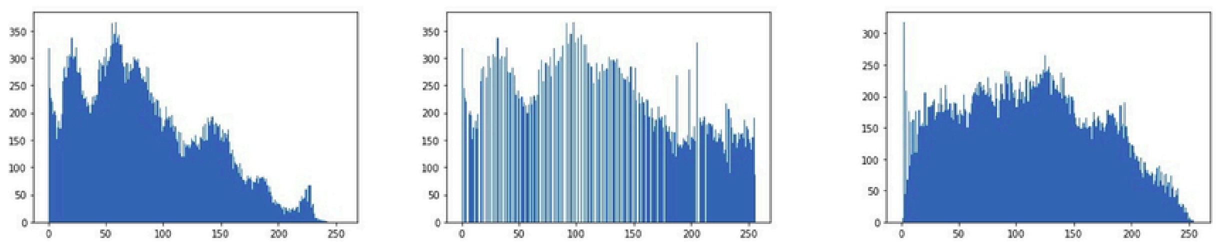
Image Processing for Computer Vision
Session 12

Histogram Equalization

(i) (ii) (iii)

(a) Image enhancement using Histogram Equalization and CLAHE



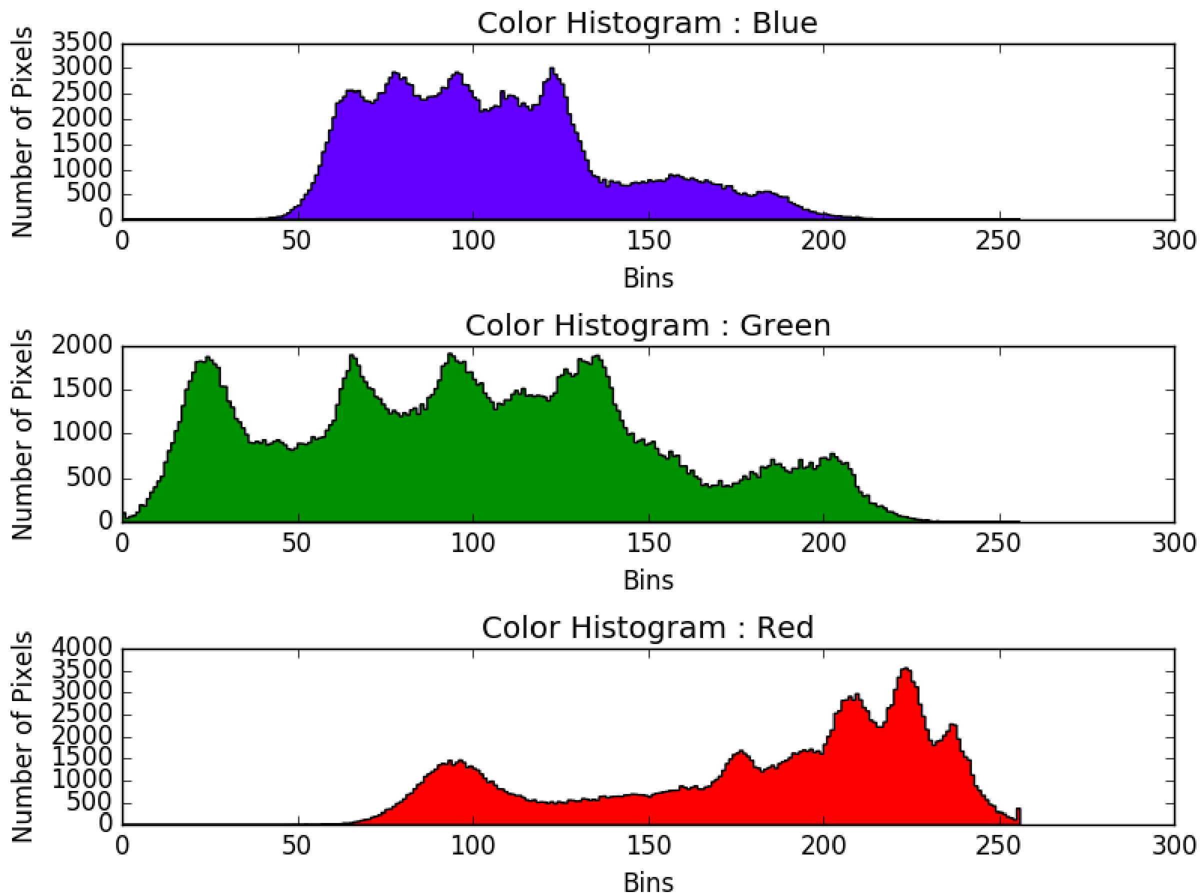
(i) (ii) (iii)

collected

Topics

- Histogram
- Histogram Equalization
- CLAHE
- Morphological Transformation
- Erosion

What is Histogram?



Histogram: A visual representation of the distribution of quantitative data.

In image processing it is:
- a graphical representation of the intensity distribution of an image
- quantifies the number of pixels for each intensity value considered

Contrast is the difference in luminance or color that makes an object (or its representation in an image or display) visible against a background of different luminance or color.

Histogram Equalization

- a technique in image processing which improves the contrast in an image
- stretch out the intensity range

https://docs.opencv.org/3.4/d4/d1b/tutorial_histogram_equalization.html

Advantages:

1. useful in images with backgrounds and foregrounds that are both bright or both dark.

2. Enhances visibility of features in an image
3. Fairly straightforward, adaptive to the input image
4. It is not computationally intensive

Disadvantages:

1. It is indiscriminate. It may increase the contrast of background noise, while decreasing the usable signal.

Applications: enhance the contrast of an image by redistributing the intensity values of pixels. the method can lead to better views of bone structure in x-ray images, and to better detail in photographs that are either over or under-exposed. a key advantage of the method is that it is a fairly straightforward technique adaptive to the input image and an invertible operator. So in theory, if the histogram equalization function is known, then the original histogram can be recovered.

How Histogram Equalization Works?

1. **Histogram Calculation:** The histogram shows how many pixels fall into each intensity level (e.g., from 0 to 255 for an 8-bit image).
2. **Cumulative Distribution Function (CDF):** The CDF is a running total of the histogram values, which gives the cumulative number of pixels for each intensity level. The CDF at a given intensity level indicates the cumulative number of pixels with intensity values less than or equal to that level. This helps in understanding how pixel intensities are distributed across the image.
   Suppose an array of intensity levels: [0, 0, 1, 1, 2, 2, 2, 3]
   Distribution of pixel by intensity
   0: 2
   1: 2
   2: 3
   3: 1
   CDF:
   0: 2
   1: 2+2
   2: 7
   3: 8

3. **Normalization:** The CDF is then normalized to map the pixel values to the full range of intensity values (0 to 255). This normalization ensures that the output image will utilize the entire range of possible intensity values.
   0: 2/8 = 0.25
   1: 4/8 = 0.5
   2: 7/8 = 0.875
   3: 8/8 = 1

4. **Mapping Intensity Values:** Each pixel in the original image is then mapped to a new intensity value based on the normalized CDF. This mapping redistributes the pixel values, enhancing the contrast of the image.
   The mapping is usually done by the below formula:

   $New\ intensity = round(normalized\ CDF * max.\ intensity\ )$

   0: 0.25*3 -> 1
   1: 0.5*3 -> 2
   2: 0.875*3 -> 3
   3: 1*3 -> 3

   Original: [0, 0, 1, 1, 2, 2, 2, 3]
   Mapped: [1, 1, 2, 2, 3, 3, 3, 3]

Histogram Equalization Techniques:

The most commonly used histogram equalization techniques in image processing and computer vision are:

1. **Global Histogram Equalization (GHE):**

   - This is the basic form of histogram equalization, where the entire image histogram is transformed to achieve a uniform distribution of pixel values.
   - It is effective for improving the overall contrast of the image, but it may not work well for images with non-uniform illumination or local contrast issues.

2. **Adaptive Histogram Equalization (AHE):**

   - AHE divides the image into small (grid), contextual regions and applies histogram equalization to each region independently.
   - This helps to enhance local contrast and preserve more details, especially in areas with non-uniform illumination.
   - However, AHE can also amplify noise in relatively homogeneous regions of the image.

   OpenCV does not have any direct function for AHE.

3. **Contrast Limited Adaptive Histogram Equalization (CLAHE):**

   - CLAHE is an extension of AHE that includes a contrast limiting step to prevent amplification of noise.

- It limits the amplification of contrast by clipping the histogram at a predefined value before applying the equalization.
- CLAHE is widely used for improving the contrast and enhancing the details in medical images, satellite imagery, and other applications where local contrast **is important.**

cv2.createCLAHE(clipLimit, tileGridSize)
clipLimit: Threshold for contrast limiting.
tileGridSize: Size of grid for histogram equalization. Input image will be divided into equally sized rectangular tiles. tileGridSize defines the number of tiles in row and column.

Learn more: Bi-Histogram Equalization (BHE), Dualistic Sub-Image Histogram Equalization (DSIHE), Brightness Preserving Bi-Histogram Equalization (BBHE) etc.

These histogram equalization techniques offer different trade-offs between contrast enhancement, noise amplification, and brightness preservation, making them suitable for various image processing and computer vision applications.

Morphological Transformations

Morphological transformations are some simple operations based on the image shape. It is normally performed on binary images. It needs two inputs, one is our original image, second one is called **structuring element** or **kernel** which decides the nature of operation.

1. Erosion

NRDC

The basic idea of erosion is just like soil erosion only, it erodes away the boundaries of foreground object (Always try to keep foreground in white). So what it does? The kernel slides through the image (as in 2D convolution). A pixel in the original image (either 1 or 0) will be considered 1 only if all the pixels under the kernel are 1, otherwise it is eroded (made to zero).

So what happens?
All the pixels near boundary will be discarded depending upon the size of kernel. So the thickness or size of the foreground object decreases or simply white region decreases in the image. It is useful for removing small white noises (as we have seen in colorspace chapter), detach two connected objects etc.

cv.erode*(img, kernel, iterations = 1)*