IMAGE SEGMENTATION BY OTSU METHOD

Ma'ruf Tojiyev[1]

Ravshan Shirinboyev[2]

Jahongirjon Bobolov[3]

Jizzakh branch of the National University of Uzbekistan

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ABSTRACT

Image segmentation has become in indispensable task in many image applications. In order to analysis this issue, the use of thresholding technique is well-known. Because of its applicability, quite a number of thresholding methods have been proposed over the years. This paper attempts to undertake the study of image segmentation and as a result of this study was implemented OTSU algorithm that has the goal to convert images to black and white and so make them better identifiable.

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[1] PhD student, Jizzakh branch of the National University of Uzbekistan, Jizzakh, Uzbekistan, mtojiyev@jbnuu.uz
[2] Master, Jizzakh branch of the National University of Uzbekistan, Jizzakh, Uzbekistan, forravshanrsh@jbnuu.uz
[3] Student, Jizzakh branch of the National University of Uzbekistan, Jizzakh, Uzbekistan, bobolovjahongir@gmail.com

1. Introduction

Segmentation is usually first step in the analysis of an image, with the idea of segmenting an object by dividing the parts, or parts considered homogeneous according to some criterion uniformity, and ends when the objects interest has been separated. There are several segmentation techniques being used in literature. In generally this techniquesis based on value number of each pixel in the texture analysis and image histogram [1].

The image segmentation consist in to subdvide the image into its constituent parts. The idea of image segmentation is to classify pixels of set of pixels. It is the first analysis stage image [2]. Segmentation helps identify differences between two or more objects, both among themselves and between each other and the background. The segmentation is based on the basic properties of intensity values in gray levels and may be a discontinuity or similarity. The discontinuity is due to the partition of the imageby intensity values of gray. While the similarity is based on partitioning an image into regions that are similar according to a set of pre-defined criteria, thresholding and regiongrowing are examples of methods in this category.

Thresholding is the identification of the best threshold in which object distinct from the background, several methods have been proposed [3]. In this context, there are two types of thresholding algorithms:

· Global thresholding algorithms

· Local or adaptive thresholding algorithms

In global thresholding, a single threshold for all the image pixels is used. When the pixel values of the components and its background are fairly consistent in their respectivevalues over the entire image, global thresholding could be used. In adaptive thresholding,different threshold values for different local areas are used. In this paper adaptive thresh-olding is used. In order to performs the analysis of images by thresholding technique, we will employee Otsu's method, which is considered one of the best method for adaptive thresholding images .

2. Theoretical Foundation

2.1. Histogram

The histogram is a graph that represents values of the shades of the pixels of an image with a particular brightness [Gonzalez and Woods 2002, Petrou and Bosdogianni 1999],in other words, is the representation of the distribution of colors in an image. The his- togram shows detail in the shadows, midtones, highlights, but first of all shows the globalimage description. If the histogram is narrow, then the image is barely visible, it is be- cause the image gray levels are low. On the other hand, an image with higher contrast andprovides a uniform visibility of these gray level histogram [4].

According [Gonzalez and Woods 2002], the histogram is a discrete probability density function represented by:

$$p_x = \frac{n_x}{N}$$

where:

x is the gray level, n_x is the number of the pixels in the image having gray level x and N is the total number of the pixels in the image.

The $x \in \{1, 2, \ldots, L\}$, where L is the value of the pixels in the scanned image.

2.2. Thresholding

The thresholding is one of the simplest techniques of segmentation, it causes the image tograyscale becomes a binary image, separating regions of an image in two other regions - the white background determined by the value (1) and the black object determined by the value (0), thus having a black/white image. This is only possible by defining a thresholdT that separates groups of image gray levels [5].

Segmentation occurs by scanning the image, pixel by pixel, thereby distinguish- ing the background of the object, depending on the relationship between the pixel value and the threshold value. However, the thresholding is effective when the subject is very different gray levels, thus the gray levels of the object and background form distinctly twopeaks and the thresholding is trivial.

Suppose that the gray level histogram corresponds to an image f (x, y) composed of dark objects on the light background, in such a way that object and background pixelshave gray levels grouped into two dominant modes. One obvious way to extract theobjects from the background is to select a threshold T that separates these modes. Then any point (x, y) for which f (x, y) > T is called an object point, otherwise, the point is called a background point.

Mathematically, thresholding may be defined as:

$$g(x,y) = \begin{cases} \text{object if } f(x,y) > T \\ \text{background if } f(x,y) \leq T \end{cases}$$

where f (x, y) is the input image, T is the threshold and g(x, y) is the output image (thresh-olding).

Usually it is very common to use the histogram to select a threshold for the thresh-olding and a threshold is obvious, when occurs at the low point between two peaks in the histogram. In this context, a histogram is a vector having the same number of dimensionsas the image does gray levels, [6].

2.3. Adaptive Thresholding

The adaptive thresholding technique which is a local aspects analyzes the image and de-termines a threshold for each region defining whether the pixel is considered black or white.

This technique has algorithms from simple solutions to the optimal solution of local thresholding. This technique is well known and there are several algorithms with different answers depending on the type of image [Ballard 1982, Sezgin 2004].

2.4. Otsu's Method

The Otsu method [7] is considered one of best methods for adaptive thresholding images, but its quality is directly coupled at the cost of complexity. The thresholding operation is considered to be the partitioning of the pixels of an image L gray levelsinto two classes, C_0 and C_1, which can represent the object and the background, or vise versa,

and this partition will be in the gray level t. This is a non-parametric methodand unsupervised, which seeks to automatically select the limits of gray levels that best separate or segment the elements of interest in an image of two classes. Thus we have:

$$C_0 = 1, 2, \ldots, k$$
$$C_1 = k+1, \ldots, L$$

A measure of region homogeneity is variance, regions with high homogeneity willhave low variance. Otsu's method selects the threshold by maximizing the between-classvariance (or, conversely, minimizes the within-class variance) of the two groups of pixelsseparated by the thresholding operator. It does not depend on modeling the probability density functions, however, it assumes a bimodal distribution of gray level values, if the image approximately fits this constraint, it will do a good job[8].

The normalized histogram is a probability distribution function.

$$p_x = \frac{n_x}{N}$$

$$\sum_{x=1}^{L} p_x = 1 \quad p_x \geq 0$$

Then the probabilities of class occurrence and the class mean levels, respectively,are given by:

$$\omega_0 = P_r(C_0) = \sum_{x=1}^{k} p_x = \omega(k)$$

$$\omega_1 = P_r(C_1) = \sum_{x=k+1}^{k} p_x = 1 - \omega(k)$$

The mean gray level value of the background pixels and the object pixels respectively will be:

$$\mu_0 = \sum_{x=1}^{k} x Pr(x|C_0) = \sum_{x=1}^{k} x p_k / \omega_0 = \mu(k)/\omega(k)$$

$$\mu_1 = \sum_{x=R+1}^{L} x \, Pr(x|C_1) = \sum_{x=k+1}^{L} x p_x \Big/ \omega_1 = \frac{\mu_T - \mu(k)}{1 - \omega(k)}$$

where

$$\omega(k) = \sum_{x=1}^{k} p_x$$

and

$$\mu(k) = \sum_{x=1}^{k} x p_x$$

are the zero$_{th}$ and the first-order cumulative moments of the histogram up to the k$_{th}$

level, respectively[9],

$$\mu_T = \mu(L) = \sum_{x=1}^{L} x p_x$$

is the total mean level of the original picture. The relation is true for any choice of k:

$$\omega_0 \mu_0 + \omega_1 \mu_1 = \mu_t$$
$$\omega_0 + \omega_1 = 1$$

The variance of the background and the object pixels will be:

$$\sigma_0^2 = \sum_{x=1}^{k} (x - \mu_0)^2 \Pr(x|C_0) = \sum_{x=1}^{k} (x - \mu_0)^2 |p_x|\omega_0)$$

$$\sigma_0^2 = \sum_{x=k+1}^{L} (x - \mu_1)^2 \Pr(x|C_1) = \sum_{x=k+1}^{k} (x - \mu_1)^2 p_x \omega_1)$$

The variance of the whole image is[9]:

$$\sigma_T^2 = \sum_{x=1}^{L} (x - \mu_T)^2 p_x$$

It can be shown that the variance can be written as follows:

$$\sigma_T^2 = \omega_0 \sigma_0^2 + \omega_1 \sigma_1^2 + \omega_0 (\mu_0 + \mu_T)^2 + \omega_1 (\mu_1 + \mu_T)^2 + \omega_W^2 + \omega_B^2$$

where ω_W^2 is defined to be the within-class variance and ω_B^2 is defined to be the between-class variance.

Since the total variance σ does not depend on T, the T minimizing σ_W^2 will be the T maximizing σ_B^2. Let's consider maximizing σ_B^2, we can rewrite σ_B^2 as follows:

$$\sigma_B^2 = \frac{[\mu_T \omega(k) - \omega(k)]^2}{\omega(k)[1 - \omega(k)]}$$

Therefore, the optimal threshold k∗ is:

$$\sigma_B^2(k*) = \max 1 \leq k < L^{\sigma_B^2}(k)$$

2.5. Algorithm

The Otsu's method is used to generate a black and white image by calculating the thresh-old automatically. He believes that the input image have two classes of pixels, the objectand the background, seeking for the optimum threshold to segment the image with betterquality. The Otsu algorithm follows these steps:

1. Get the frequency of each intensity $1 \leq x < L$ (histogram)[10].
2. Divide each frequency by the total number of pixels, obtaining the probability (histogram normalization).
3. Get the partial sums accumulated ω and μ of each intensity through the odds.
4. For each intensity k, calculate $\sigma_B^2(k)$. If this is the highest value, update the optimal threshold k∗ with k.
5. For each pixel, if the pixel intensity is less than or equal to k*, it is considered

object; otherwise, background.

3. Experiments Verifications

The following text aims to present the results achieved in implementing the Otsu's methodin targeting RGB images and also images of text. The algorithm assumes that the image to be threshold contains two classes of pixels (object and background) then calculates theoptimum threshold separating those two classes so that their combined spread (within-class variance) is minimal[11].

In this section some experiments were performed to verify the quality of the results obtained from the implementation of the Otsu's method for some images. In Figure 1(a)we quantified the original image with 256 gray levels. After segmenting the image usingOtsu's method, we obtain the optimum threshold T value to 0.3412 in 0 1 scale, as shown in Figure 1(b).

In Figure 2(a) we quantified the original image. After segmenting the image using Otsu's method, we obtain the optimal threshold T value to 0.4275 in 0 1 scale, as shownin Figure 2(b).

In Figure 3(a) we quantified the original image. After segmenting the image using Otsu's method, we obtain the optimum threshold value the 0.5608 in 0 1 scale, as shownin Figure 3(b).

In Figure 4(a) we quantified the original image. After segmenting the image using Otsu's method, we obtain the optimum threshold value the 0.4902 in 0 1 scale, as shownin Figure 4(b).

(a) (b)

Figure 1. (a) Original image. (b) Image threshoded with Otsu's method.

(a) (b)

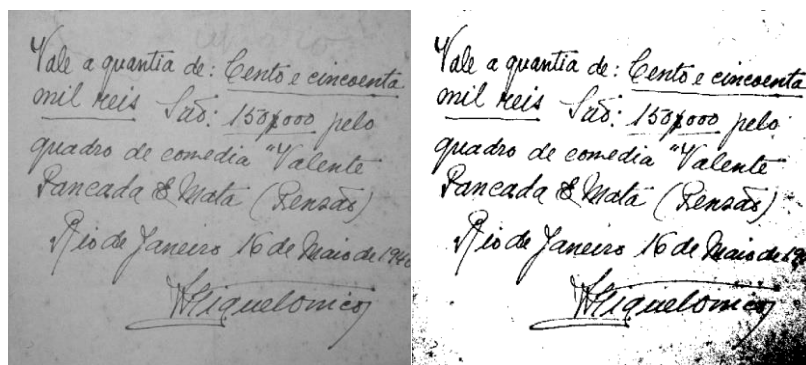*Figure 2. (a) Original image. (b) Image threshoded with Otsu's method.*

(b) (b)

Figure 3.(a) Original image. (b) Image threshoded with Otsu's method.

(a) (b)

Figure 4. (a) Original image. (b) Image threshoded with Otsu's method.

In Figure 5(a) we quantified the original image. After segmenting the image using Otsu's method, we obtain the optimum threshold value the 0.5765 in 0 1 scale, as shownin Figure 5(b).

(a) (b)

Figure 5. (a) Original image. (b) Image threshoded with Otsu's method.

4. Conclusions

The use of computational tools to aid the image segmentation process is increasingly being discussed and studied by the scientific community. The objective of this work wasto

implement the Otsu's algorithm that aims thresholding an image to a black and white image. Only after the thresholding of the images is that they should be targeted to later find a optimum threshold.

In this paper, we shown a method for automatically selecting an optimal threshold from a gray level histogram. The method was effective in improving job the visual qualityof the images. Otsu's method is characterized by its nonparametric and unsupervised nature of threshold selection and may be recommended as the most simple and standard one for automatic threshold selection that can be applied to various practical problems.

One advantage of this method is that it is not restricted to the type of image histogram. That is, histograms can be applied to unimodal, bimodal or multimodal, but has better performance in images with higher intensity variance [Otsu 1978].

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