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Batch - 7 (AIML)

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Assignment - 2

Image Enhancement Technique.

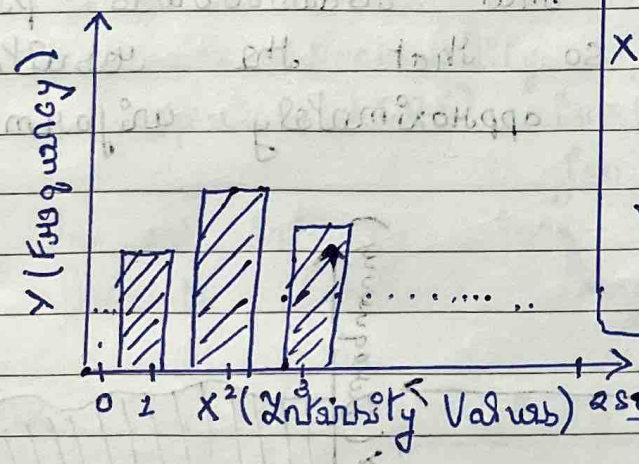
Image Enhancement is the process of improving the visual quality of a digital image by making important details clearer, reducing noise & also highlighting useful features.

Histogram Processing Method.

Before diving into Histogram Processing Method, let's understand what is an Histogram.

Image Histogram:

An image histogram is a graphical representation of how pixel intensity values are distributed in an image.



X - Axis - Intensity Values (0 to 255) for grayscale image
Y - Axis - No of pixels (Frequency)

- It helps in understanding:
  Brightness, contrast & distribution of gray levels.

Lets con observe that:
In dark image the histogram is concentrated on left whereas in bright image

the histogram is concentrated on right.

- In low contrast images the histogram is narrow & in High contrast images the histogram is spread out.

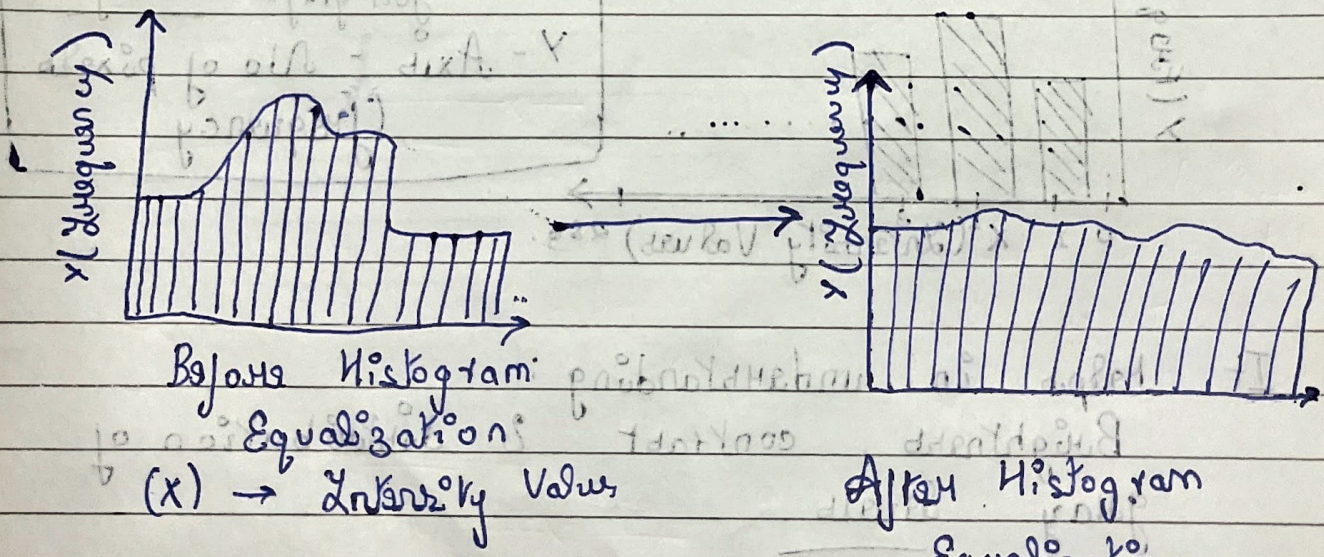
Histogram based Enhancement is used to :-

→ improve contrast (In Medical Imaging)
→ reveal Hidden details
→ make image more visually clear.

Types of Histogram Processing Technique :-

① Histogram Equalization :-

Histogram Equalization is a Histogram Processing technique that redistributes pixel intensity values so that the resulting Histogram becomes approximately uniform.



Before Histogram Equalization

(x) → Intensity Value

After Histogram Equalization.

(x) → Intensity Values

The main goal of Histogram Equalization (HE) is to Enhance global contrast. & make details visible in darker regions & as well as brighter regions.

Formula:

$$p(r_k) = \frac{n_k}{MN}$$

$$S_k = (L-1) \sum_{j=0}^{k} p(r_j)$$

r_k = input gray level
$p(r_k)$ = prob. of occurrence
L = total Gray level (256)
n_k = no of pixel with intensity r_k
$M \times N$ → image size.

Steps for Histogram Equalization:

(i) Read the grayscale image
(ii) Compute Histogram
(iii) Compute probability of Each intensity
(iv) Compute (CDF) Cumulative Distribution fxn.
(v) Map old intensity values to new values.
(vi) Generate Enhanced Image.

REAL World USE CASES

(i) Medical X-Ray image enhancement
(ii) Satellite image contrast improvement
(iii) old photograph restoration.

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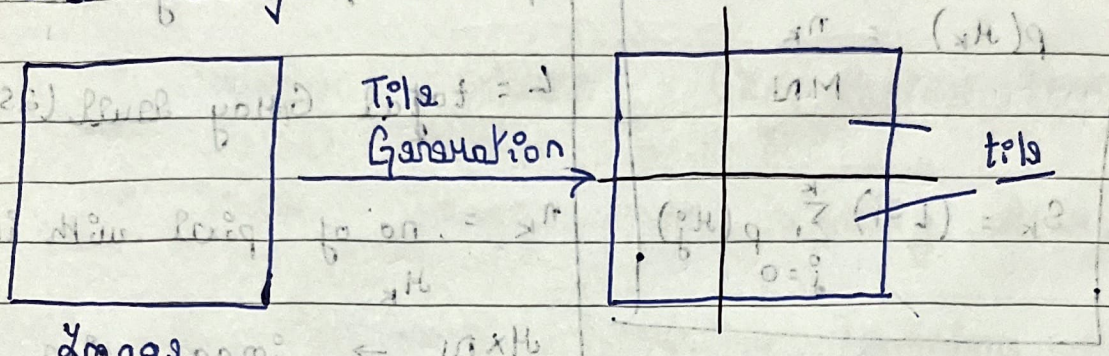
(ii) Adaptive Histogram Equalization (CLAHE)

CLAHE stands for Contrast limited Adaptive Histogram Equalization.

In Adaptive Histogram Equalization the image is divided into small tiles.



Each tile is Histogram-Equalized one by one. (that is Histogram equalization is applied locally)

~~It helps~~ The contrast is limited to avoid noise amplification.

Steps :

1. Divide images into small blocks / tiles
2. Apply histogram Equalization on Each tile
3. Clip histogram using clip limit
4. Neighbouring tiles are combined using interpolation

USE CASES

1. Medical Imaging (MRI, CT Scan)
2. Underwater image Enhancement.

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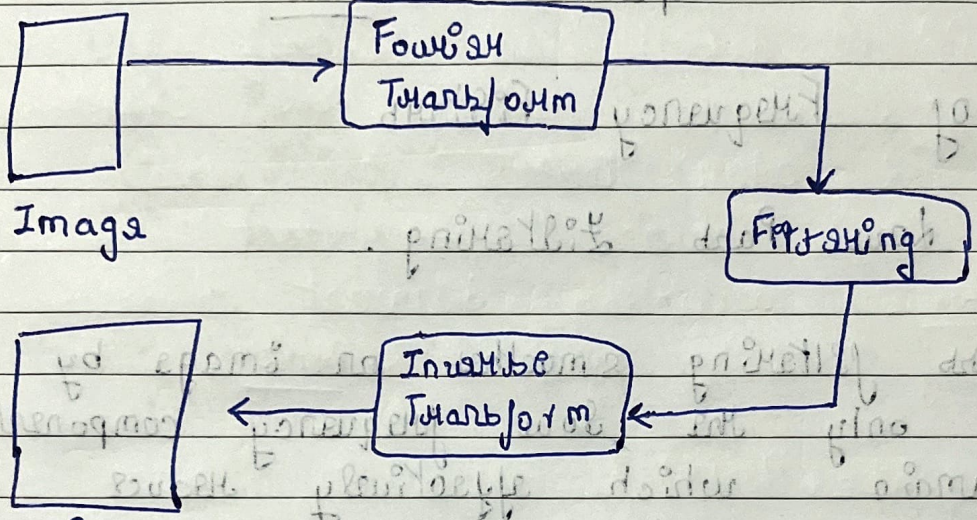
Frequency Domain Enhancement

Frequency domain Enhancement in which an image is processed by modifying its frequency components instead of directly changing pixel values.

Image is converted from spatial domain to frequency domain using Fourier Transform.



Forward Fourier Transform Formula:

For a digital image $f(x,y)$ of size $M \times N$:

$$F(u,v) = \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} f(x,y)\, e^{-j2\pi \left(\frac{ux}{M} + \frac{vy}{N}\right)}$$

where,

- $f(x,y)$ → input image in spatial domain.
- $F(u,v)$ → image in frequency domain
- x, y → spatial coordinates
- u, v → freq "

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- $M, N \rightarrow$ image dimensions.
- $j = \sqrt{-1}$.

Inverse Fourier Transform :

$$f(x,y) = \frac{1}{MN} \sum_{u=0}^{M-1} \sum_{v=0}^{N-1} F(u,v)\, e^{+j2\pi\left(\frac{ux}{M} + \frac{vy}{N}\right)}$$

used to convert filtered frequency image back to spatial domain.

TYPES of Frequency Filters :

(1) Low Pass Filtering.

Low Pass filtering smoothes an image by allowing only the low frequency component to remain which effectively reduce noise & minor details.

Blurs Edges but smoothens Image.

Mathematical Model

$$H(u,v) = \begin{cases} 1, & D(u,v) \leq D_0 \\ 0, & D(u,v) \geq D_0 \end{cases}$$

USE cases

(i) Noise Removal
(ii) Image Smoothing
(iii) Preprocessing before segmentation.

(ii) High Pass Filtering

High pass filtering sharpens the image by allowing high frequencies. It Enhances Edges & fine details & Suppresses smooth areas.

Mathematical Model

$$H(u,v) = 1 - LPF(u,v)$$

USE Cases:

(i) Edge detection
(ii) Image sharpening
(iii) Feature Extraction

• Medical Imaging
• Document Analysis

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Code Explanation

Histogram Processing:

(1) cv2.calcHist() function

This function is used to calculate the histogram of an image. It shows the frequency of each pixel intensity value present in an image.

This fxn is directly applied ~~only~~ on grayscale images by selecting one channel.

For colour images, it is applied on a single channel ~~after colour space conversion~~ by selecting different channels such as Red, green & blue.

(2) cv2.equalizeHist()

The cv2.equalizeHist() fxn improves the contrast of a grayscale image by redistributing pixel intensity values across the full intensity range.

This function is applied directly only on grayscale images & for colour images, it is applied on a single channel after colour space conversion.

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③ CLAHE (Adaptive Histogram Equalization)

CLAHE enhances images contrast by applying histogram equalization on small local regions instead of the entire image.

Ways of using the fxn:

CLAHE is implemented in two steps.

(i) the CLAHE obj is created using create CLAHE()

(ii) then the enhancement is applied using apply() fxn.

★ Effect of Parameters:

the clip limit controls the amount of contrast enhanced & prevents noise amplification. The grid size controls local enhancement, where smaller tiles enhances more details.

Frequency Domain Enhancement.

Fourier Transform converts an image from spatial domain to frequency domain. low pass filtering removes high frequency noise, while High pass filtering enhances Edges & fine details.

Ways of Using the fxn:

Filtering can be performed either in spatial domain using smoothing filters or in freq domain using Fourier Transform &

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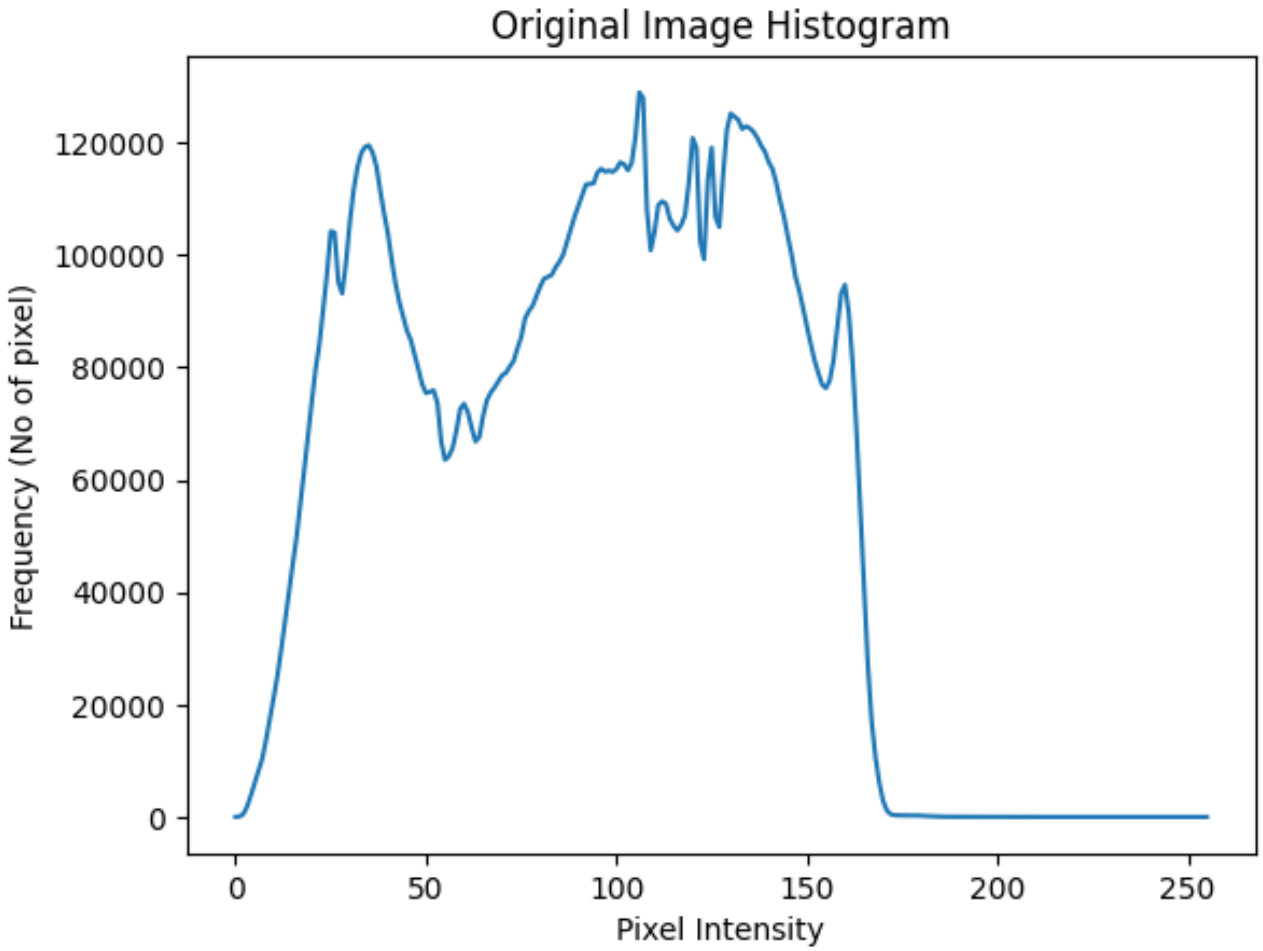
Frequency masks

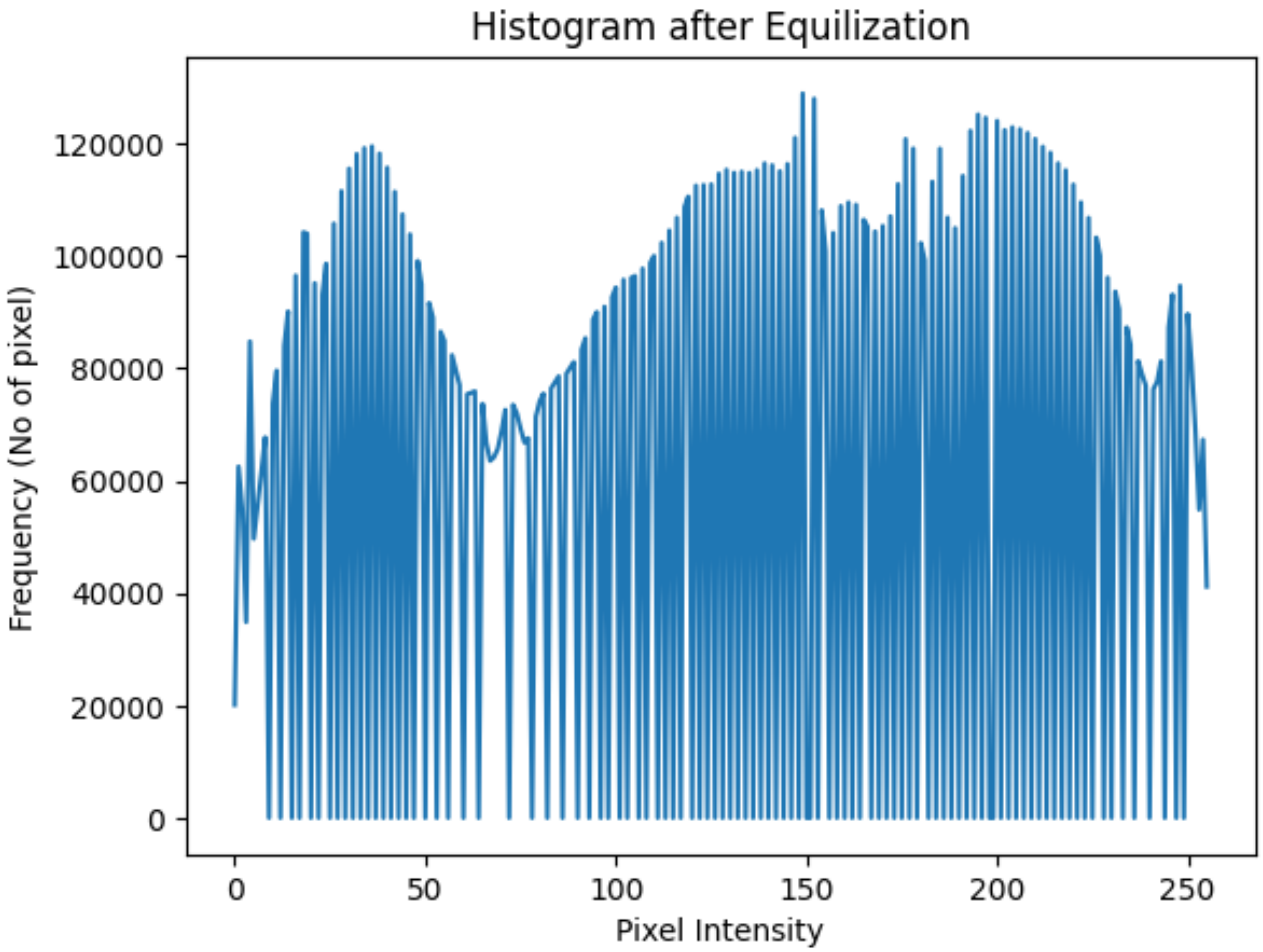
Effect of Parameters:

Changing the cut off frequency affects the following result. Smaller cut off removes more detail, while larger cut off removes more information.

Note: All explanations are based on the implemented code.

Original (Low Contrast Image)



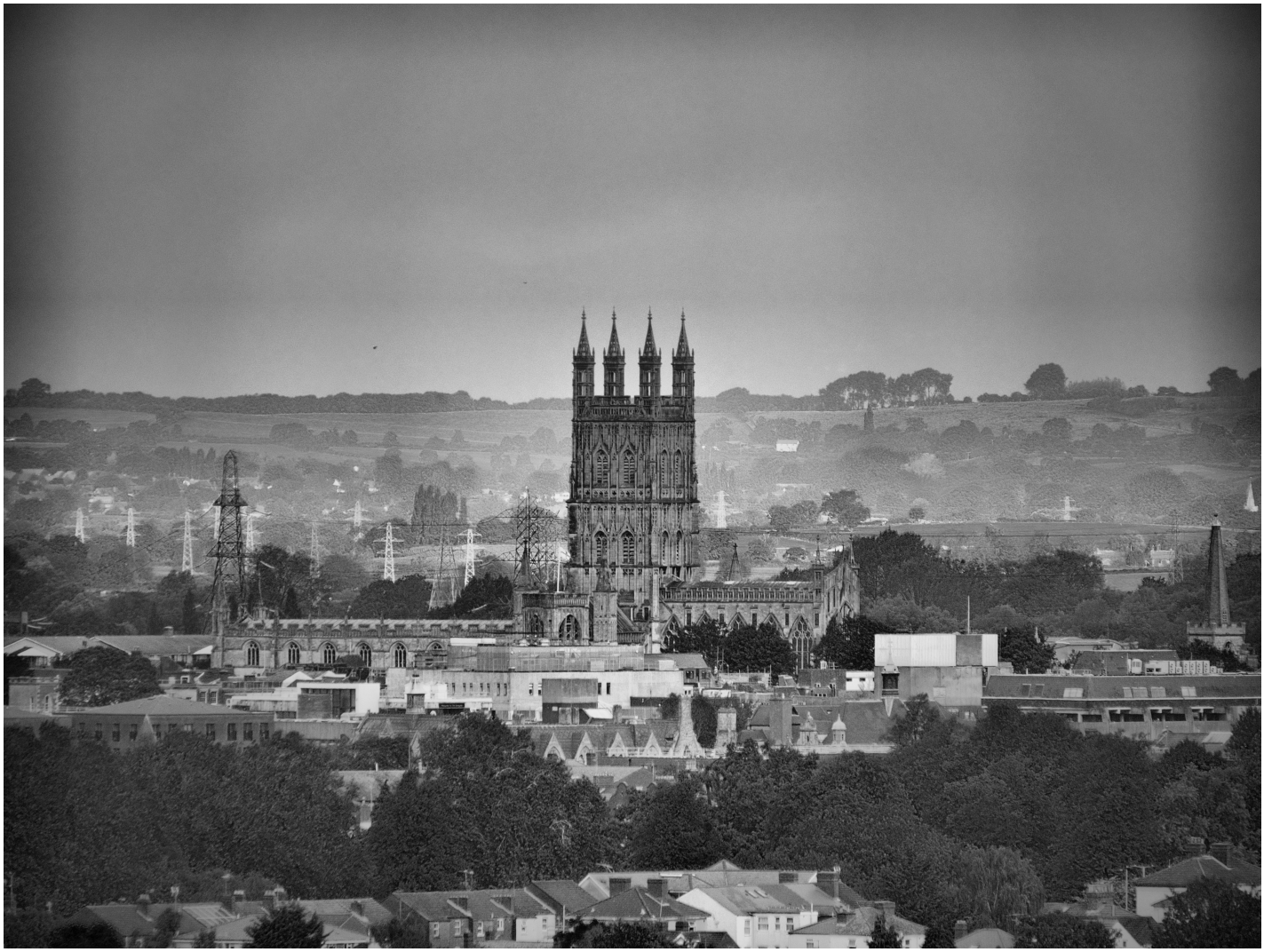


Histogram Equalised image

Original Image

Histogram Equalized Image

CLAHE (Adaptive Histogram Equalisation) image



Original Image

Clahe Image

Original Noisy Image Before Low Pass Filtering

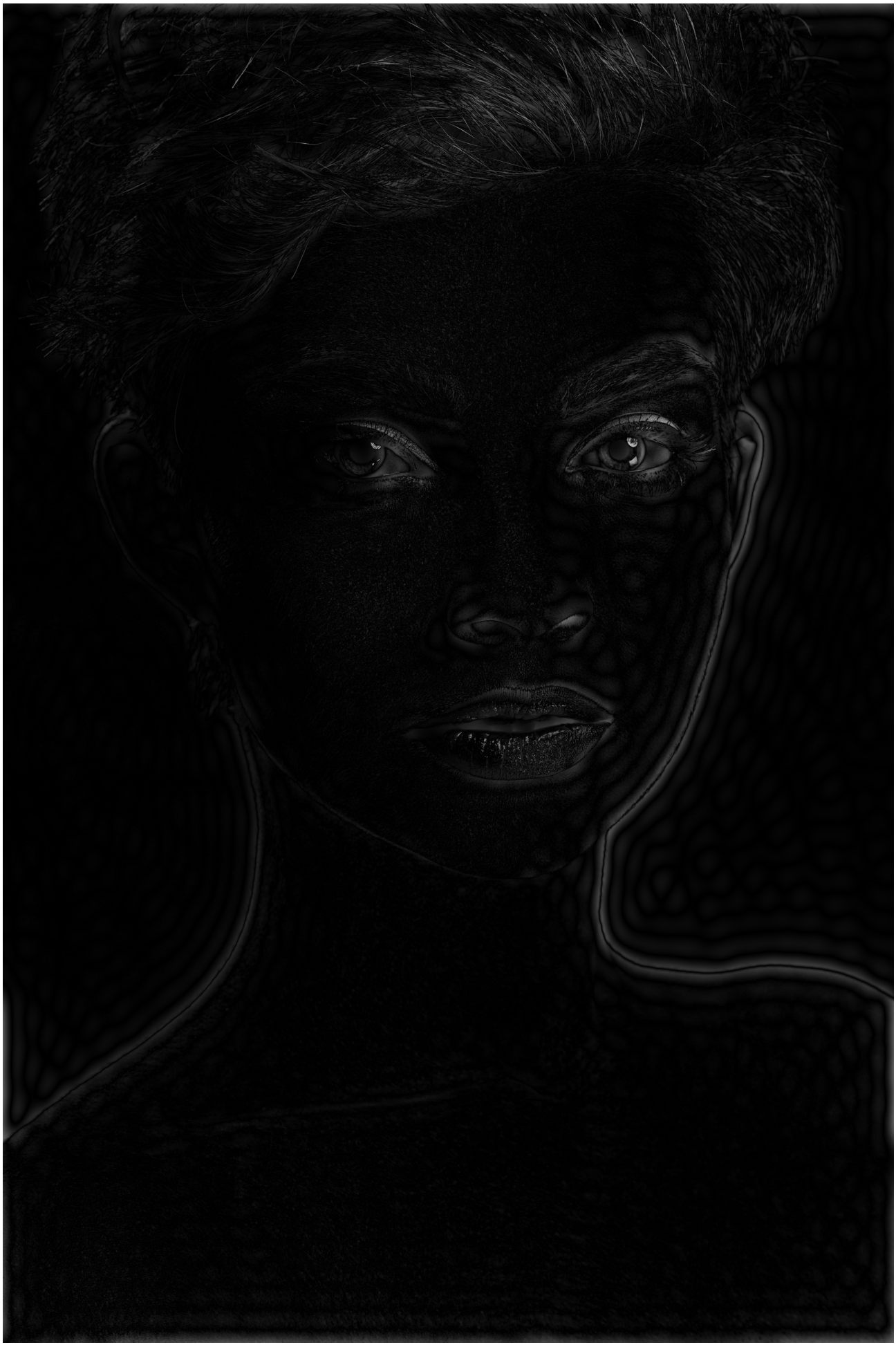
Low Pass Filtered Image

Original Noisy Image

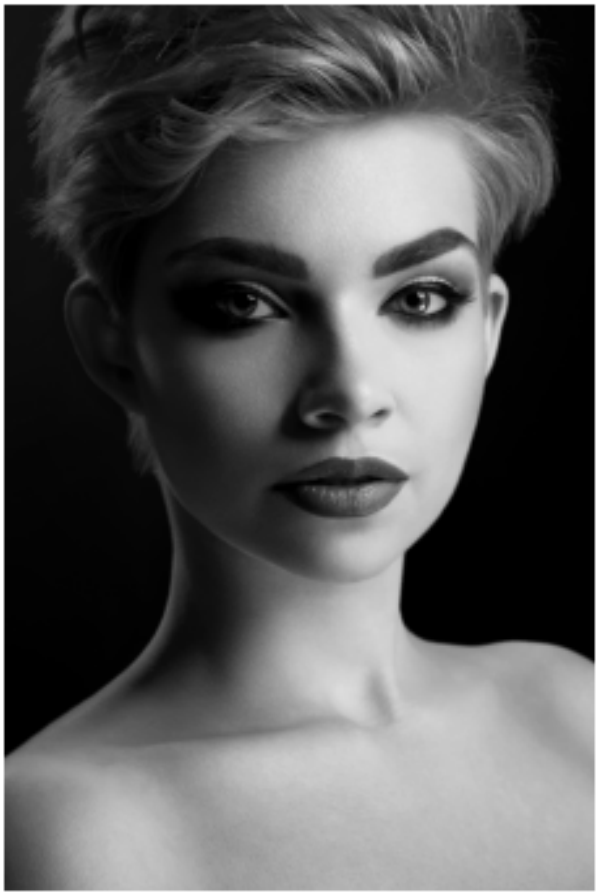
Low Pass Filtered Image

Original image before High Pass Filtering

High Pass Filtered image



Original Image



High Pass Filtered Image