What is Image Thresholding?

Image thresholding involves dividing an image into two or more regions based on intensity levels, allowing for easy analysis and extraction of desired features. By setting a threshold value, pixels with intensities above or below the threshold can be classified accordingly This technique aids in tasks such as object detection, segmentation, and image enhancement.

Image thresholding is a technique that simplifies a grayscale image into a binary image by classifying each pixel value as either black or white based on its intensity level or grey-level compared to the threshold value. This technique reduces the image to only two levels of intensity, making it easier to identify and isolate objects of interest. Binary image conversion allows for efficient processing and analysis of images, enabling various [**computer vision**](https://encord.com/blog/what-is-computer-vision/) applications such as edge detection and pattern recognition.

In imaging processing algorithms, the principle of pixel classification based on intensity threshold is widely used. By setting a specific threshold value, pixels with intensity levels above the threshold are classified as white, while those below the threshold are classified as black. This principle forms the foundation for various image enhancement techniques that help to extract important features from an image for further analysis.

In data science and image processing, an entropy-based approach to image thresholding is used to optimize the process of segmenting specific types of image, often those with intricate textures or diverse patterns. By analyzing the entropy, which measures information randomness, this technique seeks to find the optimal threshold value that maximizes the information gained when converting the image into a binary form through thresholding. This approach is especially beneficial for images with complex backgrounds or varying lighting conditions. Through this technique, the binary thresholding process becomes finely tuned, resulting in more accurate segmentation and enhanced feature extraction, which is vital for applications in image analysis and [**computer vision**](https://encord.com/glossary/computer-vision-definition/) tasks.

Image Thresholding Techniques

These are widely used in various fields such as medical imaging, computer vision, and remote sensing. These techniques are essential for accurate image processing and interpretation. They help to convert grayscale or color images into binary images, separating the foreground from the background, allowing for better segmentation and extraction of features from an image, which is crucial for various applications in computer vision and pattern recognition.

Global Thresholding

Global Thresholding is a widely used technique where a single threshold value is applied to an entire image. However, this technique  may not be suitable for images with varying lighting conditions or complex backgrounds. To overcome this limitation, adaptive thresholding techniques may be employed, which adjust the threshold value locally based on the characteristics of each pixel's neighborhood. These techniques are particularly useful in scenarios where there is significant variation in illumination across different regions of the image.

A person using a camera

Description automatically generated

[*Thresholding-Based Image Segmentation*](https://www.geeksforgeeks.org/thresholding-based-image-segmentation/)

**Simple thresholding**is a basic technique that assigns a binary value to each pixel based on a global threshold value. It is effective when the image has consistent lighting conditions and a clear foreground-background separation. However, when images contain varying lighting conditions or complex backgrounds, adaptive thresholding techniques are more suitable. These techniques dynamically adjust the threshold value for each pixel based on its local neighborhood, allowing for better segmentation and accurate object detection.

**Otsu's Method** for Automatic Threshold Determination is a widely used technique for automatically determining the optimal threshold value in image segmentation. It calculates the threshold by maximizing the between-class [**variance**](https://encord.com/glossary/variance-definition/) of pixel value, which effectively separates foreground and background regions. This method is particularly useful when dealing with images that have bimodal or multimodal intensity distributions, as it can accurately identify the threshold that best separates different objects or regions in the image.

A black and white photo of a building

Description automatically generated

[*Otsu's method - Wikipedia*](https://en.wikipedia.org/wiki/Otsu%27s_method)

*“A nonparametric and unsupervised method of automatic threshold selection for picture segmentation. An optimal threshold is selected by the discriminant criterion, so as to maximize the separability of the resultant classes in gray levels. The procedure utilizies only the zeroth- and the first-order cumulative moments of the gray-level histogram.”* - [**Nobuyuki Otsu**](https://en.wikipedia.org/wiki/Nobuyuki_Otsu)

Pros and Cons of Global Thresholding

Gobal thresholding offers several advantages, including its simplicity and efficiency in determining a single threshold value for the entire image. It is particularly effective in scenarios where the foreground and background regions have distinct intensity distributions. However, global thresholding may not be suitable for images with complex intensity distributions or when there is significant variation in lighting conditions across the image. Additionally, it may not accurately segment objects or regions that have overlapping intensity values.

Local (Adaptive) Thresholding

Local thresholding addresses the limitations of global thresholding by considering smaller regions within the image. It calculates a threshold value for each region based on its local characteristics, such as mean or median intensity. This approach allows for better adaptability to varying lighting conditions and complex intensity distributions, resulting in more accurate segmentation of objects or regions with overlapping intensity values. However, local thresholding may require more computational resources and can be sensitive to noise or uneven illumination within the image, which can affect the overall performance of the segmentation algorithm.

**Adaptive Thresholds for Different Image Regions**are needed to overcome the challenges of variations in lighting conditions and contrast within an image. These adaptive thresholds help improve the accuracy and clarity of object or region detection. This approach involves dividing the image into smaller sub-regions and calculating a threshold value for each sub-region based on its local characteristics. By doing so, the algorithm can better account for these variations and mitigate the effects of noise or uneven illumination, as each sub-region is treated independently.

The simplest method to segment an image is thresholding. Using the thresholding method, segmentation of an image is done by fixing all pixels whose intensity values are more than the threshold to a foreground value.

Mean and Gaussian Adaptive Thresholding

Two commonly used methods in image processing are Mean and Gaussian Adaptive Thresholding. **Mean adaptive thresholding**calculates the threshold value for each sub-region by taking the average intensity of all pixels within that region. On the other hand, **Gaussian adaptive thresholding** uses a weighted average of pixel intensities, giving more importance to pixels closer to the center of the sub-region. These methods are effective in enhancing image quality and improving accuracy in tasks such as object detection or segmentation.

Advantages over Global Thresholding

Adaptive Thresholding has advantages over global thresholding. One advantage is that it can handle images with varying lighting conditions or uneven illumination. This is because adaptive thresholding calculates the threshold value locally, taking into account the specific characteristics of each sub-region. Additionally, adaptive thresholding can help preserve important details and fine textures in an image, as it adjusts the threshold value based on the local pixel intensities.

Applications of Image Thresholding

Image thresholding is a technique used in computer vision that has a variety of applications, including image segmentation, object detection, and character recognition. By separating objects from their background in an image, image thresholding makes it easier to analyze and extract relevant information. Optical character recognition (OCR) systems, for example, use image thresholding to distinguish between foreground (text) and background pixels in scanned documents, making them editable. Additionally, [**QR codes**](https://www.uniqode.com/qr-code-generator), which encode information within a grid of black and white squares, can be incorporated into images as a form of data representation and retrieval.

Real-world applications

* **Object Detection:** By setting a threshold value, objects can be separated from the background, allowing for more accurate and efficient [**object detection**](https://encord.com/glossary/object-detection-definition/).
* **Medical Images**: Image thresholding can be used to segment different structures or abnormalities for diagnosis and analysis in medical imaging.
* **Quality Control**: Image thresholding plays a crucial role in quality control processes, such as inspecting manufactured products for defects or ensuring consistency in color and texture of a color image.
* **Object Segmentation**: Image thresholding is also commonly used in [**computer vision**](https://encord.com/blog/what-is-computer-vision/) tasks such as object segmentation, where it helps to separate foreground objects from the background. This enables more accurate and efficient detection of objects within an image.
* **Noise Reduction**: Thresholding can be utilized for noise reduction, as it can help to eliminate unwanted artifacts or disturbances in an image.
* **Edge Detection**: Image thresholding aids in identifying and highlighting the boundaries between different objects or regions within an image with edge detection algorithms.

 A step by step [**guide to Image Segmentation in Computer Vision**](https://encord.com/blog/image-segmentation-for-computer-vision-best-practice-guide/) can be read [**here**](https://encord.com/blog/image-segmentation-for-computer-vision-best-practice-guide/).

[*Thresholding*](https://encord.com/blog/image-segmentation-for-computer-vision-best-practice-guide/)

A cat sitting on a set of stairs

Description automatically generated

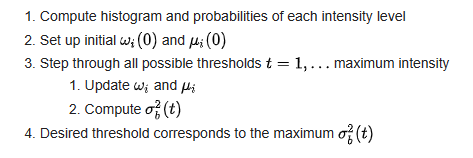
Practical Implementation and Considerations

When implementing thresholding techniques, it is important to carefully select the appropriate threshold value based on the specific image and desired outcome. This can be achieved through experimentation or through the use of adaptive thresholding methods that automatically adjust the threshold based on local image characteristics. Furthermore, it is essential to consider the potential trade-off between noise reduction and preserving important details in the image, as aggressive thresholding may lead to the loss of valuable information.

Algorithm For Global Thresholding:

1. Read an image in grayscale.
2. Randomly select a threshold value.
3. Prepare a similar array as for the grayscale image for the threshold image.
4. For each pixel in the threshold image, compare its intensity with threshold value. If intensity is greater than or equal to threshold value, set the corresponding pixel to value to maximum intensity (let’s say white). Else leave it as it is.

Algorithm For Otsu Thresholding:



Algorithm For Adaptive Mean Thresholding:

1. Load the image in grayscale.
2. Define the block size for local area (It must be odd).
3. Define constant to subtract from mean.
4. Pad the image with zeros around the border for the block operation (Not necessary).
5. Prepare an empty array for the threshold image.
6. For each pixel in the image:
   1. Calculate the mean of the local area.
   2. If pixel intensity is greater than then the (mean + constant) set the corresponding pixel in the threshold image to white (or maximum intensity).
   3. Otherwise, set the corresponding pixel in the threshold image to black or minimum intensity.

Algorithm For Gaussian Adaptive Thresholding:

1. Load the image in grayscale.
2. For each pixel in the image:
3. Calculate a threshold value based on a Gaussian weighted sum of the neighbour values.
4. Subtract a constant c from the calculated threshold value.
5. If the pixel’s intensity is less than the adjusted threshold value, set the pixel to black (0). Otherwise, set the pixel to white (255).