveform. It has a particular wavelength, which corresponds to one over the frequency.

To digitize it, samples are taken at a fixed frequency.

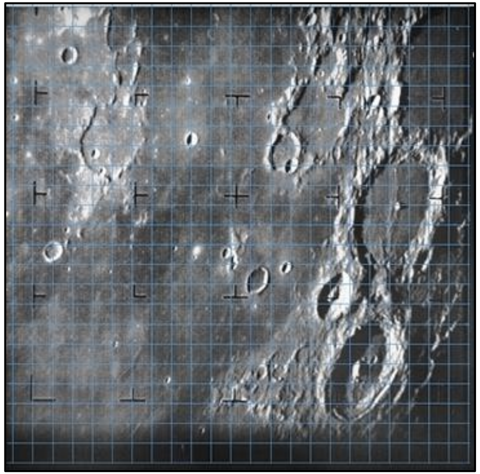
Instead of representing the full blue curve, a series of red dots are represented, taking the different values. This is the way mp3 is restored or a CD is recorded.



Digital Sampling for Images

For images, instead of taking in sampling the waveform, it samples spatially. Every single pixel is a sample of a particular intensity at a given location.

Instead of sampling across the waveform, it samples in both x and y directions to obtain a digital image.



Types of Images

Different Types of Digital Images

The most common source of digital images is the mobile phone that uses visible light.

Other types of images available are used extensively in:

- Scientific,
- Medical, and
- Security fields.

They offer a wide range of different frequencies and energy.

They require different image processing techniques.

Source of Images-Gamma Rays

The narrowest wavelengths with 1 picometer are gamma rays.

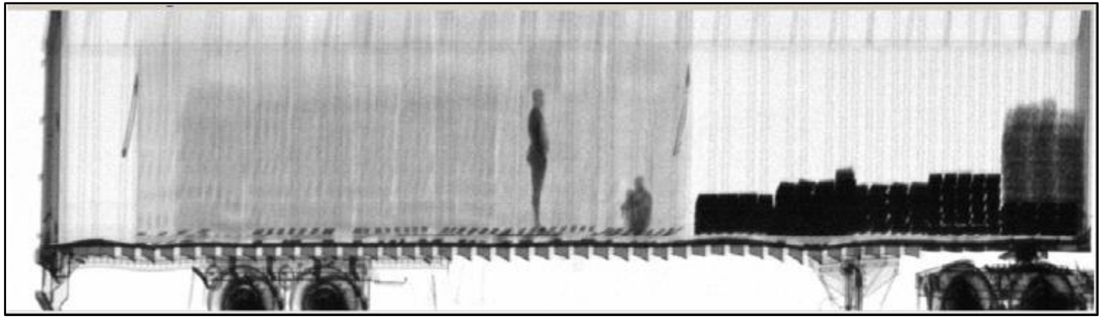
They are used in tomography images in which a patient would swallow a particular radioactive isotope that gets absorbed by a tumor. For example, a PET scan or a SPECT scan.

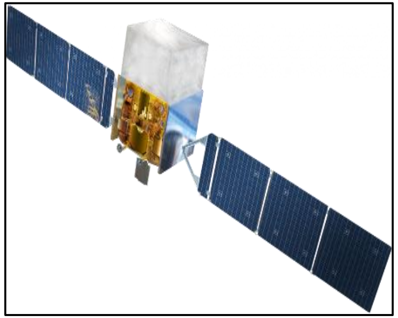
Gamma rays are widely used in medicine.

Source of Image-Security

It is useful for border security because they can go directly through and identify different objects and the cargo of a container as it passes through a border checkpoint, for instance.

Gamma rays are radiations that occur naturally. The atmosphere protects the human from gamma ray radiations. They had to launch satellites that will go outside the atmosphere and will be able to track and capture the gamma rays.





Source of Images -X-Ray

A different frequency is the X ray source of images, X rays have turned to the third to the fourth electron volts in terms of energy, and the wavelength is 0.1 to 10.

They are projected from an x ray machine, and you capture what comes behind it and get a 2D image. These are quite common in medicine.

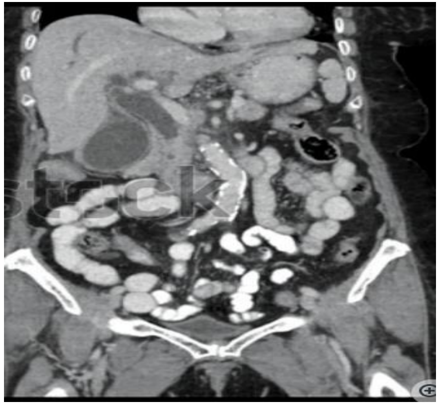
It is also used in baggage scanners at the airport, you use them at the dentist’s office to detect cavities, and so on. They can pass through different materials in different ways.

X rays are also viewed outside the atmosphere, they do not pass through the atmosphere and the Chandra X Ray Observatory has captured some remarkable images of the X ray frequencies

Source of Image X-ray -CT scan

3D reconstructions are possible using X rays. This is the idea of CT scans or CAT scans.

These are a way of computed tomography which have a short wavelength still, you could take an x ray and a receiver for that, move it around a person together, and you can reconstruct a 3D picture from the X ray CT scan.



Source of Image-Ultraviolet GFP

The ultraviolet frequencies are useful n medical imaging, there is a protein called GFP or green fluorescent protein that comes from jellyfish.

lot of the biotechnology engineers create these into cells. They will glow at a certain frequency.

It also works when you engineer it into your cat, you can engineer it into mice, and so on. You can have animals that glow at a certain frequency.

They are used for understanding the response, the amount of light that is emitted for certain biochemical experiments is proportional to the response.

Other Source of Images

Ultraviolet – Application of different dyes to different frequencies, each of which have a fluorescence that has certain frequency.

Visible - Visible light has its own frequency and its own energy, visible lights, are typically 380 to 750 nanometers.

Millimeter Wave - This contains a narrower frequency 1 to 100 millimeter.

Microwave - The microwave offers a lot of opportunity, particularly for remote sensing.

Radio Imaging - Radio images have a low frequency or low energy, that is, the wavelength is about 55 centimeters. It is possible to do Magnetic Resonance Imaging MRI and capture it.

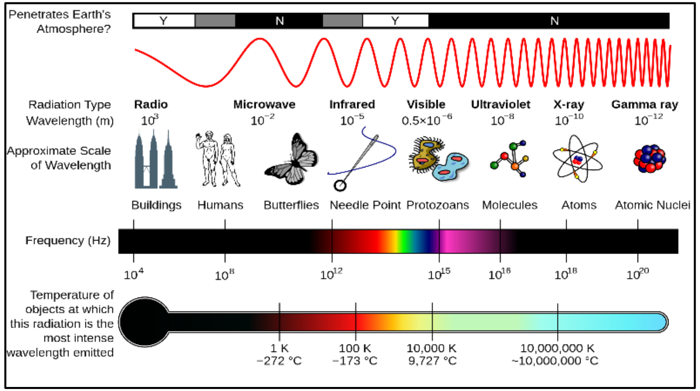
Sound- Ultrasound is used to assess the health of unborn children in the womb.

Electromagnetic Spectrum

They vary in the frequency of the different waveforms that are produced from it.

They vary in how you can use it and the distance they travel and what kinds of things they permeate.

X- rays are harmful to humans as gamma rays. But the lower frequencies are quite safe as you have radio waves all around.



Coordinate Schemes and RGB

Coordinating Scheme

The **first scheme** uses the origin. At the bottom left corner, a typical x y coordinate scheme, where the x corresponds the horizontal axis, the Y corresponds to the vertical axis.

A **second scheme** does something different Instead. It uses a row column format, starting with the origin, or the 00 point in the top left corner. In this scheme, quite often, the row is the first entry, and the column is the second entry.

Open CV is one of the common image processing libraries. It uses the row-column format, counts the number of rows starting at zero at the top, and counts the columns moving to the right from the left top left corner.

Digital Image Coordinate Systems

Grayscale images are stored as single numbers representing the black-white value.

Color images store three numbers representing the color. In the RGB scheme, these are the red-green-blue values.

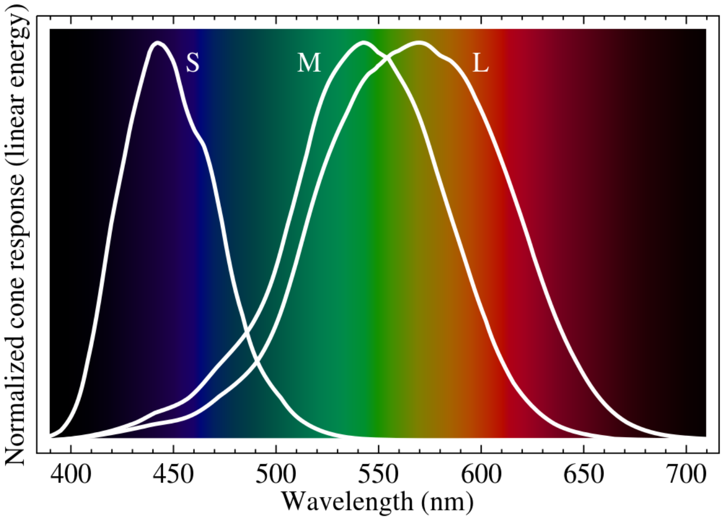
Accessing 1 pixel depends on the representation:

- (x, y) origin in the lower left corner
- (row, column) origin in the upper left corner

Color Images Follow RGB

The most common colors scheme is the red, green, blue scheme. it corresponds to the biology of our human visual system.

Human eyes have these receptors called cones that detect colors at different frequencies. Frequencies correspond to the different wavelengths. And have a short, medium, and long waveforms that are being detected by the three separate cones.



Accessing a Color Pixel

When you access a color pixel in this image, it is 1280 x 1335 x 3.

The first two correspond to the dimensions of the image.

The 3 corresponds to the three-color channels that are receives.

When you look at an individual pixel, you are not getting a single value, instead, you are getting three different integers corresponding to the red, green, and blue channels.

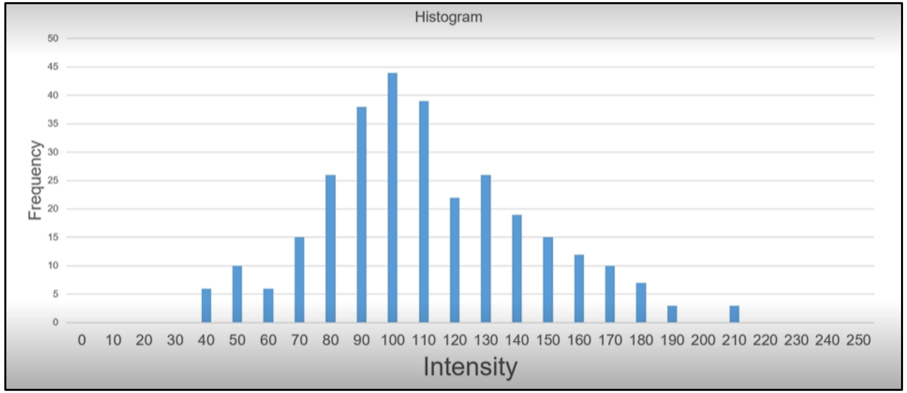
Histogram and Statistics

Histogram of Grayscale Image

A histogram corresponds to a probability mass function. For a grayscale image, which values between 0 and 255, which is of the standard eight-bit representation.

Plot the results as a histogram.

It contains the number of pixels that have a particular intensity value in the image, divided by the number of pixels across all the values in the histogram. This is called a probability mass function.



Histogram

Probability mass function of color intensities

- Normalized histogram
- Sum of the values = 1.0

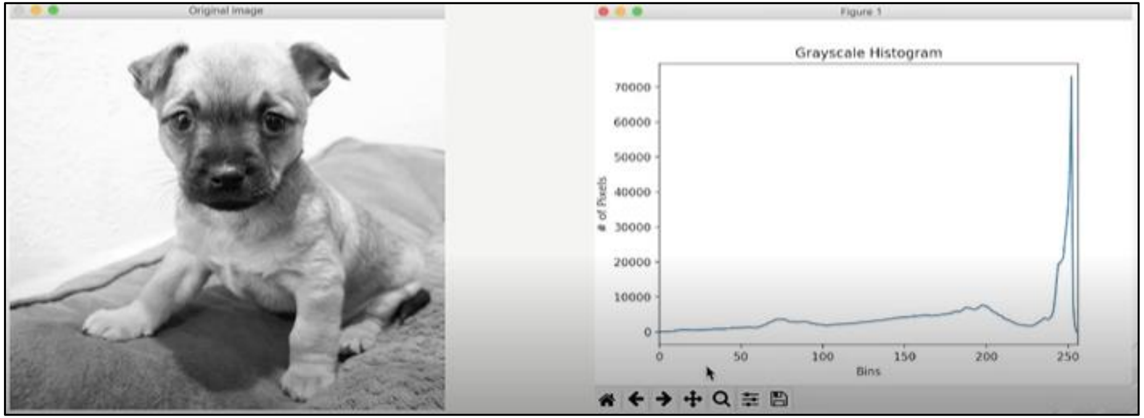
Probability mass function value:

- Mean
- Standard deviation
- Fraction of pixels > value
- Single- or multi-modal

Histogram Intensity

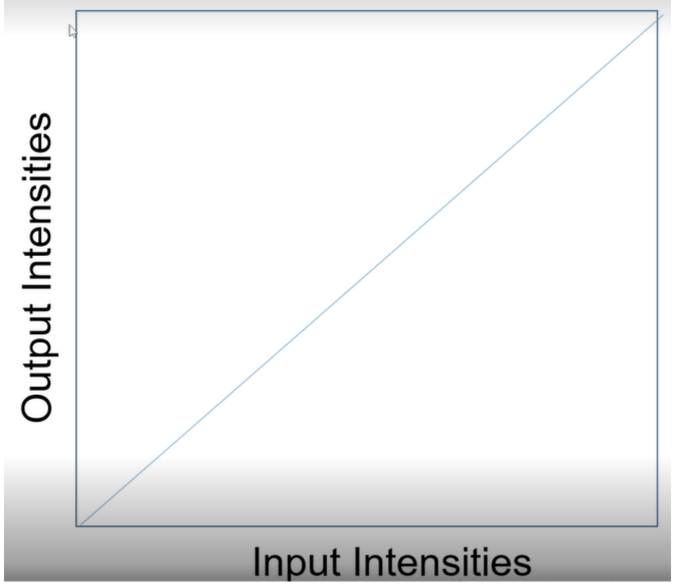
Histogram is a graph or plot, which gives you an overall idea about the intensity distribution of an image.

It is a plot with pixel values ranging from 0 to 255 on x-axis and a corresponding number of pixels in the image on Y-axis.



Intensity Transformation and Gamma

Intensity Transformation



The simplest transformation is a one-to-one mapping, that has the lowest values on the x axis on the left side correspond to an intensity, which maps directly to the output intensity.

In a one-to-one mapping the intensities are directly mapped to the output intensity without any change of value.

To map the intensities across that grayscale value different techniques are used.

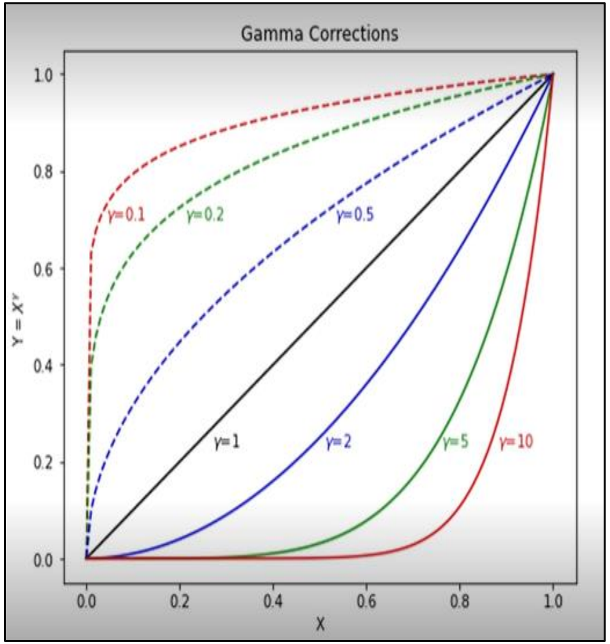
- Gamma
- Stretching
- Brightening /Darkening
- Thresholding

Gamma Correction

Different monitors display things differently. If you are on your phone, versus a PC versus a Mac, the values are displayed differently.

Based on the way that the monitor works, it might have a different gamma value.

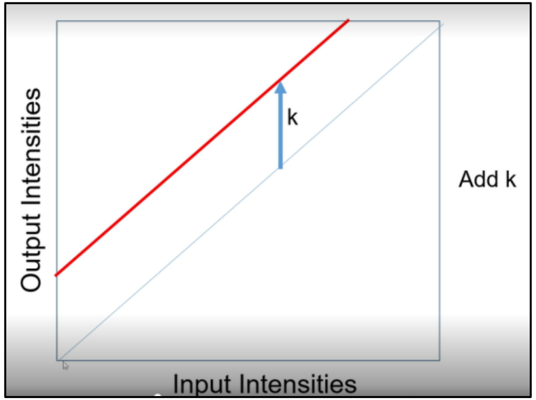
To look at the image and the same scheme, you would need to apply a gamma correction which maps the input to the output in a different way.



Brightening

For brightening the image, you are going to map the input intensities, to some higher value of output intensities.

The value close to 0, indicates that it is black. On mapping it to a value of 40 or k is 40 automatically, the black becomes less black, and it becomes a shade of Gray.

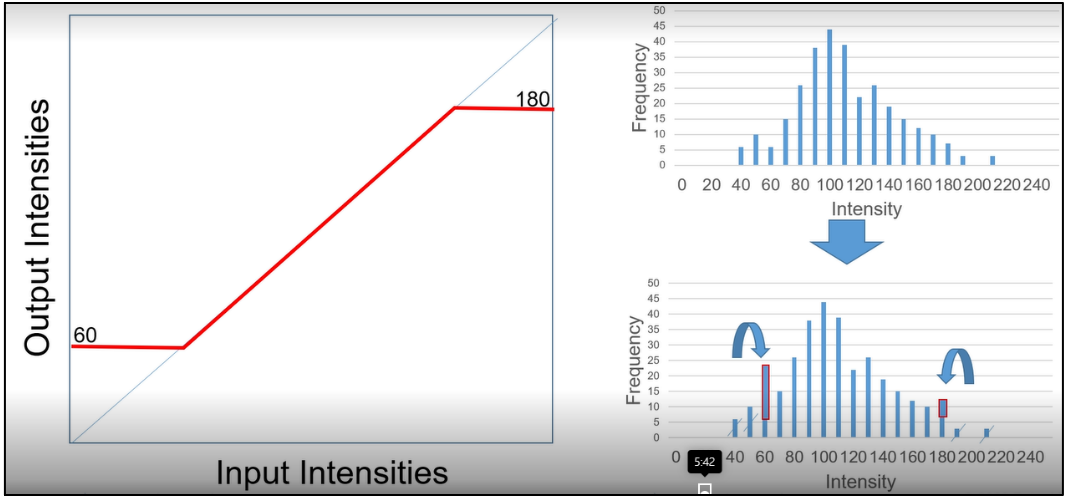


Darkening

The things can be made darker, by subtracting K from every single pixel.

If there is a full range of values for 0 to K all these will still map to black.

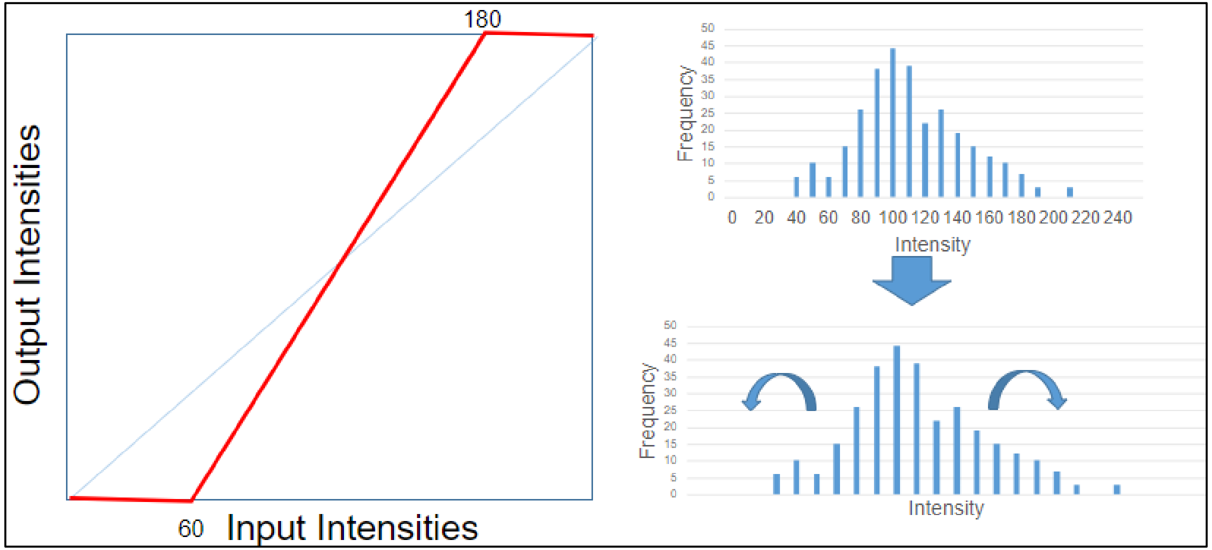
The color depth can be decreased by making everything darker in this case.



Stretching

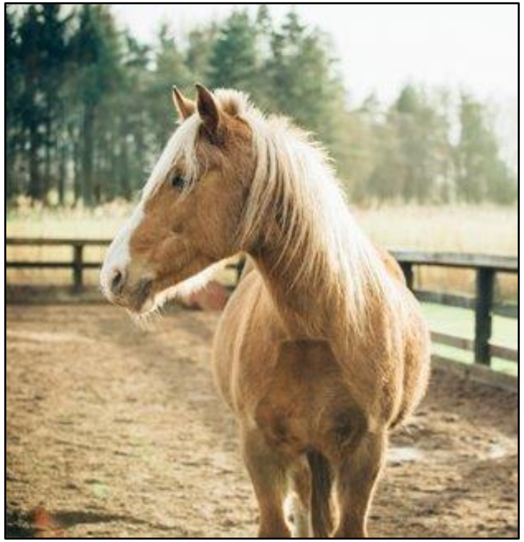
For stretching the values from 60 to 180 to the full dynamic range the values 0 to 275 range are used for the output, rather than the limited 60 to 180. This helps to improve the overall quality of an image.

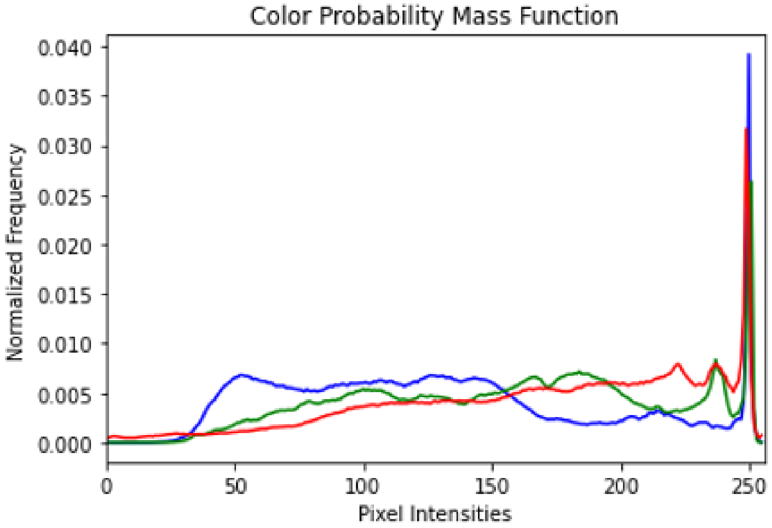
In the final transformation all values less than some threshold get a value of 0, and all the values above that get the maximum value of 255.



Application to Color Images

there is a wide range of intensities across the color scheme. The histogram saturates at some point for these color schemes.





Thresholding

Thresholding is a very popular segmentation technique used for separating an object considered as foreground from its background.

A threshold is a value which has two regions on its either side that is the value below the threshold and the value above the threshold.

Each pixel value is compared with the threshold value. If the pixel value is smaller than the threshold, it is set to 0 otherwise it is set to the maximum value.

Blending

Blending

One of the common techniques used for combining two images is called blending. Blending is a ratio output of two different images.

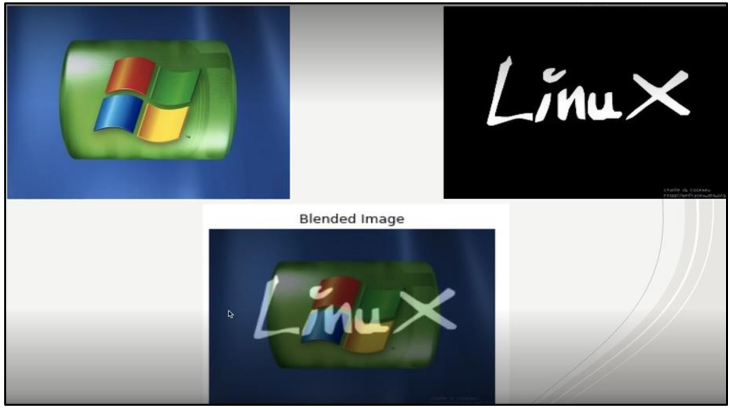
Ratio output=α* image 1+(1-α) * image 2

Blending Images

To blend two images, both images must be of same size. Assign weights to both images and weights must sum to 1.

Assign weights for both the blending images set alpha=0.5 and beta=0.5

Use the function ***Cv2.addWeighted(src 1, alpha,src 2, beta,gamma*** to blend the images and ***cv.imshow('image',blended_img)*** to display the blended image.



Convolution

One of the most important operators in signal processing, and image processing is the convolution operator.

It allows to apply a mask to an image, which can be used for several different purposes.

When there is no overlap, you get the value as 0, for a perfect overlap the value is 1.

Convolution is one of the most important operations in Signal and Image Processing. It could operate in 1D example speech processing, 2D which is image processing, or 3D which is video processing.

Each convolution operation has a kernel, which could be any matrix smaller than the original image Each kernel is useful for specific tasks, such as sharpening blurring or edge detection.

Edge Detection

Sobel Edge Detection

Convolution is the application of a smaller mask or sub image to a larger image; it is a mathematical operation. You can also think about it as a way of pattern finding, function described through math.

Sobel Edge detection

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

Gx

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

Gy

Gx convolution with image → ∇_x
Gx convolution with image → ∇_y

Full edge detection = $\nabla_x^2 + \nabla_y^2$
Finds lines in any direction

Smoothening/Sharpening

Smoothening

- Averaging over a local region.
- Uniform mask is equal throughout the mask.
- Gaussian filter: 2D Gaussian or normal distribution.
- Both filters are normalized >>> don’t increase/decrease.

Averaging Filter

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

Gaussian Filter

$$G = \alpha \exp\left[\frac{-\left(i - \frac{ksize - 1}{2}\right)^2}{2\sigma^2}\right]$$

Sharpening

Officially called “Unsharp masking” (USM)

$$\begin{bmatrix} 0 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{bmatrix} + \left(\begin{bmatrix} 0 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{bmatrix} - \begin{bmatrix} 0 & 1 & 0 \\ 1 & 1 & 1 \\ 0 & 1 & 0 \end{bmatrix} /5 \right) 5 = \begin{bmatrix} 0 & -1 & 0 \\ -1 & 5 & -1 \\ 0 & -1 & 0 \end{bmatrix}$$

Sharpening is a clever idea of removing a smoothed version

Sharpening filter concept:

- $G(x,y) = F(x,y) - F_{smoothed}(x,y)$
- Image takes image F – smoothed version

Morphological Filters

Overview: Morphological Filters

Morphological filters apply to binary images.

Dilate filter expands regions:

- Placed on every “on pixel”
- All pixels matching the filter are turned “on”

Erode filter reduces regions:

- Only pixels that match every “on” pixel of filter stay “on”

Purpose is to smooth artifacts and remove holes.

Thank you!