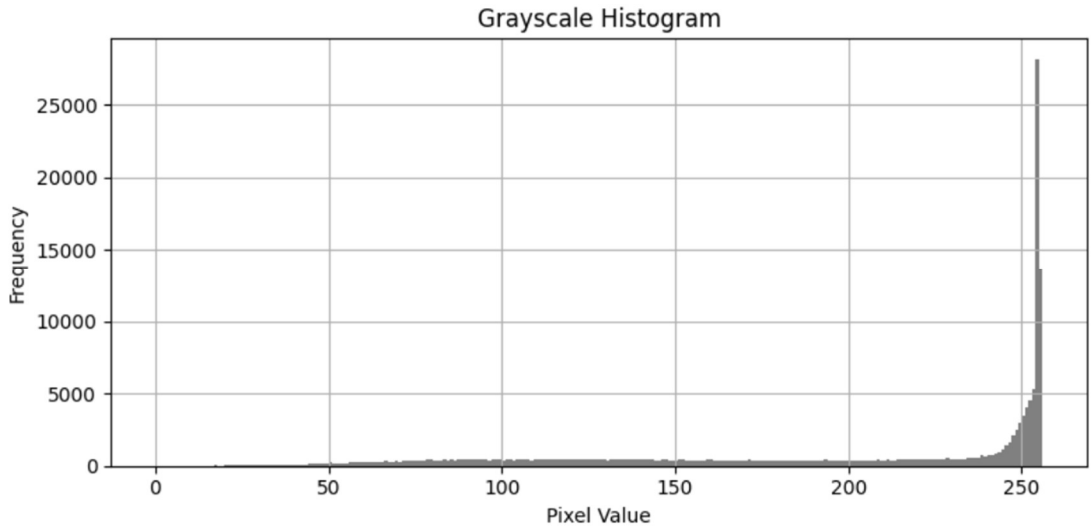
Thresholding in Image Processing

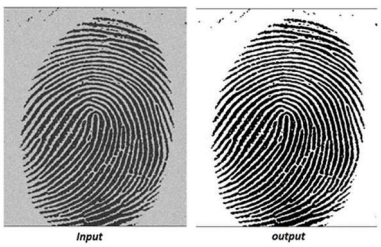
Image thresholding is a technique in computer vision that converts a grayscale image into a binary image, where pixels are classified as either foreground (object of interest) or background based on their intensity values and a predetermined threshold. Pixels with intensities above the threshold are assigned to the foreground, while those below are assigned to the background.

- It segments the image by turning all pixels below a certain threshold value to 0 (black) and those above it to 1 (white).
- Useful for separating objects from the background.



Why is Thresholding Needed?

- **Simplifies Image Analysis:** Many images processing tasks like object detection, counting, or shape analysis require clearly separating the object from the background.
- **Reduces Complexity:** Working on binary images is computationally cheaper and simpler than working on grayscale or color images.
- **Prepares for Segmentation:** Thresholding is often a first step before more complex segmentation methods.
- **Useful in Applications:** For example, in medical imaging (detect tumors), document scanning (extract text), industrial inspection (detect defects).



Process:

- **Process:** Compare each pixel's intensity to a threshold value.
- **Result:** Pixels above the threshold are set to white (255), and those below are set to black (0).
- **Purpose:** Simplifies the image, making it easier to identify and analyze regions of interest.

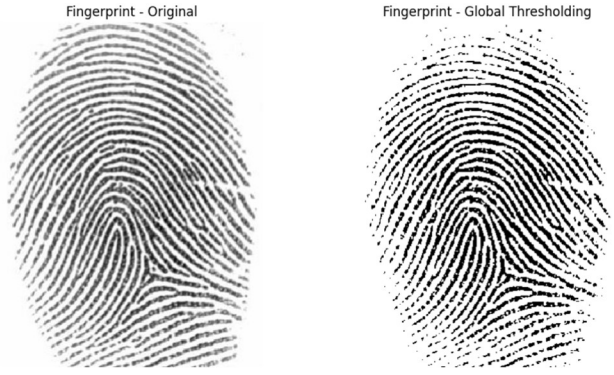
Global Thresholding:

Global Thresholding uses a single threshold value for the entire image. Each pixel is compared to this threshold. If the pixel intensity is greater than or equal to the threshold, it's set to white (255); otherwise, it's set to black (0). This method is fast and simple, ideal for images with uniform lighting and good contrast.

Global thresholding is useful when:

- Lighting conditions are **consistent across the image**.
- The **contrast between object and background** is high.
- You want a **quick binary segmentation**.

It is not suitable for images with shadows, gradients, or non-uniform illumination



Adaptive Thresholding

Adaptive Thresholding improves on global thresholding by calculating local thresholds for small blocks of the image. Each pixel's threshold is determined by the mean or Gaussian-weighted sum of neighboring pixels. This method adapts to local lighting variations, making it very effective for images with uneven lighting or texture.

Adaptive thresholding is needed when:

- The image has uneven illumination.
- There are shadows or light gradients.

- You need to segment textured or detailed areas, such as fingerprints, paper scans, or old documents.

It is slower than global thresholding but much more accurate in real-world conditions…..

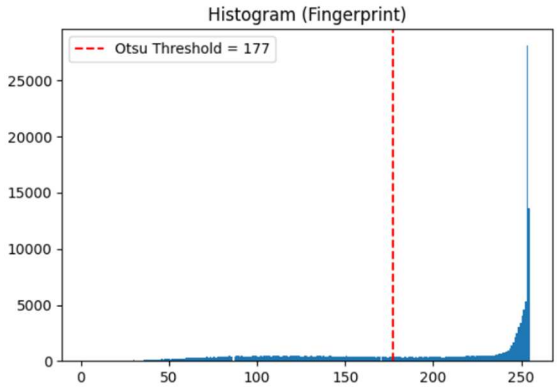
Otsu's Thresholding:

Otsu's method is a global automatic thresholding technique that calculates the optimal threshold value by analyzing the image histogram. It assumes the image contains two classes of pixels (foreground and background) and selects the threshold that minimizes intra-class variance.

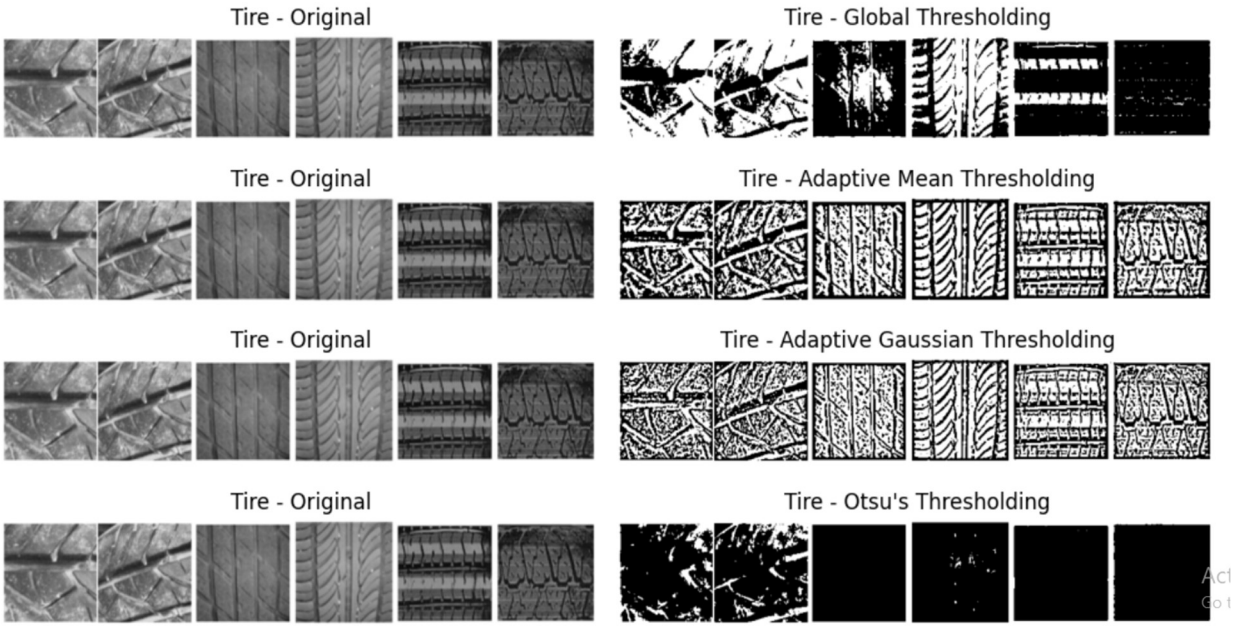
Otsu's method is useful when:

- Need an automatic thresholding method.
- The image has a bimodal histogram (two peaks: one for foreground, one for background).
- Want better accuracy than manual thresholding without handling lighting variations manually.

Otsu’s works best when the object and background are well-separated in terms of intensity including fingerprints with even lighting.



Method	When to Use	Pros	Cons
Global Thresholding	Uniform lighting, high contrast	Fast, simple	Poor with shadows
Adaptive Thresholding	Uneven lighting, local contrast (e.g., fingerprints)	Accurate under poor lighting	Slower, more parameters
Otsu’s Thresholding	Bimodal histogram, need auto threshold	No manual tuning needed	Assumes clear foreground/background split



Assignment: Thresholding and Image Segmentation for Forensic Analysis

Apply various image thresholding and segmentation techniques to forensic images such as **fingerprints**, **shoeprints**, or **tool marks**, and evaluate their effectiveness in isolating regions of interest (ROIs) for further forensic analysis.

1. **Preprocess the image**
    - Convert to grayscale
    - Apply Gaussian blur to reduce noise
2. **Apply different thresholding methods**
    - Global Thresholding
    - Adaptive Thresholding (Mean or Gaussian)
    - Otsu's Thresholding
    - Show original + thresholded result side by side
3. **Compare the results**
    - Which method gives the best separation of foreground (print) and background?
    - Where do they fail? (e.g., shadows, low contrast)
4. **Extract and show Region of Interest (ROI)**

- Use contours or binary masks to highlight features (like ridges in fingerprints)

5. **Write a report based on the analysis (2 page at least)**