Correcting circular non-uniform illumination of Sundanese lontar images

S Hadi, M Suryani, E Paulus, and A K Supriatna
Department of Computer Science, University of Padjadjaran
Jalan Raya Bandung Sumedang KM21 Jatinangor 45363, INDONESIA
E-mail: {setiawanahdi, mira.suryani, erick.paulus, a.k.supriatna}@unpad.ac.id

Abstract. This paper presents the method for enhancing quality of degraded images which is essential for information automatic extraction from the digitized ancient manuscript known as lontar. The degraded lontar images have circular non-uniform illumination characteristics that are represented by more brightness on inner center of images and darker in the outer ellipse-like area of the images. The purpose of enhanced image processing is to leveling the distribution of pixels so the images have similar characteristics. The proposed method is developed based on DEWA Framework, a novel and optimized method for object detection, combined with background subtraction technique, which is implemented in several color spaces. Background images are estimated using morphological mathematics with specific type and size of structuring element. This estimation process has to be done due to the unavailability of exact background image captured during image acquisition step. Theoretical foundations of the proposed method along with experimental results are reported in this paper. The proposed method has been tested on 12 Sundanese lontar images which shows this approach is different and unique from most of the existing methods in this field of study. Experiment demonstrated the successful results of the method which is represented by displaying profile characteristics of each images on row 128.

1. Introduction
Ancient manuscripts can be considered as a very important and valuable ethno-based documents, not only in the sense of cultural heritage, but also as part of ethnocultural documents and country intellectual properties. On one hand, some documents are treated and maintained properly. On the other hand, they are badly stored in a place that are rarely attended and on poor condition. In facts, ancient documents, which are written on palm leaves called lontar, can consist of important data or information that might be related to our modern culture and daily life. It is not impossible that some documents can explain mathematical theories or computing concepts that have not been solved today. Efforts have been performed to preserve those documents by digitizing them into digital images, however there are problems found in the acquisition process [1]. This problem becomes a challenge for researcher in this field [2].

In digital image acquisition process, some images might not be taken properly which can cause problems for the next step of processing [3]. These images, for some reasons, are pictured using camera with bad light condition, are taken using flashlight incorrectly, and are captured in uncontrolled environment. The effects of this process shows that intensity distribution of images are not uniform circularly which is represented by circular ellipse-like shape pixels distribution.
The images show more brightness at the center, but darker in the surrounded outer region. In this paper we proposed a novel combination of image processing method to normalize and leveling the intensity distribution of degraded lontar digital images by implementing two background subtraction methods and three color space models. Background images are generated by the estimation using the concept of morphological mathematics.

The experiment has been conducted by involving 12 given Sundanese lontar images, written in the period of 15th century. The quality of proposed method are visualized using histogram profile representation on row 128 for each color models and for each subtraction methods. It is showed that our proposed algorithm can solve the problem of circular non-uniform illumination problems of lontar images. The result is expected to be used for supporting the next step further processing of lontar images such as automatic pattern recognition and indexation [4].

2. Methods

The proposed method is derived partially from DeWa framework concept [5]. In this novel and optimized object detection framework, the space of input images are transformed into 3 color spaces: normalized RGB (nRGB), Hue-Saturation-Value (HSV), and YCbCr [6]. The next step is background image generation. This is performed by estimating each background in each color space using morphological mathematics concept. As we have background images, we can do the next step by subtracting each input image with background image for each color model. Two background subtraction techniques are applied, those are Direct Subtraction (DS) method, and Retrospective Correction (RC) method [8].

2.1. Color Space Transformation

The color transformation is required to obtain simpler yet accurate color separation information of the object. As previously mentioned, the color spaces used in this research are RGB, normalized RGB, HSV, and YCbCr. These color space models make the processing is focused not on the luminance but on the hue of the image. The conversion formula can be described as follows:

Conversion from RGB to Normalize RGB

\[
\begin{align*}
    r &= \frac{R}{R+G+B} \\
    g &= \frac{G}{R+G+B} \\
    b &= \frac{B}{R+G+B}.
\end{align*}
\]  

Conversion from RGB to HSV

\[
\begin{align*}
    H &= \arccos \frac{0.5((R-G)+(R-B))}{\sqrt{(R-G)^2+(R-B)(G-B)}} \\
    S &= 1 - \frac{3 \min(R,G,B)}{R+G+B} \\
    V &= \frac{1}{3}(R + G + B).
\end{align*}
\]  

Conversion from RGB to YCbCr

\[
\begin{align*}
    Y &= 0.299R + 0.587G + 0.114B \\
    C_r &= R - Y \\
    C_b &= B - Y.
\end{align*}
\]

where \( R, G, B \) are the pixel intensity values on channel Red, Green, and Blue.
2.2. Background Image Estimation
The background image generation is estimated by applying opening morphological mathematics technique which consists of erosion followed by dilation with structuring element parameter ‘disk’ with a size of 15. The theoretical concept of this method can be defined as follows:

**Definition 1** Erosion can be formulated as 
\[ A - B = \bigcup_{b \in B} A_b = \{ p | B_p \cap A \neq \emptyset \} \]

**Definition 2** Dilation can be formulated as 
\[ A \oplus B = \bigcup_{b \in B} A_b = \{ p | B_p \cap A \neq \emptyset \} \]

This mathematics definition of erosion can be simplified descriptively as follows:
- Let \( A \) is a set of Euclidean coordinate which corresponds with a binary image as data input.
- Let \( B \) is a structuring element that consists of small elements that are used as the determination elements for erosion process.
- \( B_x \) is a transformation process of \( B \) for all image regions.
- Erosion \( A \) by \( B \) simply can be defined as a set of all points in \( x \) which satisfy the condition that \( B_x \) is a subset of \( A \).

Similar with the above, dilation operation can be described as:
- Let \( A \) is a set of Euclidean coordinate which corresponds with a binary image as data input.
- Let \( B \) is a structuring element that consists of small elements that are used as the determination elements for dilation process.
- \( B_x \) is a transformation process of \( B \) for all image regions.
- So the dilation \( A \) by \( B \) can be defined as a set of all points \( x \) that follow the rule so the intersection between \( B_x \) and \( A \) is not empty.

The combination of erosion followed by dilation is known as an opening operator. The dilation operation followed by erosion operation is known as a closing operator.

2.3. Background Subtraction Techniques
Two techniques are applied in this part, those are Direct Subtraction (DS) technique, and Retrospective Correction (RC) technique. DS technique is the simplest method which merely does subtraction operation between input image and background image.

The RC technique is a more complex step that involves statistical calculation. All methods are applied in grayscale image. The formula for RC techniques can be stated as follows:

\[ g(x, y) = \frac{f(x, y)}{b(x, y)} \cdot C \]

where
\[ C = \frac{1}{f(x, y) \cdot \frac{1}{b(x, y)}}. \]

\( f(x, y) \) is the original image, \( b(x, y) \) is the estimated background image, and \( C \) is a normalization constant that is used to recover the initial intensities.

2.4. Measurement
The result of the proposed method is presented by histogram profiling [7], snapshot on row 128 in 2D. This is visualization of pixel distribution characteristics on specified row the intensity value on each pixel on a row.

The other measurement method is to calculate the simple statistics of each image which is represented by number of pixels mean, standard deviation, minimum value, and maximum value. This measurement shows how the intensity distribution of each image.
3. Implementation
Lontar images used in this experiment are obtained from personal repository which cannot be considered as good quality images. The images are not only taken using average-quality camera but also difficult to be re-taken due to complex procedures and cultural constraints. However, these images are challenging for us to develop special image processing algorithms for correcting the intensity distribution. Figure 1 shows the 3 of 12 selected-cropped lontars.

![Figure 1. Pictures of 3 of 12 selected-cropped Lontar used in this research](image)

We can see that the image intensities are unevenly distributed with more brightness on the center circularly. This is usually caused by the bad quality of flashlight. The intensities on the outer circle are darker especially on the most left and right side.

Getting internal characteristics of the images is performed by histogram profiling. Theoretically this can be done vertically and/or vertically. In this case we took rows 128 horizontally as displayed on the Figure 2.

![Figure 2. Profile Histogram of Lontar on Row 128](image)

We can see the internal characteristics of those three images by evaluating each histogram profile. The lower histogram is shown on the left and right side. We can infer that the bar is getting higher to the right and after reaching the center then getting lower. It is looked like sinusoidal wave. The profile informs us that the intensities on the center is brighter than on the
sides. What we are going to do is to normalize the sinusoidal-like form of profile into straight-like line.

The algorithm that is applied to those input images to normalize the images can be described as follows. It is noted that we are working on grayscale images, so we have to preprocess the images by transforming from color images into grayscale images.

(i) Convert preprocessed input image to selected color model
(ii) Generate estimated background images using morphological opening using 'disk' structuring element with size 15
(iii) Perform background subtraction using
   (a) Direct subscription
   (b) Retrospective Correction
(iv) Perform histogram profiling for the result images

Figure 3 and Figure 4 show the histogram profile of corrected lontar 3306 using DS and RC background subtraction techniques respectively.

![Figure 3. Profile of Corrected Lontar 3308 using DS Technique](image1)

![Figure 4. Profile of Corrected Lontar 3308 using RC Technique](image2)

To view the numerical value of the intensity distribution, simple image statistics has been applied. The result of lontar 3308 image statistics and its pixel-range normalized are presented
on the Table 1 and Table 2. These tables consist of columns that represent: type of color space (Color Space), method of correction used (Corr.), number of pixels (Sum), pixel intensities average (Mean), standard deviation (Std), minimum and maximum intensity value of pixels (Min, Max).

### Table 1. Image Statistics of Corrected Lontar 3308

| Color Space | Corr. | Sum   | Mean  | Std   | Min | Max |
|-------------|-------|-------|-------|-------|-----|-----|
| RGB         | None  | 104727728 | 96.65 | 40.08 | 2   | 255 |
| nRGB        | None  | 115281829 | 106.39| 33.13 | 38  | 255 |
| HSV         | None  | 91906324  | 84.82 |13.37  | 0   | 154 |
| YCbCr       | None  | 121735669 | 112.34| 11.07 | 90  | 176 |
| RGB         | RC    | 103359441 | 95.39 | 30.70 | 60  | 255 |
| nGB         | RC    | 114555097 | 105.72| 26.47 | 89  | 255 |
| HSV         | RC    | 91658512  | 84.59 |19.68  | 0   | 255 |
| YCbCr       | RC    | 121893531 | 112.49| 7.74  | 106 | 184 |
| RGB         | DS    | 36262725  | 33.47 | 29.54 | 0   | 255 |
| nGB         | DS    | 18165601  | 16.76 |27.61  | 0   | 208 |
| HSV         | DS    | 13491113  | 12.45 | 9.35  | 0   | 122 |
| YCbCr       | DS    | 7151192   | 6.60  | 7.47  | 0   | 74  |

### Table 2. Image Statistics of Corrected Lontar 3308 with Pixel-range Adjusted

| Color Space | Corr.  | Sum   | Mean  | Std   | Min | Max |
|-------------|--------|-------|-------|-------|-----|-----|
| RGB         | None   | 74732957 | 68.97 | 46.67 | 0   | 255 |
| nRGB        | None   | 35070265 | 32.36 | 49.53 | 0   | 255 |
| HSV         | None   | 195067216 | 180.02| 42.49 | 0   | 255 |
| YCbCr       | None   | 53127569 | 49.03 | 47.30 | 0   | 255 |
| RGB         | RC     | 51272922 | 47.32 | 39.21 | 0   | 255 |
| nRGB        | RC     | 27828681 | 25.68 | 40.41 | 0   | 255 |
| HSV         | RC     | 35085530 | 32.38 | 36.60 | 0   | 255 |
| YCbCr       | RC     | 38067007 | 35.13 | 35.22 | 0   | 255 |
| RGB         | DS     | 46347949 | 42.77 | 36.53 | 0   | 255 |
| nRGB        | DS     | 26565527 | 24.52 | 39.81 | 0   | 255 |
| HSV         | DS     | 65732134 | 60.66 | 43.29 | 0   | 255 |
| YCbCr       | DS     | 34155388 | 31.52 | 36.03 | 0   | 255 |

As previously mentioned, we used 12 lontar images for the experiment, so we do averaging for all image intensity adjusted results. The result is presented on the Table 3. To get more impressive result, we presented the standard deviation values for all correction methods on Figure 5.

The implementation of proposed methods on Lontar images can be considered as a novelty of this paper. The numerical result presented on the tables followed the resulting images of the proposed method, so the numerical result can be inferred as a novelty as well.

4. Conclusion and Future Works

We have developed an algorithm for correcting circular illumination problem in Lontar images. The method is based on background subtraction technique which is implemented in two approaches, the first is using direct subtraction approach, and the second is using retrospective...
Table 3. Image Statistics of Corrected All Images (12 Lontars)

| Color Space | Corr. | Sum     | Mean   | Std    | Min | Max |
|-------------|-------|---------|--------|--------|-----|-----|
| RGB         | None  | 69216487| 65.98  | 45.92  | 0   | 255 |
| nRGB        | None  | 34150915| 32.58  | 47.49  | 0   | 255 |
| HSV         | None  | 182561967| 173.80 | 43.70  | 0   | 255 |
| YCbCr       | None  | 48864597| 46.62  | 45.51  | 0   | 255 |
| RGB         | RC    | 48415162| 46.08  | 37.63  | 0   | 255 |
| nRGB        | RC    | 27466880| 26.16  | 39.99  | 0   | 255 |
| HSV         | RC    | 28704876| 27.37  | 35.27  | 0   | 255 |
| YCbCr       | RC    | 34251970| 32.60  | 34.43  | 0   | 255 |
| RGB         | DS    | 43302293| 41.22  | 35.25  | 0   | 255 |
| nRGB        | DS    | 24751186| 23.57  | 38.40  | 0   | 255 |
| HSV         | DS    | 61088057| 58.25  | 43.49  | 0   | 255 |
| YCbCr       | DS    | 31335609| 29.86  | 34.83  | 0   | 255 |

Figure 5. Standard Deviation Visualization for All Correction Methods

correction approach. Both methods are applied in 3 different color space models: normalized RGB, HSV, and YCbCr. The background images are estimated using mathematical morphology idea using disk structuring element with size of 15. The results are evaluated by computing the simple statistics for each results and displaying using profile characteristic histogram taken on row 128.

Based on conducted experiment that involved 12 lontar images, we can see that the result is promising. The histogram profile shows the changing from sinusoidal-like form into straight-line form. It means that the pixel intensity is uniformly distributed. The image statistics present the decreasing value of standard deviation which means the distribution value is not too sparse. However, even we have better intensity distribution, the resulting image is visually not better than the original image. This can be other challenge to make the output image is clearer especially in the area where the written text is located.

Acknowledgments
The authors would like to thank the Rector of Unpad, the Dean of Faculty of Math. and Nat. Sciences Unpad, and Prof. Jean-Christophe Burie from the University of La Rochelle, for supporting of this research. Great appreciation is pointed to the AMADI team Unpad for the hard work and contribution.
References

[1] Yahya S R, Abdullah S N H S, Omar K, Zakaria M S and Liong C Y 2010 Review on Image Enhancement Methods of Old Manuscript with Damaged Background, *Int. Jour. on EE and Informatics* 2 p 1

[2] Kesiman M W A et al. 2017 Southeast Asian Palm Leaf Manuscript Images: A New Challenge for Handwritten Text Line Segmentation Method, *Int. Jour. of Electronic Imaging* 26 p 1

[3] Paulus E, Suryani M and Hadi S 2016 Preliminary Study On Binarization Methods Of Ancient Sundanese Manuscript Images *Asian Mathematical Conference*

[4] Suryani M and Hadi S 2016 Sundanese Ancient Manuscripts Search Engine Using Probabilistic Approach *Asian Mathematical Conference*

[5] Hadi S, Suwardi I S and Ahmad A S 2007 DeWa : A multi aspect approach for multiple face detection in complex scene digital image *ITB Journal of ICT* 1C p 1

[6] Dubois E 2007 *The Structure and Properties of Color Spaces and the Representation of Color Images*, (Morgan & Claypool Publishers)

[7] C Lundström 2006 Technical report: Measuring digital image quality *diva-portal.org*

[8] Gonzalez R C, Woods R E and Eddins S L 2009 Digital Image Processing Using MATLAB 2nd edition (Gatesmark Publishing)