OPTIMUM THRESHOLDING OF IMAGES USING PHASE CORRELATION

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Abstract: *The automatic binarization of grey level images or the automatic determination of optimum threshold value that separates objects from their background is still a difficult and challenging problem in many applications in the area of digital image processing.*

A new algorithm is proposed for the optimum automatic thresholding of digital images. The algorithm is based on determining the best threshold value that maximizes a correlation function between the binary and original grey level images. Experimental results to compare the proposed algorithm to various thresholding techniques are also presented.

1. INTRODUCTION

Thresholding is one of the major image-segmentation operations. It concerns the process of separating an object from its background. Image pixels that belong to background are given one value (say 1) and the pixels that belong to the object are given another value (say zero).

An optimum threshold value is the value at which the maximum amount of information about the object of interest is revealed and the minimum amount of information is lost. The automatic determination of the optimum threshold value is not an easy process [1]. The difficulty arises when the object of interest has dark grey-levels against bright background and a specific threshold value need to be selected. When this value is set too low, portions of the object may disappear, conversely, if the threshold value is set too high, portions of the background may appear as an object [2].

This problem has been extensively studied for its obvious practical importance as well as its theoretical interest. Many thresholding techniques have been proposed to solve this segmentation problem [3-5]. All these techniques optimize a criterion function based on information obtained from either histogram generation or spatial distribution.

In this paper a new technique for automatic thresholding of images is introduced. This technique is based on selecting an optimum threshold value that maximizes the correlation between the phase of the grey-level image and the phase of the thresholded image. The proposed algorithm does not require the bimodality of the image histogram. The performance of this novel technique has been verified experimentally on both clean and noisy images. The experimental results revealed that the correlated phase algorithm achieved the best overall performance among several popular threshoding techniques. The problem of non-homogenous or weak illumination has little effect on the proposed technique.

2. CORRELATED PHASE THRESHOLDING

The phase of signals has been extensively studied for signal reconstruction and recovery [6]. It is well known that the phase of the Fourier transform of the digital image is more important than the magnitude and contains more essential information [7].

The Fourier transform of the image consists of two parts the phase and the magnitude. For digital image, the discrete Fourier transform DFT is given by:

$$
\begin{aligned}
F(u,v) &= \frac{1}{mn}\sum_{x=0}^{m-1}\sum_{y=0}^{n-1} f(x,y)\exp^{\left[-2j\pi\left(\frac{ux}{m}+\frac{vy}{n}\right)\right]} \\
u &= 0,...,m-1, v=0,...,n-1
\end{aligned}
$$

In polar form

$$F(u,v) = |F(u,v)|\exp^{\Phi(u,v)}$$

Correlating the phases of both the binary image and the grey image could serve as indication of the similarity of the two images. This fact represents the basic idea behind the proposed algorithm. In this context, the new algorithm for automatic thresholding can be suggested as follows:

Let the phase of the grey level image be $\Phi_g(u,v)$ and that of the thresholded image be $\Phi_{th}(u,v)$. The optimum threshold can then be defined as the value that will maximize the correlation between the two phases, $\Phi_g(u,v)$ and $\Phi_{th}(u,v)$.

For a given grey-level image the phase is obtained and then the grey level image is thresholded at several grey-level values, and at each threshold value the phase of the resulted binary image is obtained. Then the optimum threshold value is defined as the value at which the phase of the resulted binary image and the phase of the original grey-level image are close to each other. This means that the shape of the binary image is as close as possible to the shape of the original grey-level image and threshold value can be considered as the optimum value. Correlation is a measure of the degree to which two variables agree not necessarily in actual value but in general behavior. So the two-dimensional correlation is used to measure how the two phases agree. The correlation of the two phase variables at threshold level ρ is defined as:

$$C(\rho) = \frac{\sum_{u=0}^{n-1}\sum_{v=0}^{m-1}\left[\Phi_g(u,v)-\mu_g\right].\left[\Phi_{th}(u,v)-\mu_{th}\right]}{\sqrt{Q_g.Q_{th}}}$$

where

$$
\begin{aligned}
Q_g &= \sum_{u=0}^{n-1}\sum_{v=0}^{m-1}\left[\Phi_g(u,v)-\mu_g\right]^2 \\
Q_{th} &= \sum_{u=0}^{n-1}\sum_{v=0}^{m-1}\left[\Phi_{th}(u,v)-\mu_{th}\right]^2 \\
\mu_g &= E(\Phi_g(u,v)) \\
\mu_{th} &= E(\Phi_{th}(u,v))
\end{aligned}
$$

The optimum threshold value ρ_{opt} is the value that maximizes $C(\rho)$.

The basic steps of the above correlated-phase thresholding algorithm **(CPT)**, can be summarized as follows:

- Obtain the DFT of the grey level image.
- From the DFT obtain the phase $\Phi_g(u,v)$.
- **For** ρ = $\rho_{\min}$ **to** $\rho_{\max}$ **Do**
  - Threshold the image at grey-level ρ and obtain the DFT of the resulted binary image and obtain its phase; $\Phi_{th}(u,v)$.
  - Determine the correlation $C(\rho)$ between $\Phi_g(u,v)$ and $\Phi_{th}(u,v)$.
- Find the optimum threshold value ρ, which gives the maximum value of $C(\rho)$.
- **End**

3. EXPERIMENTAL RESULTS

An experimental test images have been prepared to cover a variety of situations and conditions.

A set of noisy and clean images was used to evaluate the performance of the proposed algorithm as well as some of the popular algorithms reported in the literature. All images are 128 x128 pixels with grey-level between 0 and 255. The test images were selected such that they cover one or more of the following situations:

- Unimodal, bimodal, multimodal histograms.
- Shadowy and non-homogenous background.
- Disproportional histogram peaks.
- Reflections due to strong illumination.
- Noisy images.
- Non uniformly illuminated images.

The performance of the new technique is compared with the performance of the following techniques:

- The Histogram Dependent Thresholding (HDT) technique[9].
- The Laplacian Histogram Dependent Thresholding (LHDT) technique[11].
- The Quad Tree Thresholding (QTT) technique[10].
- The Edge Thresholding (EDT) technique[13].
- The Perimeter Maximization Thresholding (PMT) technique[8]

The main comparison criterion is the absolute error ratio which is defined as the absolute difference in the number of pixels between the optimally thresholded image and the thresholded image obtained by each method. The error rate is then computed by dividing the absolute difference by the total number of pixel for each image. The optimum thresholding performance, which has been obtained manually using visual inspection, and the deviation from the optimum threshold value for each algorithm are shown in Table (1).

In most cases, as demonstrated in Figure 1, thresholding based on the proposed algorithm gave less error rate than thresholding based on the other techniques, this can be noticed form the error rate, presented in Table (1). Figure 1 depicts a typical test image. The figure shows the original grey-level image, the manually thresholded image, and thresholded image using each method. It was observed that the proposed algorithm transformed grey-level into a bi-level image even if its histogram is not bimodal.

Algorithm	**Error Performance**
HDT	0.053
LHDT	0.057
QTT	0.049
EDT	0.052
PMT	0.013
Proposed Algorithm	0,003

Table 1: Comparative Performance of the Proposed Thresholding Algorithm

4. CONCLUSION

The use of thresholding techniques to segment and produce a binary or bi-level image from grey level image has been attempted. The problems associated with selecting an optimum single threshold value (Global Thresholding) have been addressed.

A new technique for automatic thresholding of images has been introduced. This technique is based on maximizing the correlation between the phase of the grey-level image and the phase of the thresholded image. The proposed algorithms does not need the histogram of an image to be bimodal. Experimental results were presented. These results demonstrated that in comparison with other five commonly used thresholding techniques, the proposed algorithm performed the best in terms of error ratio performance.

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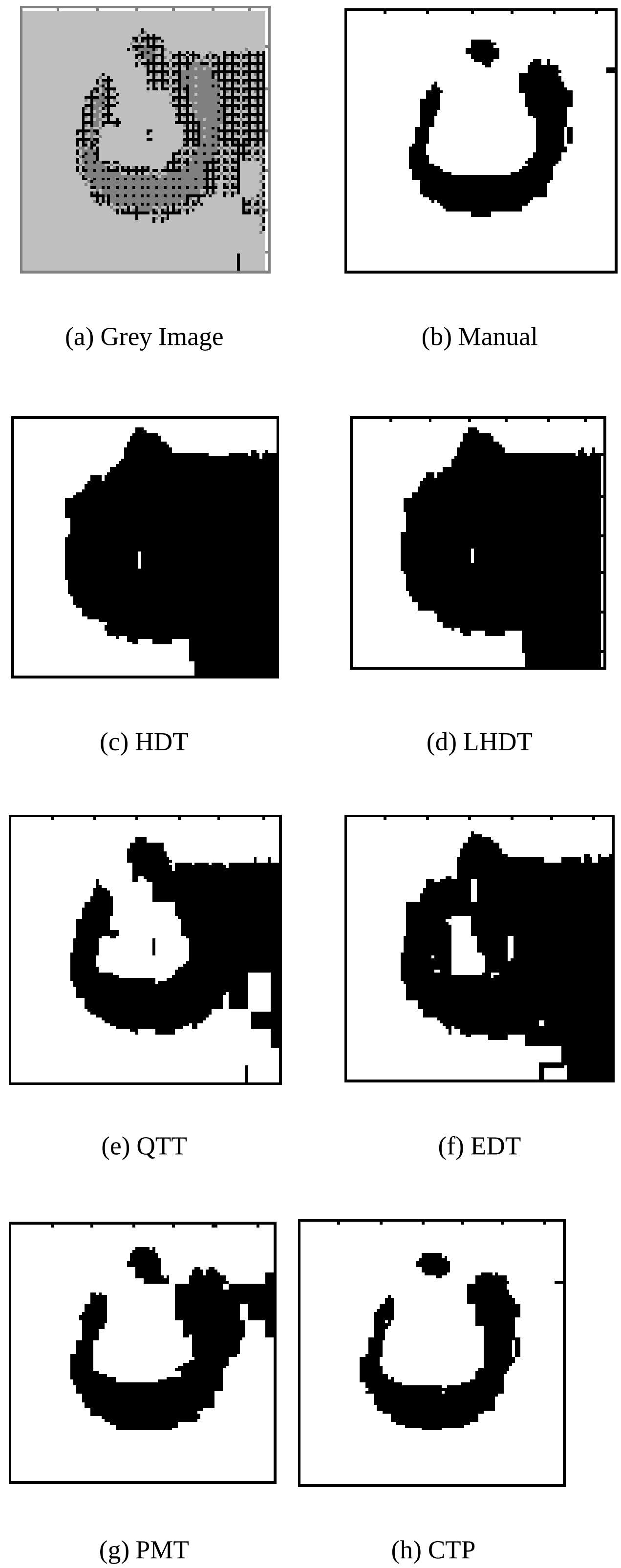

(a) Grey Image (b) Manual

(c) HDT (d) LHDT

(e) QTT (f) EDT

(g) PMT (h) CTP

Figure 1: Performance of a Number of Automatic Thresholding Techniques

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