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Local Thresholding Techniques in Image Binarization

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Abstract: *Binarization is a process of separation of pixel values of an input image into two pixel values like white as background and black as foreground. It is an important part in image processing and the first step in many document analysis and OCR processes. Most of the binarization techniques associate a certain intensity value called threshold. Each and every pixel of the concerned grayscale input image should be compared with the threshold value and according to it, pixels are separated into two classes background and foreground. Thus threshold plays a major role in binarization and choosing of an appropriate threshold value is an important one. It can be approached by two ways, first is the global thresholding and second is the local thresholding techniques. The global thesholding are suitable for converting any grayscale image into a binary form but are inappropriate for complex documents, and degraded documents. If the illumination over the document is not uniform, it produces marginal noise along the page borders. To overcome these complexities, local thresholding techniques have been proposed for document binarization. These techniques estimate a different threshold for each pixel according to the grayscale information of the neighboring pixels. In this paper various local thresholding techniques are compared.*

Keyword – Image Binarization, local thresholding.

1. Introduction

In general, scanned documents include text, line-drawings and graphic regions. It can also be considered as mixed type documents. In many practical applications, we need to recognize or improve the content of the document. In such cases, it is preferable to convert the documents into a binary form. Thus Image binarization plays a key role in the field of Image Processing. Binarization is a process of transforming a gray scale image to a binary image which contains only two classes of pixels white as background and black as foreground. Classification is carried out with a separation intensity value called threshold.

Thresholding then becomes a simple but effective tool to separate objects from the background. Examples of thresholding applications are document image analysis, where the goal is to extract printed characters, logos, graphical content,: map processing, where lines, legends, and characters are to be found scene processing, where a target is to be detected and quality inspection of materials where defective parts must be delineated.

The binarization techniques for grayscale documents can be grouped into two broad categories: global thresholding binarization and local thresholding binarization [2]. Global methods find a single threshold value for the whole document. Then each pixel is assigned to page foreground or background based on its gray value comparing with the threshold value. Global methods are very fast and they give good results for typical scanned documents. For many years, the binarization of a grayscale document was based on the global thresholding statistical algorithms. These statistical methods, which can be considered as clustering approaches, are inappropriate for complex documents, and for degraded documents. If the illumination over the document is not uniform global binarization methods tend to produce marginal noise along the page borders. To overcome these complexities, local thresholding techniques have been proposed for document binarization. These techniques estimate a different threshold for each pixel according to the grayscale information of the neighboring pixels. The techniques of Bernsen, Chow and Kaneko, Eikvil, Mardia and Hainsworth, Niblack [4], Yanowitz and Bruckstein [3], and TR Singh belong to this category. The hybrid techniques: L.O'Gorman and Liu, which combine information of global and local thresholds belong to another category.

In this paper we focus on the binarization of grayscale documents using local thresholding technique, because in most cases color documents can be converted to grayscale without losing much information as far as distinction between page foreground and background is concerned. This method can achieve good results even on severely degraded documents, but it is slow since the computation of local mean, max and min from the local neighborhood is to be done for each image pixel.

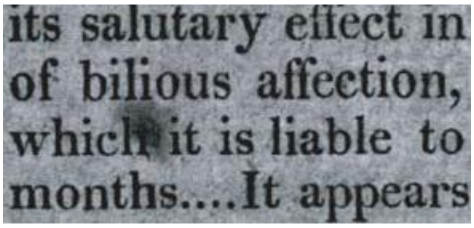


Fig 1.1 Original image

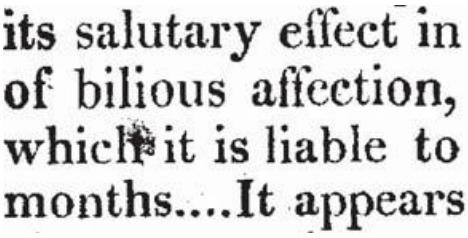


Fig 1.2 Binarized image

2. Techniques of Local Thresholding

In local thresholding technique, a threshold T(x, y) is calculated for each pixel, based on some local statistics such as range, variance, or surface-fitting parameters of the neighborhood pixels within a local block of size w × w. Consider a grayscale document image in which I(x, y) be the intensity of a pixel at location (x , y) In local adaptive thresholding techniques, the aim is to compute a local threshold T(x , y) for each pixel such that

If I(x, y) >T(x, y)
Then
b(x, y) = 1
Else
b(x, y) = 0

Where b(x, y) is the binarized image and I(x, y) ∈ [0, 1] be the intensity of a pixel at location (x, y) of the image I [1]. In local adaptive technique, a threshold is calculated for each pixel, based on some local statistics such as range, variance, or surface-fitting parameters of the neighborhood pixels.

2.1 Niblack's Techniques
In this method local threshold value T(x, y) at (x, y) is calculated within a window of size w × w as:

$$T(x, y) = m(x, y) + k * \delta(x, y)$$

Where m(x, y) and δ(x, y) are the local mean and standard deviation of the pixels inside the local window and *k* is a bias. Set as *k* = -0.2 and local window size is w=15.The local mean m(x, y) and standard deviation δ(x, y) adapt the value of the threshold according to the contrast in the local neighborhood of the pixel. The bias *k* controls the level of adaptation varying the threshold value. Here

pixel = (pixel > mean + k * standard deviation)? object : background.

2.2 **Sauvola's Technique**
In Sauvola's technique, the threshold T(x, y) is computed using the mean m(x, y) and standard deviation δ(x, y) of the pixel intensities in a w × w window centered around the pixel at (x, y) and express as:

$$T(x, y) = m(x, y) \left[1+ k \left(\frac{\delta(x,y)}{R} - 1\right)\right]$$

Where R is the maximum value of the standard deviation (R=128 for a grayscale document), and k is a parameter which takes positive values in the range [0.2, 0.5].Here

pixel = (pixel > mean * (1 + k *(standard deviation / r - 1))) ? object : background

When there is high contrast in some region of the image, δ(x, y) ~ R which results in T(x, y) ~ m(x, y). This is the same result as in Niblack's method. However, the difference comes in when the contrast in the local neighborhood is quite low. In that case the threshold T(x, y) goes below the mean value thereby successfully removing the relatively dark regions of the background [1].
In order to compute the threshold T(x, y), local mean and standard deviation have to be computed for each pixel its computational complexity is O ($n^2 \times w^2$) in a naive way for an image of size n × n [3]. It means that its computational complexity is window size dependent. T.R Singh proposed window size independent technique of thersholding using integral sum image as prior process.

2.3 T.R Singh's Technique
To minimize the computational time of local thresholding calculation, T.R Singh propose an efficient way of determining local threshold using integral sum image as prior process for determining local sum [2]. It uses only local mean and it is very convenient to use integral sum while other techniques like Sauvola's and Niblack's. Techniques are not much convenient because of using both use local mean and standard deviation. Due to uses of integral sum image this technique is local window size independent. This technique is expressed as:

$$T(x, y) = m(x, y) \left[1+ k \left(\frac{\partial(x,y)}{1-\partial(x,y)} - 1\right)\right]$$

Where $\partial(x, y) = I(x, y) - m(x, y)$ is the local mean deviation and is a bias which can control the level of adaptation varying threshold value. The value of *k* takes a major role in determining threshold value. The lower value of *k* makes the threshold value higher and vice versa.

2.4 LAAB (Local Adaptive Automatic Binarization)
Automatic binarization, proposed by T.R Singh, is a process of transforming a gray scale image I(x, y) to a binary image b(x, y) automatically without using any threshold T(x, y) by adapting the pixels within a local region environment. It is an automatic binarization with local adaptation [5]. Local adaptation is carried out within a local window of size w × w with the help of local mean m(x, y) of pixel intensity values of pixels within the local region.
The automatic binarization is designed as:

$$b(x, y) = \frac{|1-2v|-(1-2v)}{2|1-2v|}$$

Where $v = \frac{k(1+\partial)}{(1-\partial)}$,

k is a bias such that $0.5 < k < 0.6$

$\partial = \{g(x, y) - m(x, y)\}\{1-m(x, y)\}$

And g(x, y) is the original pixel at (x, y).

The bias controls the level of adaptation of pixels within the local region at the time of transformation to the binarised image b(x, y). The greater the value of k, the more area of background and less area of foreground and vice versa.

2.5 Bernsen's Technique

This technique, proposed by Bernsen, is a local binarization technique, which uses local contrast value to determine local threshold value. The local threshold value for each pixel (x, y) is calculated by the relation

$$T(x, y) = \frac{Imax + Imin}{2}$$

Where Imax and Imin are the maximum and minimum gray level value in a w × w window centered at (x, y) respectively [4]. But the threshold assignment is based on local contrast value and hence it can be expressed as

if Imax – Imin >L //if the gray scale image is not uniform

Then

$T(x, y) = \frac{Imax + Imin}{2}$

Else

T(x, y) = GT //(else threshold value is calculated by global thresholding technique.)

Where L is a contrast threshold and GT is a global threshold value.

2.6 **Yanowitz and Bruckstein's Method**

Yanowitz and Bruckstein suggested using the grey-level values at high gradient regions as known data to interpolate the threshold surface of image document texture features[5].The key steps of this method are:

1. Smooth the image by average filtering.
2. Derive the gradient magnitude.
3. Apply a thinning algorithm to find the object boundary points.
4. Sample the grey-level in the smoothed image at the boundary points. These are the support points for interpolation in step 5.
5. Find the threshold surface *T(x, y)* that is equal to the image values at the support points and satisfies the Laplace equation $\frac{\partial^2 P(x,y)}{\partial x^2} + \frac{\partial^2 P(x,y)}{\partial y^2}$ using Southwell's successive over relaxation method.
6. Using the obtained T(x, y), segment the image.
7. Apply a post-processing method to validate the segmented image.

3. Literature Review

In the year 2012 O. Imocha Singh and Tejmani Sinam has proposed the Local Contrast and Mean based Thresholding Technique in Image Binarization.

In the year 2011 Er.Nirpjeet kaur and Er Rajpreet kaur has present the review on various methods of image thresholding.

In the year 2011 T.Romen Singh, Sudipta Roy and Kh.Manglem Singh has proposed the Local Adaptive Thresholding Technique in Binarization.

4. Proposed Methodology

This proposed technique of binarization is carried out with a local thresholding technique which uses local contrast and mean.

It is expressed as below:

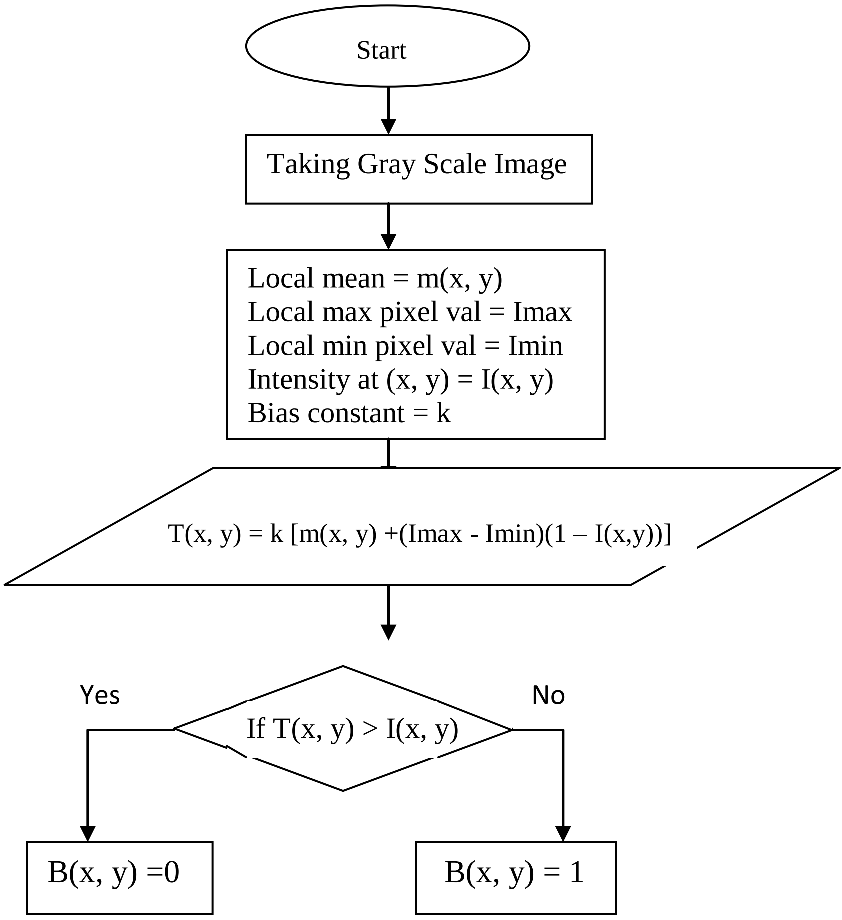
$$T(x, y) = k [m(x, y) + (Imax - Imin) (1 – I(x, y))]$$

where k (0, 1) is a bias constant, m(x, y) is local mean, and Imax , Imin are the local maximum and minimum pixel values within the local window of size w × w and I(x, y) is the concerned pixel value.

In this technique local maximum and local minimum pixel values are associated. As a result of using local minimum and maximum this technique is not suitable for using integral image which is suitable for finding local mean with no time. Hence it works like the other local techniques whose computational time is local window size dependent.

The bias constant k takes a major role to control the level of binarization by controlling the threshold value. The higher the value of k will result the higher value of threshold resulting more in foreground (black) and like this less the value of k will result the less in foreground (black). If the local region is uniform i.e. Imax – Imin ~ 0, then T(x, y) ~k * m(x, y). Thus the value of T(x, y) depends on the value of k. In this case the region becomes background for the other techniques while this technique, T(x, y) is under controlled. In this way this technique gives unlike result of the other local techniques in a better way regarding results.

4.1 Proposed System



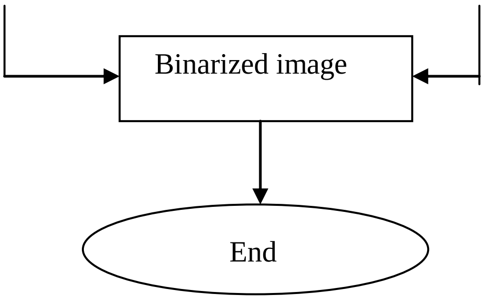


Fig 4.1 :- Proposed system's flow of work.

5. Expected Outcome

Fig 5.1:- Binarised scanned image by different techniques with local window size w=5: (a) original image (b) LAAB at k=0.502, (c) T.R Singh at k=0.02, (d) Sauvola at k=0.02. (e) Bernsen at c=0.06 (f) Niblack at k=-0.3 and (g) Proposed at k=0.9.

6. Conclusion

In this paper we compare different methods of thresholding .These approaches aiming at removal of background noise from historical and ancient documents.

From all these study of thresholding techniques we came to the conclusion that Niblack algorithm failed to remove noise from the background as with the optimum value of k (-0.2), noise is still visible on the background . With the mean filter, Yanowitz and Bruckstein's algorithm managed to remove noise from the background. In Sauvola algorithm threshold value is applied globally which tends to threshold the smaller and darker background pixels. And hence reduce the background noise problem that faced by the Niblack's algorithm. Here the Bernsen's algorithm follow local gray range method and others follow local variance methods.

This paper also presents a new way of image binarization using a local threshold value which is determined using contrast pixel value within a local window size w for local adaptation.

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