THRESHOLDING TECHNIQUES

Thresholding is a simple and widely used image segmentation technique in medical image analysis. It separates the region of interest (ROI), such as organs, tissues, tumors, or bones, from the background by converting a grayscale image into a binary image using a threshold value (T).

During thresholding, pixels with intensity values greater than or equal to T are classified as the foreground (ROI), while pixels with intensity values less than T are classified as the background.

Thresholding improves image segmentation and is commonly used for tumor detection, organ segmentation, blood vessel extraction, and computer-aided diagnosis (CAD). The main thresholding techniques are Global Thresholding, Adaptive (Local) Thresholding, Otsu's Thresholding, and Multi-Level Thresholding.

Thresholding Techniques

1. Global Thresholding
2. Local Thresholding
3. Otsu's Thresholding
4. Multi-Level Thresholding

1. GLOBAL THRESHOLDING

Global Thresholding is one of the simplest and most widely used image segmentation techniques. It converts a grayscale image into a binary image by selecting a single threshold value (T) for the entire image.

Pixels with intensity values greater than or equal to the threshold are classified as the foreground (object), while pixels with intensity values less than the threshold are classified as the background.

This technique is suitable when the image has uniform illumination and there is a clear intensity difference between the object and the background.

The thresholding operation is defined as

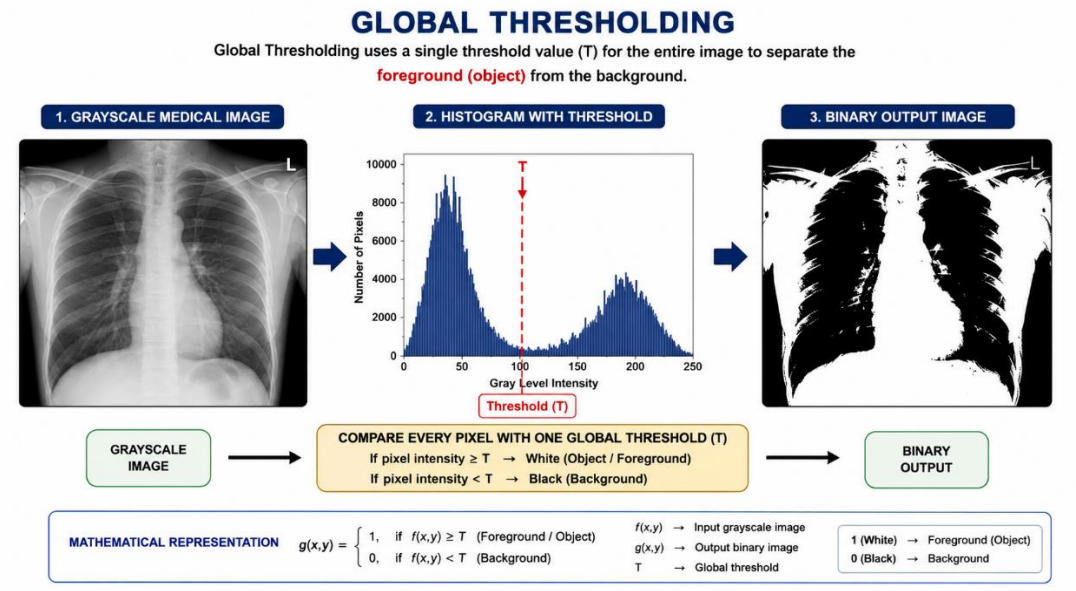
$$g(x,y) = \begin{cases} 1, & f(x,y) \geq T \\ 0, & f(x,y) < T \end{cases}$$

Where

1 (White) = Object (Foreground)

0 (Black) = Background

Global Thresholding is a simple, fast, and computationally efficient segmentation technique that uses a single threshold value to separate foreground objects from the background. It performs well on images with uniform illumination and high contrast, making it useful for basic medical image segmentation tasks such as bone extraction in X-rays. However, it is less effective for noisy or non-uniform medical images, where adaptive or Otsu's thresholding methods are generally preferred.



2. LOCAL THRESHOLDING

Local Thresholding, also known as Adaptive Thresholding, is an advanced image segmentation technique used to convert a grayscale image into a binary image by calculating a different threshold value for each local region of the image.

Unlike Global Thresholding, which applies a single threshold to the entire image, Adaptive Thresholding divides the image into small neighborhoods (windows) and computes an individual threshold for each neighborhood. This makes it highly effective for images with uneven illumination, shadows, low contrast, and varying background intensity, which are common in medical imaging.

Adaptive Thresholding is widely used in MRI, CT, Ultrasound, Retinal, Histopathology, and Microscopic medical images, where intensity varies across different regions.

The thresholding equation is

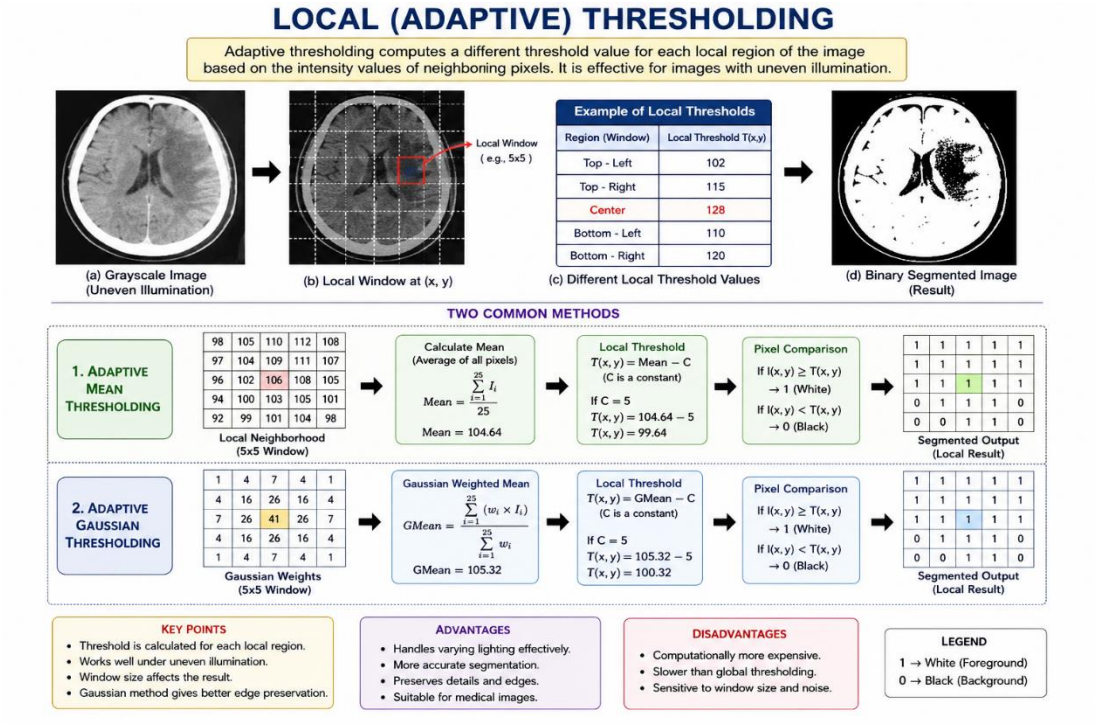
$$g(x,y) = \begin{cases} 1, & f(x,y) \geq T(x,y) \\ 0, & f(x,y) < T(x,y) \end{cases}$$

Where

1 = Foreground (White)

0 = Background (Black)

Unlike Global Thresholding, T(x,y) changes from one region to another.



3. OTSU'S THRESHOLDING

Otsu's Thresholding is an automatic image thresholding technique proposed by Nobuyuki Otsu in 1979. Unlike Global Thresholding, where the threshold value is selected manually, Otsu's method automatically determines the optimal threshold value from the image histogram.

The method assumes that the image contains two classes of pixels (foreground and background) and finds the threshold that best separates these two classes by maximizing the between-class variance (or equivalently minimizing the within-class variance).

Otsu's Thresholding is widely used in medical image analysis for segmenting organs, tumors, bones, cells, and tissues from MRI, CT, X-ray, and microscopic images.

The between-class variance is

$$\sigma_b^2 = \omega_0\omega_1(\mu_0 - \mu_1)^2$$

The threshold T that produces the maximum value of σ_b^2 is selected as the optimal threshold.

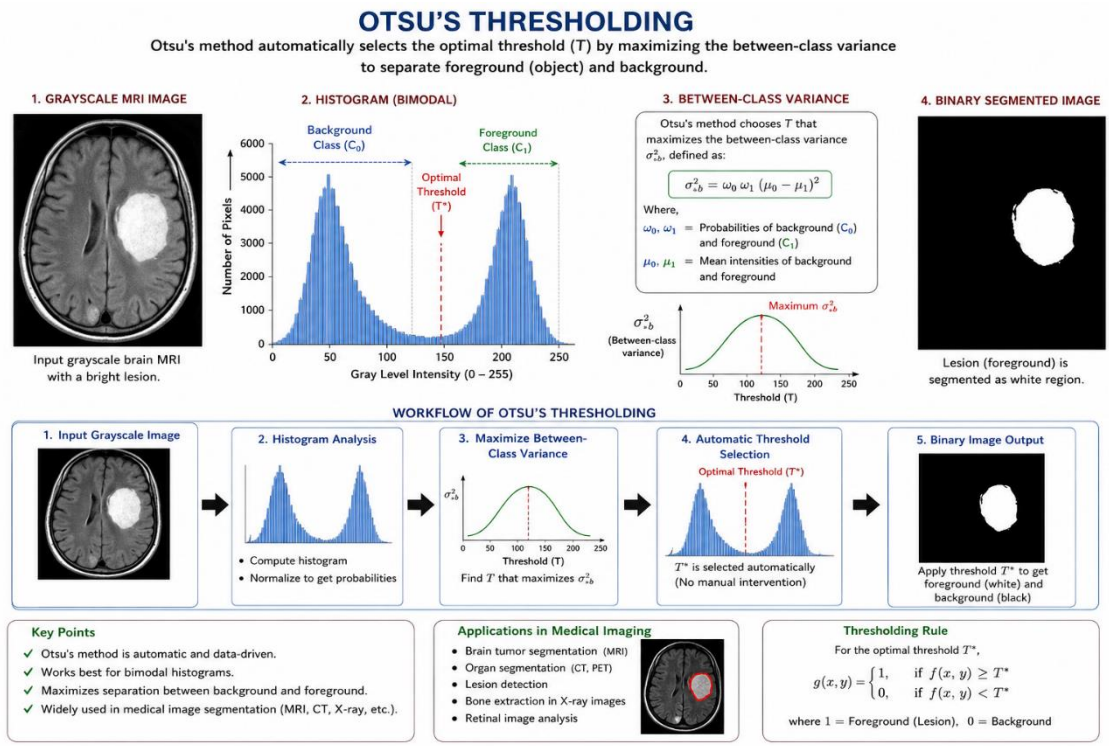
After finding T, the binary image is obtained using

$$g(x,y) = \begin{cases} 1, & f(x,y) \geq T \\ 0, & f(x,y) < T \end{cases}$$

Where

1 = Foreground

0 = Background



4. MULTI-LEVEL THRESHOLDING

Multi-Level Thresholding is an advanced image segmentation technique in which two or more threshold values are used to divide a grayscale image into multiple regions or classes.

Unlike Global Thresholding, which uses only one threshold to separate the image into foreground and background, Multi-Level Thresholding divides the image into several intensity ranges. This makes it suitable for medical images containing different tissues or organs with varying gray-level intensities.

It is widely used in MRI, CT, X-ray, ultrasound, and microscopic images for segmenting different anatomical structures.

For three classes, the segmentation is

$$g(x,y) = \begin{cases} 0, & f(x,y) < T_1 \\ 1, & T_1 \le f(x,y) < T_2 \\ 2, & f(x,y) \ge T_2 \end{cases}$$

Where

Class 0 = Background

Class 1 = Intermediate tissue

Class 2 = Foreground / High-intensity object

For more classes, additional threshold values (T_3, T_4, …) are used.