# Image Binarization using Otsu Thresholding Algorithm

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## Abstract

Binarization plays an important role in digital image processing, mainly in computer vision applications. Thresholding is an efficient technique in binarization. The choice of thresholding technique is crucial in binarization. Several thresholding algorithms have been investigated and proposed to define the optimal threshold value. In this experimental study, Otsu and Gaussian Otsu thresholding algorithms were developed and tested with several images. The results of these two methods then compared in their performance to determine the threshold value. Results show better performance for Gaussian Otsu's method compared to Otsu's method.

**Keywords**: Image binarization, Thresholding value, Otso's method, Guassian Otsu's method

## 1 Introduction

Binary images are found useful in many image processing applications due to their simplicity and effectiveness. A binary image is produced by quantization of the image gray levels to two values, usually 0 and 1. Over the last twenty years binarization has been an active research area in digital image processing domain. Binarization can be used in recognising text and symbols, e.g. document processing. Identifying objects with distinctive silhouettes, e.g. components on a conveyor in a manufacturing plant, and determining the orientation of objects are some other examples of binarization applications [3]. Binarization generally involves two steps including determination of a gray threshold according to some objective criteria and assigning each pixel to one class of background or foreground. If the pixels intensity is greater than the determined threshold then it belongs to foreground class and otherwise to the background [1]. The main problem in binarization is the choice of thresholding technique [2]. Several thresholding algorithms have been investigated and proposed to define the optimal threshold value. The thresholding algorithms can be categorized into six classes: histogram shape-based methods, clustering-based methods, entropy-based methods, object attribute-based methods, the spatial methods and local methods based on the local characteristics of each pixel [7]. Among these classes, many thresholding algorithms are based on a minimum variance [4]. Otsu's thresholding technique is a classification-based method which searches for the the threshold that minimizes the intra-class variance, defined as a weighted sum of variances of the two classes [6]. Gaussian Otsu's method is an extention of Otsu's method and it uses maximum between class variance as an optimal threshold value. This paper presents an experimental study on Otsu and Gaussian Otsu thresholding algorithms. Otsu and Gaussian Otsu methods were developed and tested with several images. The results from those methods then compared in their performance to determine the threshold value. This paper is organized as follows: In Section 2 we discuss the basics of the Otsu and Gaussian Otsu thresholding algorithms. In Section 3, we discuss the experiments detail and results. Conclusions are presented in Section 4.

# 2 Background

In this section, we present the overview of the Otsu and Gaussian Otsu thresholding algorithms.

## 2.1 Otsu's method

Otsu's thresholding method correscponds to the linear discriminant criteria that assumes that the image consists of only object (foreground) and background, and the heterogeneity and diversity of the background is ignored [6]. Otsu set the threshold so as to try to minimize the overlapping of the class distributions [6]. Given this definition, the Otsu's method segments the image into two light and dark regions T0 and T1, where region T0 is a set of intensity level from 0 to t or in set notation $T0 = \{0, 1, ..., t\}$ and region $T1 = \{t, t+1, ..., l-1, l\}$ where t is the threshold value, l is the image maximum gray level (for instance 256). T0 and T1 can be assigned to object and background or vice versa (object not necessarily always occupies the light region). Otsu's thresholding method scans all the possible thresholding values and calculates the minimum value for the pixel levels each side of the threshold. The goal is to find the threshold value with the minimum entropy for sum of foreground and background. Otsu's method determines the threshold value based on the statistical information of the image where for a chosen threshold value t the variance of clusters T0 and T1 can be computed. The optimal threshold value is calculated by minimizing the sum of the weighted group variances, where the weights are the probability of the respective groups.

Given: p(i) as the histogram probabilities of the observed gray value i=1,...,l

$$P(i) = \frac{number\{(r,c)|image(r,c)=i\}}{(R,C)}$$

Where r, c is index for row and column of the image, respectively, R and C is the number of rows and columns of the image, respectively.

$w_b(t)$, $\mu_b(t)$, and $\sigma_b^2(t)$ as the weight, mean, and variance of class T0 with intensity value from 0 to t, respectively.

$w_f(t)$, $\mu_f(t)$, and $\sigma_f^2(t)$ as the weight, mean, and variance of class T1 with intensity value from t+1 to l, respectively.

$\sigma_w^2$ as the weighed sum of group variances.

The best threshold value t* is the value with the minimum within class variance. The within class variance defines as following:

$$\sigma_w^2 = w_b(t) * \sigma_b^2(t) + w_f(t) * \sigma_f^2(t)$$

where

$$w_b(t) = \sum_{i=1}^{t} P(i)$$

$$w_f(t) = \sum_{i=t+1}^{l} P(i)$$

$$\mu_b(t) = \frac{\sum_{i=1}^{t} i * P(i)}{w_b(t)}$$

$$\mu_f(t) = \frac{\sum_{i=t+1}^{l} i * P(i)}{w_f(t)}$$

$$\sigma_b^2(t) = \frac{\sum_{i=1}^{t}(i-\mu_b(t))^2 * P(i)}{w_b(t)}$$

$$\sigma_f^2(t) = \frac{\sum_{i=t+1}^{l}(i-\mu_f(t))^2 * P(i)}{w_f(t)}$$

## 2.2 Gaussian Otsu's method

Gaussian Otsu's method is a an extension of Otsu thresholding technique based on between class variance from the foreground and background regions. This approach is far faster than the optimal Otsu method. This thresholding approach calculates the maximum between class variance in which uses the minimum within class variance. The between-class variance defines as following:

$$\begin{aligned}&\sigma_B^2(t) = \sigma^2 - \sigma_w^2(t)\\ &= w_b(t) * (\mu_b(t) - \mu))^2 + w_f(t) * (\mu_f(t) - \mu)^2\\ &= w_b(t) * w_f(t) * (\mu_b(t) - \mu_f(t))^2\end{aligned}$$

Where $\sigma^2$ and $\mu$ are the total variance and the total mean of the image, respectively.

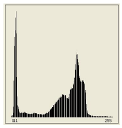
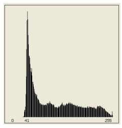
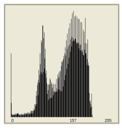
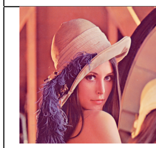
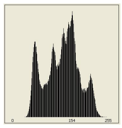
| Original image | Histogram | thresholding value Otsu | G.Otsu |
|---|---|---|---|
|  Walkbridge |  | 0 | 124 |
|  Womandarkhair |  | 0 | 119 |
|  Womanblonde |  | 121 | 121 |
|  Lena |  | 116 | 116 |

Table 1: Thresholding values for both methods

# 3 Results and discussion

This section presents the results obtained for both thresholding algorithm.
To test the performance of the developed method we have used 40 images from the "Standard" test images (a set of images found frequently in the literature) [5]. We assessed the techniques and evaluated the results qualitatively based on subjective evaluation. The results show that Otsu's method correctly classified the pixles into foreground and background regions for 68% of images while Gaussian Otsu's method 100% accurately detected foreground regions. Table 1 shows the thresholding values for each thresholding approach, and Table 2 shows the typical results after thresholding operations using both methods.

By observing histograms and the thresholding values in Table 1, it is clear that the Guassian Otsu' method works well in images that have bimodal distributions (have two modes in their histograms) while Otsu's method gives incorrect threshold value that fails the binarization process . From the result binary images in Table 2, it is also clear that Gaussian Otsu's method is able to generate a binary image for this cases while Otsu's method falsely classifies the background pixles as foreground (object). Image 'womandarkhair' with two modes in its histogram, is an example of Otsu's method dificulty in detecting the background and the object correctly. The other falsify classification with Otsu's method occurs in "walkbridge" image where even visuallly it is hard to determine the parts of the image belonging to object and back-

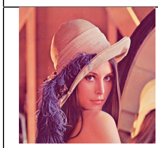
| Original image | Binary Image Otsu | G. Otsu |
|---|---|---|
|  Walkbridge | |  |
|  Womandarkhair | |  |
|  Womanblonde |  |  |
|  Lena |  |  |

Table 2: The results after thresholding for both methods

ground. The reults in Table 2 also show that both methods perform same for images with more complex histogram patterns (multiple modals). 'Lena' and 'womanblonde' are good examples for multiple modals.

# 4 Conclusions

In this paper we have reviewed and compared Otsu and Guassian Otsu thresholding methods. Otsu's method attempts to find the best threshold value by minimizing within class vaiance while Gaussian Otsu tries to find the best thresholding value by maximizing between class variance. Both methods are tested to several images and evaluated. The finding shows that Gaussian Otsu's method significantly performs better on the images with two modes in their histogram and othewise both methods find the same threshold value and perform same in the classification of images with multiple modals.

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