Binarisation Algorithms Analysis on Document and Natural Scene Images

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Abstract:-The binarisation plays an important role in a system for text extraction from images which is a prominent area in digital image processing. The primary goal of the binarisation techniques are to covert colored and gray scale image into black and white image so that overall computational overhead can be minimized. It has great impact on performance of the system for text extraction from image. Such system has number of applications like navigation system for visually impaired persons, automatic text extraction from document images, and number plate detection to enforcement traffic rules etc. The present study analysed the performance of well known binarisation algorithms on degraded documents and camera captured images. The statistical parameters namely Precession, Recall and F-measure and PSNR are used to evaluate the performance. To find the suitability of the binarisation method for text preservation in natural scene images, we have also considered visual observation

Keywords:- *Binarisation, Ostu, Niblack, Sauvola, Kittler, Frengs, Bernsen, Natural scene image, degraded documents*

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I. Introduction:

The information present in document images and camera captured scene images can be used for many applications such as automatic document reader, Navigation System for Visually handicap. A lot of research is being carried out to improve the performance and efficiency of OCR for documents and text extraction system for camera captured images. In the standard OCR and text extraction system, the binarization is carried out to convert colored or grey scale image to monochromatic or binary images. The binarization algorithms [1] are classified into two categories based on discontinuity or similarity of grey values. The algorithms, using discontinuity, segment an image based on abrupt changes in grey level, whereas algorithms using similarity are based on thresholding, region growing, region splitting and merging. In case of thresholding algorithms, the conversion is based on finding a threshold grey value and deciding whether a pixel having a particular grey value is to be converted to black or white. Usually within an image the pixels having grey value greater than the threshold is transformed to white and the pixels having grey value lesser than the threshold is transformed to black

The major challenges faced in document binarisation are presence of noise, improper illumination, ink overlapping, sequences. Whereas in case of digital images like X-ray, Ultrasound images, MRI images and camera captured images, binarisation process have to address different level of complexity. Particularly, when we are working on medical images, binarisation is going to be hardest task as very fine detail in image has great significant. In literature [2], it is found that most of the time; these images are suffered due to noise like Speckle, Gaussian noise and Salt Pepper noise. The camera captured images which are also termed as natural scene images have its own complexity issues. As natural scene images carry itself complex background around the object of interest in the scene. The binarisation of such images is work of art as we are interested in objects in the image which are sometime very hard to distinguish from background. The present study has considered well known Binarization algorithm from literature that has shown good results for Document images or camera capture image. These algorithms are tested on document and natural scene image which are different from document images. The complication level of document and camera captured images is discussed and compared as below:

TABLE I. TABLE1: COMPARISON BETWEEN DOCUMENT IMAGES AND NATURAL SCENE IMAGES

Sr.no.	*Complexity*	*Document Binarization*	*Natural Scene Image*
1	Background color	The images have homogenous colored background. Generally back or white is preferred as background of most of documents.	The images have heterogeneous colored background. Natural scene is full of colors and color combination is also very from scene to scene.
2	Shapes in background	Generally, the documents do not have shapes in background. If document has shapes then shapes are clearly separated from text.	The images have full of different shapes and there is no clear separation between text and background object. It is difficult to separate text from background.
3	Foreground text	The document images have homogenous text style and color in text and are easy to identify text as foreground. There is clear division of text and non text regions.	The natural scene images have different style and shape of text and are difficult to identify text in background.

4.	Orientation of Text	We can predict orientation of text in document image. Generally text is in horizontal and vertical orientation. Moreover, orientation of the text in most of cases is uniform throughout the page.	The orientation of text in un-predicted, text may have any orientation i.e. horizontal, vertical, and diagonal. In many cases single scene may have text in multiple orientations.
6	Illumination	Most of the document images are equally and highly illuminated. Even in some case there is minor variation in illumination which can be overcome with simple image enhancement methods	The natural scene images are unequally illuminated due to multiple sources of light like sun light, tube light, reflection, shadow etc. It can also be affected with weather conditions at the time of capturing the image.
7.	Size of text	The document images have similar size of text size like all heading in documents have similar size, text under heading have similar size, etc.	In case of the natural scene image, there no standard rule can be framed to categorize size of text.
8	Text like pattern	In documents images, there are very rare object which mislead as content as text and non text. There is very clear classification between text and non text regions in a document image.	In the natural scene images, there are objects which may mislead to identification of text like fences, leaf.

II. BINARISATION

Binarisation segments input image into two sections i.e. background and foreground. Usually two intensity levels 0 for background and 1 for foreground are considered. The appropriate threshold value is needed to calculate to segments the image into appropriate segments. We have under gone recent literature [15-21] in the field of binarisation and find out most frequent techniques used for binarisation of documents and camera captured images. The following well known algorithms are considered for analysis.

TABLE2: LIST OF BINARISATION TECHNIQUES

1. Otsu's Binarization Technique
2. Niblack's Binarization technique
3. Souvola's Binarization technique
4. Morphological Binarization methods
5. Bernsen's Binarization
6. Feng's Binarization
7. Sliding Window Mean Thresholding
8. Sliding Window Median Thresholding method
9. Sliding Window MidGray Thresholding method
10. Wolf's Binarization method
11. White and Rohrer's Binarization
12. T.R.Singh's Binarization method

2.1. Otsu binarization

Otsu's binarization technique [2,3] is global thresholding technique in which single threshold value is used to binarized the whole image. The algorithm assumes that the image is to represent into two classes of pixels i.e. foreground and background. The optimum thresholding value is calculated such that intra-class variance is minimal. It is one of the fastest binarization algorithms because only histogram calculation is required using array of length 256. The histogram calculation helps to calculate mean value of pixels. The calculation of the inter-classes or intra-classes variances is based on the normalized histogram

Hn= { Hn(0)……………………….Hn(255)} of image, where $\sum_{i=0}^{n} Hn(i) = 1$

The inter-classes variance for each gray level is given by

Vinter_variance=q1(t) × q2(t)×[μ1(t)- μ2(t)]2

Where, $\mu 1(t)=\frac{1}{q1(t)}\sum_{i=0}^{t-1} Hn(i) \times i$

$$\mu 2(t)=\frac{1}{q2(t)}\sum_{i=0}^{255} Hn(i) \times i$$

$$q1(t)=\sum_{i=0}^{t-1} Hn(i)$$

and $q2(t)=\sum_{i=0}^{255} Hn(i)$

Niblack Binarization Technique

Niblack's binarisation [10, 4] is local Binarization method based on sliding window in which thresholding is computed for each and every pixels of the image. The sliding window is a rectangular region about the pixel for which thresholding is being computed. In this technique local mean and standard deviation is calculated within rectangular region to find out thresholding value for central pixel surrounded by neighborhood pixels. The thresholding is decided by the following formula.

T(x,y)=m(x,y)+K* S(x,y),

Where m(x,y) and S(x,y) are the average of intensity values in local area of window and standard deviation for pixel intensity values of the window. Drawback of the method given above is considerable sensitivity of the choice of window size and decision parameters K. To overcome the problem of sensitivity the parameters 'K' and 'R' are used as

T(x,y)=m(x,y)*[1+K(1-S(x,y)/R] where R and K are empirical constants.

2.2. Souvola Binarization Technique

Sauvola's binarization [14,5] is a locally adaptive thresholding of grey scale image. According to the algorithm, local mean and standard deviation are calculated on W× W window around a pixel. Let us consider T threshold for pixels of image and Mw(i ,j),σw(i,j) are considered as local mean and standard deviation on local window of size WxW for pixel location (i,j). The value of T can be calculated as

Tw,k(i,j)= Mw(i,j) *(1+ K (σw (i,j) /R – 1))

Where, Mw(i,j) is called local mean for pixels in window of size Wx, σw(i,j) represents standard deviation for pixels in window of size of size W × W. The parameters, R, k are constant parameters (also called control Factors) to control sensitivity to noise.

2.3. Bernsen's Binarization

Bernsen's binarization [17,6] introduced local thresholding method. In this method we compute local minimum and maximum for neighborhood around each pixel f(x,y) ϵ [0,L-1] and use median of two as the threshold for each pixel in image with reference of size of window. The sliding window is mask of size NxN centered pixel is coincide with the pixel in focus. We keep on slide window from one pixel location to another pixel position in the image to find out appropriate threshold value.

T(x,y)= (Plow +Phigh)/2 , If Phigh - Plow ≥ L

T(x,y)= GT , If Phigh - Plow < L

Where Plow is low value of gray pixel value in the N×M size window, Phigh is high value of gray pixel value in the NXM size window. GT stands for Global Thresholding using Otsu's Binarization.

G(x,y)=(F_{max}(x,y)+F_{min}(x,y))/2 and B(x,y)= 1 if f(x,y)<g(x,y), otherwise 0.

2.4. Feng's Binarization:

Feng's binarization [7] is based on local thresholding in which in place of single sliding window two local windows are used. One window is sliding over each pixel and calculates attributes on the basis of intensity values of neighborhood pixels. Second window differ in the size, usually larger than the size of local window. The values of local mean (Mean Local-m) and minimum gray value (MinGray-M) are calculated in the primary local window with reference to pixels located in the neighborhood. The values of standard deviation are calculated in the both the Windows. The variable S(Local Deviation) and Rs (standard deviation) of pixels of large window. The following formula is used to calculate threshold:

Tfeng =(1- α 1)*m+α2*(S/Rs)*(m-M)+ α3*M

Where α2=k1*(S/Rs)ϒ , α3=k2*(S/Rs)ϒ, value of ϒ=2, S is Standard deviation within local windows standard deviation of secondary window, m is local mean within primary window, M is minimum gray value within primary window.

Sliding Window Mean Thresholding

Sliding window mean thresholding [21] is performed by using calculating mean of gray scale value within local window. The sliding window is placed over each pixel of the image and neighboring pixels values are considered for calculating mean. The following equation is used to find local mean using sliding window.

pixel={ Pixel value > Local Mean-C ? Object: Background}, where c=0 or any value to control noise level.

Sliding Window Median Thresholding

Sliding window median thresholding [21] is performed by using calculating mean of gray scale value within local window. The sliding window is placed over each pixel of the image and neighboring pixels values are considered for calculating median. The pixels surrounded by central pixels are considered for sorting and after sorting the pixel median is calculated. The following equation is used to find local mean using sliding window.

Pixel= {Pixel value > Local Median-C? Object: Background}, Where, c=0 or any value to control noise level.

2.5. Sliding Window MidGray Thresholding

Sliding window median thresholding [21] is performed by using calculating mean of gray scale value within local window. The sliding window is placed over each pixel of the image and neighboring pixels values are considered for calculating median. The following equation is used to find local mean using sliding window.

Pixel= {Pixel value > (Local Maximum + Median)/2 –C ? Object: Background}, usually c=0 or any value to control noise level.

2.6. Wolf's binarization technique

Wolf's binarization technique [8,10] is implemented by calculating stranded deviation and mean within local window and over whole image. The sliding window is placed over each pixel of the image and neighboring pixels values are considered for calculating m(mean) and S(standard deviation). The following equation is used to find the threshold over local window.

Twolf=(1-K)*m+K*M+K*S/R(m-M)

Where k=0.5(Fixed), M- Minimum Gray value, m-mean local, M-mean global, S-Standard Deviation local, R Standard Global

2.7. White and Rohrer's Binarization

White and Rohrer's binarization technique [11] is used to calculate threshold value for Binarization of image by using bias parameters as multiple to pixel value under consideration. The concept of sliding window is used to find out mean value of neighborhood pixels around centered pixel. The following equation is used to compute threshold value for central pixel in the image.

mlocal(x,y)<I(x,y).Bias set pixel I(x,y) to 1, otherwise 0

Where, mlocal(x,y) is the value of local mean within window by using neighborhood pixels. I(x,y) is the value of pixel considered for Binarized. Bias is the control variable (suitable value is 2).

2.8. T.R. Singh and et. al 's binarization

T.R Singh et. al [12]introduced local thresholding computation by calculate local mean and mean deviation by using following equation.

$$T(x,y)=m(x,y)[1+K*(\delta(x,y)/(1-\delta)-1)]$$

Where δ (x,y)=I(x,y)-m(x,y), k is a bias and k € [0,1] , mlocal(x,y) is the value of local mean within window by using neighborhood pixels. I(x,y) is the value of pixel considered for Binarized.

III. ANALYSIS:

We have considered ICDAR2009[13] dataset for binarisation of degraded document images and ICDAR 2011[14] for natural scene images.In literature several papers are found that use precision, recall analysis and f-measure. But in case of natural scene image, the background is too complex that it is not easy to separate object from it. There is lot of text like objects like tree leaf, branches, window, etc. In current study the following methods are used. The more than two thousand images are captures using Nikon D3200 Digital Camera. Images covered different location that contains sign board, notice board, banners, and text written on wall and vehicles in city Patiala. The text present in these boards is in Gurmukhi Script. The images are captured at different locations and at time so that different lighting conditions are covered. Images are resized to cover come computation overhead.

3.1. Parameters of analysis.

The outputs from different Binarization algorithms are evaluated to find out the best suitable algorithm.

- Visual Observation: visual observation is a most efficient method to observe the effect of binarization techniques separating text from background
- Recall(r): It is ratio of number of relevant object pixels retrieved to the total number of relevant object pixels in the reference image.
- Recall= (A/(A+B))*100

Precision (p): It is ratio of number of the number of relevant object pixels retrieved to the total number of irrelevant and relevant object pixels retrieved. The precision can be expressed by the following equation

Precision= ((A)/(A + C))*100

F-measure (f): it is defined to show goodness of the results. A higher value of F-measure represents a better result. It is expressed by the following equation

F-measure= (2 * Recall * Precision)/(Recall + Precision)

Peak Signal to Noise Ratio (PSNR): it is defined as the ratio of peak signal power to average noise power. It can be calculated as

PSNR= 10 log10 2552*MN/ Σi Σj(x(i,j)-y(i,j)2

The different algorithms which are consider for Binarization are Otsu's Binarization Technique, Niblack's Binarization technique, Souvola's Binarization technique, Morphological Binarization, Bernsen's Binarization, Feng's Binarization, Sliding Window Mean Thresholding, Sliding Window Median Thresholding, Sliding Window MidGray Thresholding, Wolf's Binarization, White and Rohrer's Binarization, T.R.Singh's Binarization

3.2. **Ground Truth Images:** The ground truth images are created with manual tool and image is divided into two area foreground and background. The area contains text is labeled as foreground and other area is labeled as background. The databases of ground truth images [14] from Eleventh International Conference on Document Analysis and Recognition (ICDAR 2011) are consider of evaluation of the Binarization algorithms. The following are few sample ground truth images.

TABLE3: GROUND TRUTH IMAGES FROM ICDAR 2009.

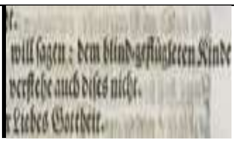
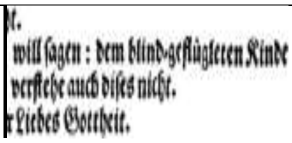
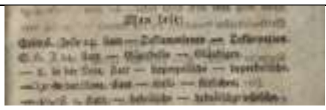
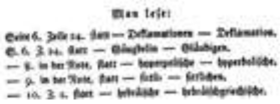
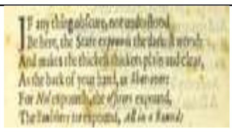
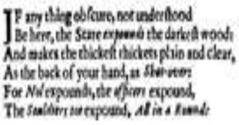
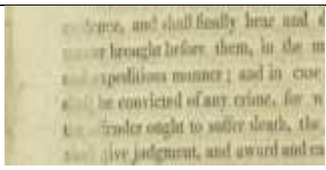
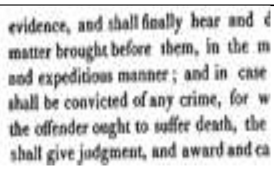
Original Image	Ground Truth Image	Original Image	Ground Truth Image
			
			
			

TABLE4: GROUND TRUTH NATURAL SCENE IMAGES FROM ICDAR 2011

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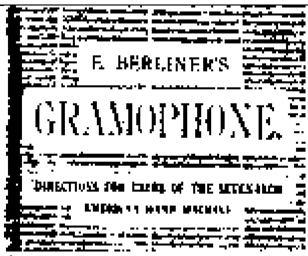
TABLE 5: GROUND TRUTH IMAGE OF NATURAL SCENE IMAGES CAPTURED DURING STUDY

Original Image	Ground Truth Image	Original Image	Ground Truth Image
			
			

1.1. **Visual performance:** Visual performance of Binarisation methods on document images:

Kitter's method	**Otsu's**	**Niblack's method**	**Wolf's method**
			
Souvola's method	**Wolf's Binarisation**	**Bernsen's method**	**White&Rohrer's**
			
Feng's method	**Median filter**	**MidGray filter**	**T.R.S.'s method**

Analysis of statistical parameters: We use recall, precision, f-measure and PSNR to access the performance of document and natural scene images. The following table shows performance using these parameters.

1.2. Decision parameters based analysis: The following parameters are used to access the performance of the different methods.

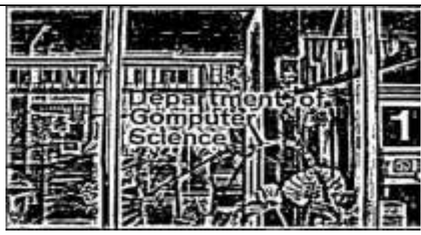
TABLE7. ANALYSIS ON BASED PRECISION, RECALL, F-MEASURE AND PSNR.

Sr.No	Method	Precision	Recall	f-measure	PSNR
1.	Otsu's Binarisation	0.8967	0.9270	91.16829	20.01837
2.	Niblack's Binarisation	0.2364	0.9843	38.1246	7.9908
3.	Souvola's Binarisation	0.8802	0.9332	90.5918	20.1616
4.	Wolf's Binarisation	0.9846	0.5021	66.5088	12.9281
5.	Bernsen's Binarisation	0.1699	0.8658	28.4012	3.5669
6.	Feng's Binarisation	0.0153	0.1251	2.7198	0.4498
7.	Median filter's Binarisation	0.9409	30.2122	0.0988	3.5857
8.	MidGray filter's Binarisation	0.7728	36.0587	0.1269	5.5863
9.	Mean filter's Binarisation	0.3184	11.2004	0.0453	2.9353
10.	Wolf's Binarisation	0.9846	0.5021	66.5088	12.9281
11.	White&Rohrer's Binarisation	0.9255	0.3917	55.0452	11.9066
12.	T.R.S.'s Binarisation	0.2106	0.8992	34.1320	4.5634
13.	Kitter's Binarisation	0.8968	0.9271	91.1683	20.4922

TABLE 8: ICDAR-2011(SAMPLE DATABASE)

ICDAR-2011 Image	Ostu	Niblack
		


EMERGENCY
STOP
LITTER
PEPSI
UK DANCE
PROTOTYPE &
INSPIRED RECORDS
THE
RAB BUTLER
BUILDING

Results: The best suitable algorithms for Binarization of Natural Scene images are implemented on ICDAR-2011 database which gave satisfactory results. The above are few examples with results.

TABLE 9: IMPLEMENTATION OF BINARISATION METHODS ON NATURAL SCENE IMAGES

Original Image	Otsu's Binarization	Original Image	Niblack's Binarization
			
Original Image	Otsu's Binarization	Original Image	Bernsen's Binarization
			
Original Image	Wolf's binarization	Original Image	White and Rohrer's

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3.3. Detail Analysis:

The Binarization is one of the key steps to recognize text in the image so that it can be used for appropriate function such as automatic document reader, Navigation System for Visually handicap. The twelve algorithms from literature has been considered for present research work and their performance has been evaluated using Visual Observation and Mathematical noise and Error calculation methods such as Recall, Precision and F-measure and PSNR. The following observations have been noticed to find out best suitable algorithm.

1. Otsu's method is good Global Binarization method for image where background is uniformly illuminated. It is one of the fasted methods as computational over head is very low. It produces noise into image when there is non-uniform illumination. It gives best result for uniform illumination i.e. Histogram should be bimodal.
2. Window size plays an important role in performance of Niblack's Binarization techniques. The size of the sliding window should be small enough to preserve local significance and large enough to suppress noise. Through experiments it is come to know that 15 x 15 is an ideal size for Binarization. But larger the window

   size slow down the binarization process. So it is recommended to use appropriate size of window like 15 X15 or 17x17. It is good algorithm to segment text region in the image but it produce a large amount of binarization noise in the non-text regions. Large window size minimizes the noise. The values of parameters p and k play an important role to overcome noise problem in the output Binarized image. The most suitable value of p=0.5 and k=-0.2.
3. Sauvola's Binarization algorithm is modification of Niblack's Algorithm as in case of Niback's algorithm there is unwanted noise in non-text area. In this algorithm noise control is better than Niblack. The value of K is always positive and lies between interval [0.2 to 0.5].The experiment results reveal that appropriate value are k=0.5 and k=0.34. The size of the window plays important role to segment the image, the value of window size 15 x 15 gives good results as in the case of Niblack. Similarly there is trade-off between size of window and execution time.
4. In Sauvola's Binarization, value of R=128 is fixed for Gray scale Image.
   When loca neighborhood has high contrast then σw(i,j)=R
   T=Mw(i,J)*(1+k(1-1)), When local neighborhood has low constant then Twk(i,j) goes below the mean value. Sauvola's technique reduces noise and enhances textual part. Computation of Mw and σw(i,j) for each neighborhood is time consuming and computing complexity O(n2w2) for MxN size of image. If the text part of the image is small as compare to total image size then local standard deviation of pixels in the window of image suppress text regions in the image.
5. Feng's Binarization introduced concept of two sliding window where one is local and other is of larger size depending upon the application type. The current research used local window of size 15 x 15 and second window of size NxM, where N and M are dimensions of the image. It gives good result for all type of images but the Drawback of the method is determination of empirical parameters. Through experiment it is revealed that one set of parameters which are good for specific types of images may not be suitable for other kind of images. There are two types of windows to compute local thresholding so it is slow as compare to single window algorithm. Output of sample images are displayed above in the table.
6. The method used by TR Singh is based on calculation of loam mean and Bias constant which may take value between(0,1). The significant improvement in this algorithm is the size of sliding window. It gives good result even for small size of window for example w=7. If it is compare with Niblack and Sauvola, visually outputs are almost similar but there is lot of difference in computational time. In case of Niblack and Sauvola's Binarization methods suitable size of window is 17 to 21 but TR Singh's method requires only 7 to 9 size window to show significant result. Comparatively it is faster than Niback and Sauvola Binarization methods.
7. Morphological Binarization method make use of Erosion operation as it gives good result as compare to Dilation, opening and closing operation. It is suitable for image where text size is large and there is uniform font is used. It distorts the shape of small text and disappear text of very small size. The best convocation mask suitable for Binarization of text images is 7x7.
8. Sliding window mean make use of window of size 7 x 7 to find out local mean of the image. The local mean is compare with current pixel of the local window to find out the threshold. it is good method for images where text written on uniform background. it also add lot of noise in the image as multiple colored background image have different mean in their local area result is non-uniform black and white area as shown in the above table.
9. As in the case of sliding mean thresholding, local window is used to calculate median of the local area in the window.

The pixels in the neighborhood are stored in acceding order with their gray values than threshold is calculated by comparing current pixel and median value. it gives good result only when there is uniform background or minimum color are used in the text area. Even in it good result significant noise is noticed. It is good for only very few images as natural scene images are generally full of background color. MidGray value is calculated by considering pixel in the window and it is also useful when there is large text area.

10. The algorithm suggested by Wolf et al. is based on calculation of local standard deviation and local mean. The sliding window is used to find values of standard deviation and local mean so size of the sliding window is in the key role. Through experiments is revealed that best suitable size of window is 11x 11 and above. It gave good result for almost all kind of images. The image with uniform background is clearly Binarized and exact shape and size of the text is preserved as compare to Otsu's Binarization is a little bit slow but is gives good result even with non-uniform background which is not possible by Otsu. If it is compared with Niblack's and Sauvola's Binarization is good as there is less amount of Noise as compare to both the algorithm. The suitable size of sliding window of Niblack's and Sauvola's Binarization is 17x17 and more where as in case of Wolf we can get good result even at size of 11X11.

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