## ****HISTOGRAM PROCESSING****

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| **Table of Contents** |
| 1. **Introduction** |
| 1. **What is a Histogram?** |
| 1. **Histogram Equalization** 3.1 Concept 3.2 Cumulative Distribution Function (CDF) |
| 1. **Histogram Matching** 4.1 Concept 4.2 Applications |
| 1. **Local Histogram Processing** |
| 1. **CLAHE (Contrast Limited Adaptive Histogram Equalization)** |
| 1. **Algorithms** 7.1 Histogram Equalization (Global) 7.2 Histogram Matching (Histogram Specification) 7.3 Local Histogram Processing (Adaptive Histogram Equalization) |
| 1. **Applications of Histogram Processing** |
| 1. **Conclusion** |

1. **Introduction:**

In this document we are going to see about Histogram Processing.

### ****What is a Histogram?****

A histogram is a graphical representation of the tonal distribution in a digital image. It shows the number of pixels for each intensity value. The **x-axis** represents pixel intensity levels (from black to white), and the **y-axis** shows the frequency of each intensity.

By analyzing the histogram, we can understand the **contrast**, **brightness**, and **tonal balance** of an image.

### ****Histogram Equalization****

Histogram Equalization is a technique used to **enhance image contrast**. It works by redistributing pixel intensities so that they span the entire range of possible values, making dark and bright regions more visible.

This method is especially useful for **low-contrast images**, as it spreads out the intensity values, making image features more distinguishable.

The process involves:

* Calculating the **Cumulative Distribution Function (CDF)**.
* Mapping original intensities to new values using the CDF.
* The result is an image with a **more uniform histogram** and improved visual details.

### ****Histogram Equalization Visualization****

The original image’s CDF is typically non-linear and clustered in a small range, indicating poor contrast.  
After histogram equalization:

* The CDF becomes **linear**, indicating a uniform distribution.
* Pixel values are **stretched** across the full intensity range.
* **Contrast is enhanced**, and hidden details become visible.

### ****Histogram Matching (Histogram Specification)****

Histogram Matching adjusts the intensity distribution of one image to **match** the histogram of another image, known as the **reference image**.

**Steps:**

* Compute the histograms and CDFs of both images.
* Match intensities by finding a mapping between input and reference histograms via inverse CDF.
* Apply the mapping to transform the input image.

This technique is used in:

* Medical imaging
* Remote sensing
* Image normalization

### ****4.2 Importance of Histogram Matching****

Histogram matching helps:

* **Standardize lighting** conditions in multiple images.
* Maintain **visual consistency** across datasets.
* Allow **better comparison** in domains like medical scans and satellite imagery.

### ****Local Histogram Processing****

Unlike global methods, **Local Histogram Processing** enhances contrast in **specific regions** of an image.

**Steps:**

* Divide the image into small blocks (e.g., 8×8 or 32×32).
* Apply histogram equalization **individually** to each block.
* Use **bilinear interpolation** between blocks to smooth transitions.
* Reconstruct the final image with enhanced local contrast.

This is useful when different areas of an image have **uneven lighting**.

### ****6. CLAHE: Contrast Limited Adaptive Histogram Equalization****

**CLAHE** is an advanced local contrast enhancement technique.

Key features:

* The image is divided into small **tiles**.
* Histogram equalization is applied to each tile.
* **Contrast is limited** to avoid noise amplification by clipping the histogram.
* Suitable for **medical imaging** and **low-light** scenarios.

CLAHE improves local contrast while minimizing visual artifacts.

### ****7 Histogram Processing Algorithms****

#### ****7.1. Histogram Equalization (Global)****

Enhances overall contrast by spreading out intensity values.

**Steps:**

* Compute the histogram of the image.
* Normalize it to obtain the PDF.
* Compute the CDF of the PDF.
* Multiply CDF by (L−1), where L = number of intensity levels.
* Map original pixel values using the new intensity values.
* Construct the output image.

#### ****7.2. Histogram Matching (Histogram Specification)****

Makes the histogram of an image resemble that of a reference.

**Steps:**

* Compute histogram and CDF of input image.
* Compute histogram and CDF of reference image.
* Create a mapping using inverse CDF matching.
* Transform pixel values based on the mapping.
* Generate the output image.

#### ****7.3. Local Histogram Processing (Adaptive Equalization)****

Enhances local contrast in varying lighting conditions.

**Steps:**

* Divide the image into small tiles.
* Apply histogram equalization to each tile.
* Interpolate between tile boundaries (e.g., bilinear).
* Combine tiles to form the enhanced image.

8 **Applications of Histogram Processing**

* **Medical Imaging**: Enhancing features in X-rays, MRIs.
* **Satellite Imaging**: Revealing terrain details in remote sensing.
* **Computer Vision**: Preprocessing for object detection and classification.
* **Photography**: Enhancing aesthetic quality and correcting exposure.

### ****9 Conclusion****

Histogram processing is a fundamental tool in digital image enhancement. Techniques such as:

* **Histogram Equalization** (global contrast),
* **Histogram Matching** (standardization), and
* **Local Histogram Processing** (local enhancement)

Help improve image visibility, interpretability, and consistency across multiple domains.