Image Binarization Methods

Otsu 1D

Overview

Otsu method is based on a very simple idea: find the threshold that minimizes the weighted within-class variance, defined as a weighted sum of variances of the two classes.

$$\sigma_w^2(t) = \omega_1(t)\sigma_1^2(t) + \omega_2(t)\sigma_2^2(t)$$

Weights ω_i are the probabilities of the two classes separated by a threshold t and σ_i^2 variances of these classes.

This can be demonstrated to be the same as maximizing the between-class variance.

$$\sigma_b^2(t) = \sigma^2 - \sigma_w^2(t) = \omega_1(t)\omega_2(t)\left[\mu_1(t) - \mu_2(t)\right]^2$$

Where μ_i represent the class means.

A detailed description can be found here:

http://www.labbookpages.co.uk/software/imgProc/otsuThreshold.html

Implementation

This method was first implemented for rectangular regions and then adapted so that it can be used for non-rectangular zones. We simply compute the class means and their probabilities.

Parameters

If someone considers that the Otsu binarization result is too dark or too light, can apply a threshold percentage which can vary from -100 to 100, where 0 corresponds to Otsu threshold. A positive percent means lightening (the threshold value will be increased) and a negative percent means darkening (the threshold value will be decreased). For this parameter we recommend a value of -40%.

Advantages

This method is fast because operates directly on the gray level histogram.
It provides very good results when the numbers of pixels in each class are close to each other.

Disadvantages

When the object and background pixels are extremely unbalanced, it produces poor results. If the image background is uneven, then finding a global threshold that provides satisfactory results can be impossible.

Results

Input:

Output:

Otsu1d binarization without threshold percentage:

Otsu1d binarization with threshold percentage (-40%):

Otsu 2D

Overview

OTSU2D algorithm considers both the gray value of a pixel and the average gray value of it neighborhood, thus is more robust to noise than OTSU1D. Pixels are partitioned into two classes B and F (background and foreground) by a threshold pair (s, t), where s is gray level of a pixel and t it's local average gray level. Otsu2D method is based on the same principles as classic Otsu, but it uses a two dimensional histogram instead of a one dimensional histogram. By using the trace of the between-class variance matrix as the measurement of between class variance and maximizing it we select the corresponding threshold (s, t) for this value.

A detailed description can be found here: http://www.hflab.ips.waseda.ac.jp/~jinglu/Publics/ICGC-Wunhan-published.pdf

Implementation

This method was first implemented for rectangular regions and then adapted so that it can be used for non-rectangular zones. We tried different implementation using more data structure types, in order to obtain a better time performance. We use a fast recursive algorithm to implement OTSU2d method.

Parameters

The window size (width & height) which define the pixels neighborhood, which affects the results should be set considering a set of picture elements like font size. However, according to some tests analysis we can say that better results are obtained for small window size like 4x4.

Similarly to Otsu1d, for Otsu2d binarization can also be applied a threshold percentage for lightening or darkening, which can vary from -100 to 100. For this parameter we recommend a value of -40%.

Advantages

OTSU2D algorithm considers both the gray value of a pixel and the average gray value of it neighborhood, thus is more robust to noise than OTSU1D.

It provides very good results when the numbers of pixels in each class are close to each other.
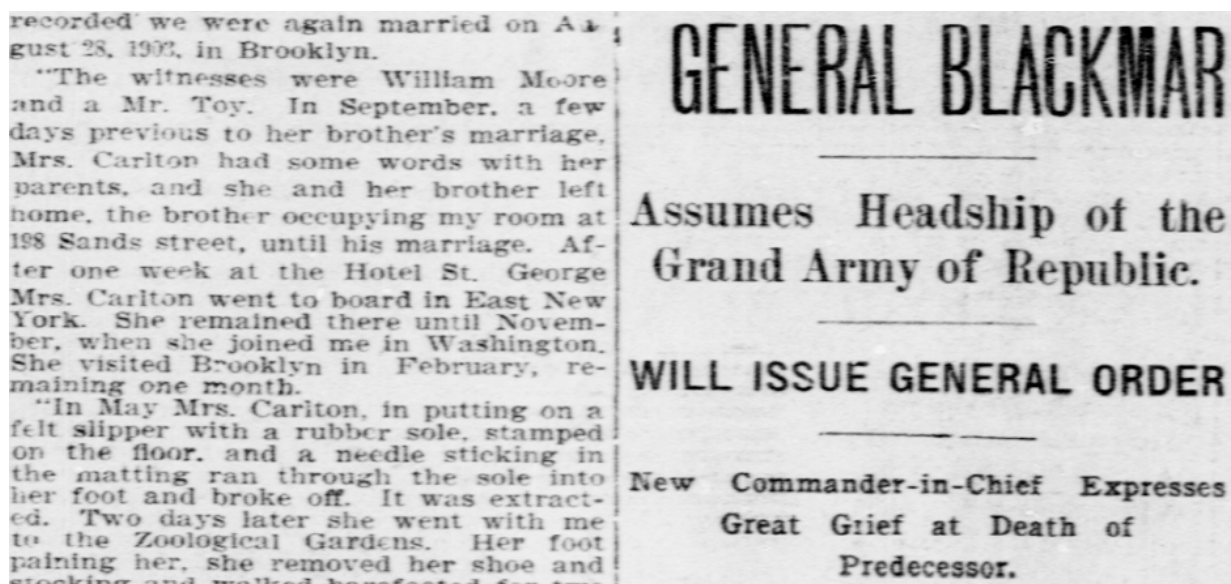
Disadvantages

Is very computationally intensive because iterates through every pixel in the neighborhood for every pixel in the image.

When the object and background pixels are extremely unbalanced, it produce better results than OTSU1D, but still poor results.

Results

Input:

Output:

Otsu2d binarization without threshold percentage and with a 6x6 window:

Otsu2d binarization with threshold percentage(-40%) and with a 6x6 window:

Otsu2d binarization without threshold percentage and with a 2x4 window:

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GENERAL BLACKMAR

Assumes Headship of the
Grand Army of Republic.

WILL ISSUE GENERAL ORDER

New   Commander-in-Chief   Expresses
Great   Grief   at   Death   of
Predecessor.

Otsu2d binarization with threshold percentage(-40%) and with a 2x4 window:

day, May 8, 1902, after a correspondence
of about five months, through a letter
of introduction from McLaughlin   We
were married secretly the next month.
Owing to a failure to have the marriage
recorded we were again married on Au
gust 28, 1902, in Brooklyn.
    "The witnesses were William Moore
and a Mr Toy. In September, a few
days previous to her brother's marriage,
Mrs. Carlton had some words with her
parents, and she and her brother left
home, the brother occupying my room at
198 Sands street, until his marriage. Af-
ter one week at the Hotel St. George
Mrs. Carlton went to board in East New
York. She remained there until Novem-
ber, when she joined me in Washington.
She visited Brooklyn in February, re-
maining one month.
    "In May Mrs. Carlton, in putting on a
felt slipper with a rubber sole, stamped
on the floor, and a needle sticking in
the matting ran through the sole into
her foot and broke off. It was extract-
ed. Two days later she went with me
to the Zoological Gardens. Her foot
p
aining her, she removed her shoe and
stocking and walked barefooted for two
hours Returning home the feet to

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Niblack

Overview

Niblack's method is a local threshold binarization method which involves computing for each pixel in the grayscale image the mean and standard deviation of the colors of the neighboring pixels in an area (window) of predefined size. The threshold for determining if the pixel will be black or white is computed by the formula:

$$T = mean + k * stdev$$

where *k* is a constant, preselected coefficient.

Implementation

We simply slide the window onto each pixel and recompute the mean and standard deviation. No improvement on this method seems to exist.

Parameters

The window size (width & height) and the *k* coefficient affect the results of this method. However, according to our observations and several other studies, it seems that there are some "magic" values for these parameters: ***15x15* pixels window and *k = -0.2***. Apparently, the window size seems to be correlated with the size of the characters in the text, but modifying the window size, as well as the *k* coefficient has unpredictable results.

Advantages

In many articles it is considered the best binarization technique for images containing text. It does not involve a unique threshold for the entire image and thus is adaptable for local particularities.

Disadvantages

In our tests, it ***produced poorer results even in comparison to the simple Otsu 1D method***. Niblack's method produces and extreme amount of noise in the binarized image, especially in the "white" areas (ones which contain no text). Many techniques for removing such noise exist but no not prove very effective.

Furthermore, Niblack's method is very slow on a single threaded CPU taking as much as several minutes for a 17x17 pixel window on a 6000x8000 image. However, it can and should be parallelized for multiple cores / processors, which will improve the running time dramatically.

Results

Input

Output – window size 15x15 pixels, k = -0.2

Color Difference

Overview

This is a **preprocessing technique** for grayscale images before the binarization step. It creates an intermediate grayscale image which binarized with global methods like Otsu 1D or Otsu 2D produces better results than without the preprocessing.

The main idea is to "diffuse" color differences weighted by distances between neighboring pixels. Each pixel in the intermediate image is computed using the following sum, for the pixels in a neighboring area (window) of predefined size:

$$\sigma(x,y) = \sum_{(x',y')\in W} [color(x',y') - color(x,y)]^\delta [|x-x'|^\alpha + |y-y'|^\beta]^\gamma$$

for every pixel of coordinated *(x', y')* located in the window *W* centered in *(x, y)*. The exponents $\alpha, \beta, \gamma, \delta$ are preselected. Finally, these sums for all the pixels in the image are scaled to the interval $0 - 255$ to correspond to a level of gray in the intermediate image.

Implementation

Similar to Niblack's method, we slide the window onto each pixel, computing the sum. However, due to the fact that the formula allows symmetries to be taken advantage of, we iterate through only half of the pixels in the window. Also, we precompute tables with the powers of color deltas and the powers of sums of *x* and *y* deltas.

Parameters

We performed tests only with $\alpha = 2, \beta = 2, \gamma = -0.5, \delta = 1$. Thus the formula above is equivalent to:

$$\sigma(x,y) = \sum_{(x',y')\in W} \frac{color(x',y') - color(x,y)}{\sqrt{(x-x')^2 + (y-y')^2}}$$

We haven't established a correlation between the quality of the output and these exponents. Existence of this correlation should be investigated. On the other hand, it seems that increasing the window size produces better results. We performed test for window sizes between 7x7 and 15x15 pixels. A 30x30 window should produce even better results at the cost of greater running time.
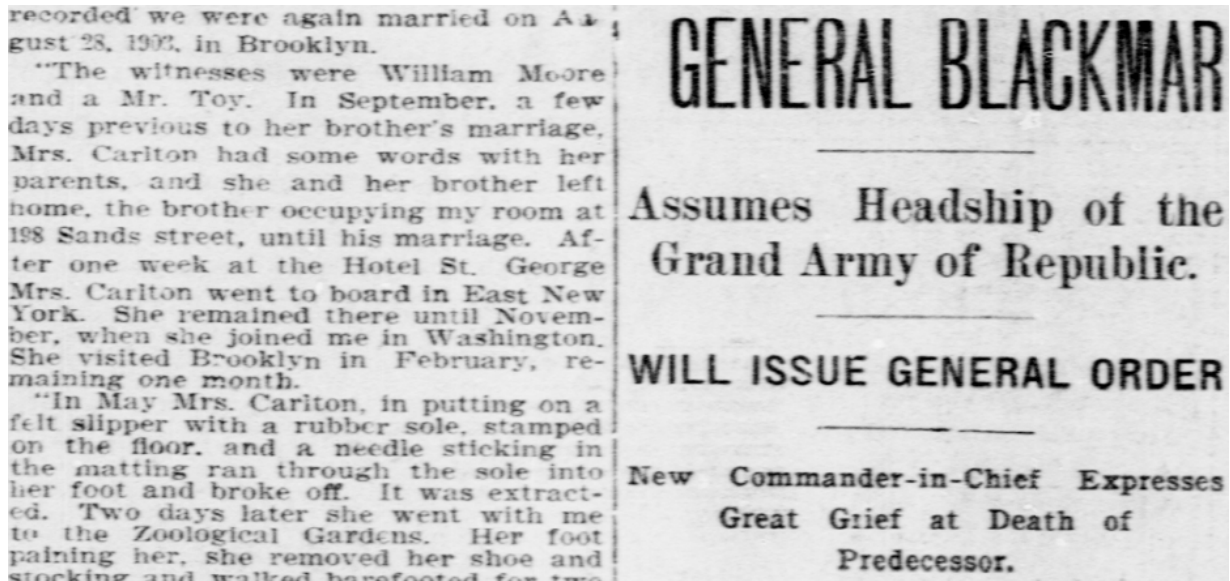
Advantages

We obtained a ***great improvement in the image binarized with Otsu 1D and Otsu 2D using this preprocessing step*** as compared to binarizing without it.
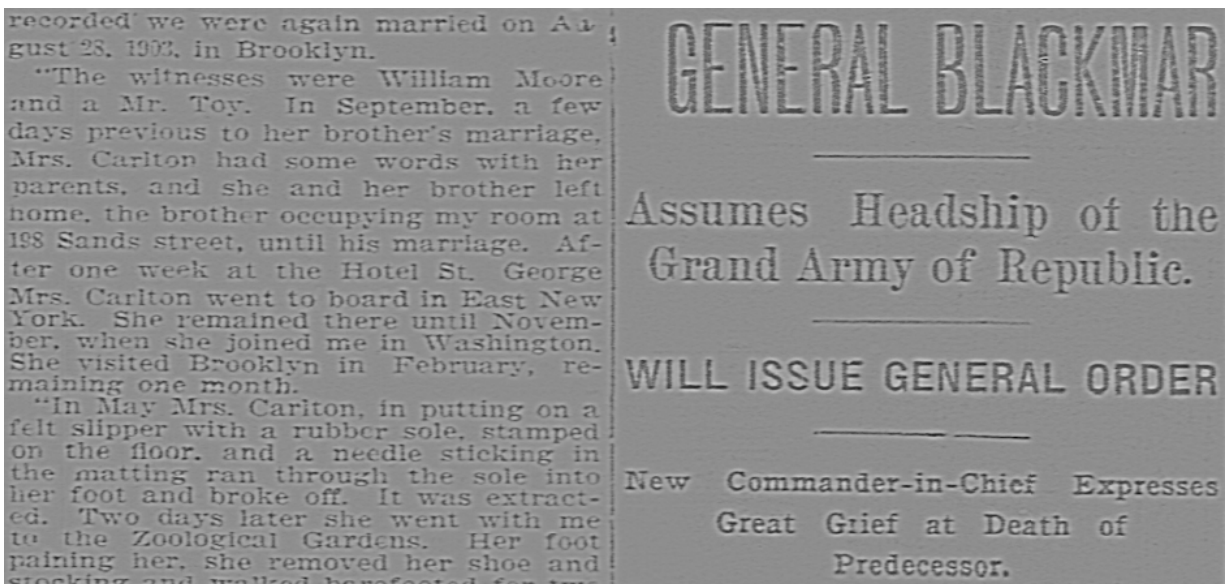
Disadvantages

Similar to Niblack's method, iterating through every pixel in the window for every pixel in the image is very computationally intensive. However, this method is also easily parallelizable reducing the time required from the order of minutes to seconds.

Results

Input

Intermediate image – window size 15x15 pixels

Output – Otsu 1D on intermediate image

Output – Otsu 1D on original image