Evenly brightening using kurtosis Gaussian pattern to simplify image binarization

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Abstract. A problem of separating object from background using thresholding in image segmentation is uneven image brightness. Some binary image objects vanish because the pixel intensity value on the edge side is greater than the pixel’s background intensity. The others at the edge of image are covered by background pixel. The background pixel at the edge is bigger than the pixel value of the object in the inside of image. A light source type affects the spread of brightness adding thresholding difficulty. The object’s light distribution from the exposed light source follows the Gaussian distribution. A kurtosis value depends on the light source type. Following the kurtosis of standard deviation, the method for creating brightness evenly is designed. The Gaussian pattern is formed from the distribution of Gaussian values in the cells of the Gaussian matrix. The pixel values in the corresponding images will be added to the matrix cells. The pixel value will increase according to the Gaussian matrix pattern. This process results in the highest pixel value not getting added value, while the lowest pixel intensity value will get the greatest value addition.

1. Introduction

A grayscale image using thresholding method is a general process to binarize an image. This process will compares the grayscale value from the image grayscale to the threshold value [1][2][3]. Thresholding process at the image binarization needed evenly bright of image. Unfortunately, the image capture process is due not always at evenly lightening. Uneven image brightness due to poor lighting causes uneven pixel intensity [4][5][6][7]. The part of the image that gets lighter will have a greater pixel intensity value so that it is brighter than other parts that are less light.

When the pixel intensity range is separated by the thresholding operation, the pixel value which is lower than the threshold value is set to 0, while the pixel intensity value that is greater than the threshold value is set to 1. While the background pixel’s values are set to 1, some pixels of the object with greater than or equal of the threshold are set to 1 to. In other side, while the object pixels are set to 0, some pixels of background that has values are lower than threshold value is set to 0 too. Setting down threshold value to lower value or setting up threshold value cannot help the segmentation.
For example, the image that shown in Figure 1 has uneven pixel intensity, the center side of the image has higher values than others. After thresholding process, the binary image result can be seen Figure 2. Figure 2 shows that the object pixels on the image are broken as some pixels on the center side of the objects are set to white as background pixels. Other objects at the around side are broken because the background pixels near the objects are set to black as like as the pixels objects.

Because of unevenly of image brightness, the thresholding process to make a binary image cannot work properly. There are some objects disappear and the other are blended with background pixels. The different source of light kind causes the contrast of image part higher. The aim of this research is to simplify the thresholding of image binarization process. The purpose of this study is to simplify the process of image binarization using thresholding. Whereas, the spread conditions image brightness according to Gaussian kurtosis that caused by a single light source.

2. Method design
Generally, the light source has the distribution similar with Gaussian pattern [8][9]. The kurtosis of Gaussian is presenting depend on light source type. The brightening process using Gaussian pattern is the process to evenly the distribution of pixel intensity. Since the distribution of intensity is evenly in every pixel, the thresholding process to make a binary image will easier. Brightening process using Gaussian pattern is depend on the standard deviation value. Gaussian with two variables need the standard deviation to fill the value in each cell of Gaussian matrix. Standard deviation will determine the value of Gaussian in every two variables of x and y as the address of cell Gaussian matrix.

2.1. Standard deviation
The brightening process using the Gaussian pattern is based on two variables as seen in the Equation 1. A $G(x,y)$ function is the distribution function of Gaussian at every cell where the address in row x and column y. The function is filling every cell at the address of x column x and row y with powering the exponential (e) constant value with minus of power x row that subtract with power of y column. Standard of deviation is distribution measure that represent deviation of means. Variant is average measurement deviation power of means [10][11][12].

$$G(x, y) = e^{-\left(\frac{x^2 - y^2}{2\sigma^2}\right)}$$  \hspace{0.5cm} (1)

Where:

$G(x,y)$ : function of Gaussian distribution the cell (x,y),

$x$ : column position

$y$ : row position

$e$ : exponential

$\sigma^2$ : a common variance
There are three kinds of kurtosis that show in Figure 3 [13]. Zero kurtosis or Gaussian distribution called as Mesokurtic, caused by the standard deviation value is equal with the farthest cell distance from the center of matrix [14]. Positive kurtosis called as Leptokurtic, is caused while the standard deviation value is less than farthest cell distance from the center of matrix. Negative kurtosis called as Platykurtic is caused of the standard deviation value is greater than the farthest cell distance from the center of matrix [15]. The bigger standard deviation value makes the curve more focus, and the smaller of standard deviation value makes the curve flatter [16][17][18]. In other research, Gaussian filter of brightness bi-histogram equalization technique can be used for contrast stretching and brightness preservation to performance evaluation [19] and usually use to remove noise or to image smoothing process. [20][21].

![Kurtosis Types](image)

**Figure 3.** Standard of deviation affect to the kurtosis

2.2. *Image evenly brightening and image binarization*

Image binarization be processed with thresholding of grayscale intensity value from grayscale image. In this process, the thresholding following the brightness process using gaussian pattern. The brightness using gaussian pattern is due to evenly the distribution of intensity base on area division. This process to evenly the brightness is modeled by gaussian pattern. The gaussian matrix is build and be implemented to controlling distribution of pixels intensity of images. The intensity of light source that different one another at the captured of image process can adapted by standard of deviation that set to follow the gaussian distribution of pixels intensity distribution from the image. After grayscale intensity of every area division is evenly, the binarization process using thresholding process can be implemented.

\[
\text{matrixWidth} = 2 \times \text{imageWidth} \\
\text{matrixHeight} = 2 \times \text{imageHeight}
\]

Flowchart are shown at the figure 4 show the sequence of overall evenly the brightness and binarization process to make a binary image. The brightening image is following the pattern of gaussian matrix. The height and width of image are needed to make the gaussian matrix size. Matrix width is set twice of image width as show on equation (1). Matrix height is set twice of image height as show on equation (2). The matrix size must be fourth of image size to accommodate the light focus of image that can be anywhere at the image. The size of the gaussian matrix which is twice the height and the width of the image to anticipate if the gaussian center is squeezed on one of the corners of the image, then the pixels at the other corner opposite the pixel remain on the matrix gaussians.

The standard of deviation at the gaussian zero mean is the achievement of the center of the matrix to the edge of the matrix. To determine the variant, the Standard of deviation is needed. The gradation
values $\sigma^2$ in each cell of the gaussian matrix can be determined by variant, to make sure the farthest cell from the center in the gaussian matrix will be zero [22].

\[
\sigma = \max(\text{width}, \text{height}) + (\max(\text{width}, \text{height}) \times \text{PercentDistance})
\]

**Figure 4.** Flowchart process of brightening image using Gaussian pattern and binarization

2.3. Kurtosis implementation

The input of this process contains of input of ‘percent distance’ value to determine the standard of deviation based of the equation (4). The input range of ‘percent distance’ is from minus 90% to positive unlimited as the needed% to represent the empirical rule kurtosis. The range value standard deviation represents the type of distributed light intensity depends on source of light are used. Based on the above process, the zero mean gaussian with two variables is implemented to the gaussian matrix from the cell (0,0) until cell (2x,2y). Leptokurtic kurtosis is represented while the input ‘percent distance’ is negative, it means the gaussian matrix is smaller than image size. Mesokurtic kurtosis is represented while the input ‘percent distance’ is zero. It means that the gaussian matrix size is twice of image width and image height. Platykurtic kurtosis is represented while input ‘percent distance’ is positive, it means the cell contains of zero value is very far from the center of gaussian matrix.

\[
\sigma = \max(\text{imageWidth}, \text{imageHeight}) + \max(\text{imageWidth}, \text{imageHeight}) \times \text{inputPercent}
\]

\[
\text{BrightnessMatrix}(x,y) = (\max\text{Intensity} - \min\text{Intensity}) \times (1 - G(x,y))
\]

Brightness matrix is build based on the Gaussian matrix is illustrated by Figure 5. This matrix is needed to control brightness at every pixel. To fill the brightness matrix cell is needed the distance between most high value and the lowest value of intensity from whole pixels at the image. The distance will reduce depend on the values at every cell of gaussian matrix as the percent to fill every cell at the brightness matrix. Equation (5) shows the process to fill every cell at matrix to control brightness.

Brightness matrix will superimpose to the bitmap, with the center of matrix is placed to the center of brightest pixels and every pixel is add with the value that cell of brightness matrix that superimpose. This process will reduce the pixels value as the pattern of Gaussian distribution.
Figure 5. Example of Gaussian brightness that build from reversed of Gaussian matrix with distance between minimum and maximum pixel intensity is 24

The input of ‘binary threshold’ is needed to make the thresholding process after pixels intensity is evenly distributed. If the result pixel is smaller than threshold value, the pixel will be set to 0. If the result pixel is greater than threshold value, the pixel will be set to 1.

3. Result and Discussion
The purpose of enlightenment with a Gaussian pattern is to simplify the process of image binarization. This method is tested for binarized images that contain very bright pixel portions. The results of this process are images that have uniform brightness in each part of the image, so that the binarization process can be easier because the brightness distribution is almost the same. The sample images in Figures 6 through 9 show how the gaussian pattern brightness process is useful for comparing images.

Figure 6. Raw gray scale image
Figure 7. Gray scale image after brightening with gaussian pattern brightness
Figure 8. Binary image with thresholding until there are no black flood background, many objects at the center are hide
Figure 9. Binary image from result image of Gaussian pattern brightness
The image is showed in Figure 6 is the grayscale image before process by Gaussian pattern brightness. The pixel intensity is unevenly distributed. The image thresholding results of the image are shown at Figure 2 and Figure 8. There are many objects are broken. The center part of the image has the broken objects because some pixels are set to white as like as background pixels. If the threshold value be set to lower value, the binary image will be look like Figure 2. The center part still not so good enough and the corners side are flood by black pixels, so the objects are broken too.

The Image that has been process by gaussian pattern brightness is shown at Figure 7. Because all over part are looks like the same brightness, there is no too light part or too dark part except the objects. The image result of thresholding process is shown at Figure 9. The objects contain of this image separate better and clearly. There are no objects are hide or broke.

Every part of matrix divides by n × n pixels. If the most right and the most bottom area is less then n will be replicated from the most right and most bottom pixel that contains of intensity value of the image. Average of the pixel intensity every part is measured to find out the smallest and biggest average to measure the success. Distance between the smallest and biggest average from the divided areas will compare to measure the effectiveness of brightness.

The input percent of standard deviation will be trace from +200% to -90% of matrix perimeter to find out the best input. The best input is first time of distance between highest and lowest average value to the lowest value before it raise again. The lowest value after the it raised up again is not useful because it means all pixel became very light until white. If nothing the evenly brightness, the process is noted as fail.

The reason of not use biggest and smallest intensity at the measurement is: because the object pixel must very dark and the background must very bright, so the measurement pixel to pixel cannot represent the evenly of intensity. The using the average intensity of area of n × n pixels are presented the condition of evenly the distribution of pixel intensity. Every part of image will contain of some pixel object and some pixel background.

The experiments will be due depend on kurtosis of leptokurtic, mesokurtic and platykurtic of standard deviation as the input percent to generate the gaussian matrix. To compare how is the kurtosis will affect to the result and to proving the advantage that this process is make binarization simplier, the result of brightening by gaussian will be binarized to the binary images. The measurement of effectively this process is how clear the object binary image that separate from background by the binarization process.

| Gaussian Pattern Brightness Kurtosis | Brightening Success | Before Brightening | After Brightening | Binarization Success | Increase |
|-------------------------------------|---------------------|--------------------|-------------------|---------------------|----------|
| Leptokurtic                         | 95%                 | 32%                | 77%               | 45%                 |
| Platykurtic                         | 92%                 | 50%                | 100%              | 50%                 |
| Mesokurtic                          | 100%                | 100%               | 100%              | 0%                  |
| **Average**                         | **96%**             | **61%**            | **92%**           | **32%**             |

The success of brightening using Gaussian Pattern Brightness is showed at Table 1. The Brightening process in Leptokurtic pattern has 95% of brightening proces and can increase the success of binarized 45% from 32% binarized success without brightening to 77% binarized success with brightening. The brightening process in Platykurtic pattern has 92% of brightening process and can increase the success of binarized 50% from 50% success binarized without brightening process to 100% success binarized with brightening process. The brightening process in Mesokurtic pattern has 100% of brightening process and can increase the success of binarized 0% because both success binarized without brightening and success brightening process are 100% success. The overall success of brightening is 96%. Overall increasing success of binarized with gaussian pattern brightening is 32% from 61% success dari binarized without brightening of gaussian pattern. The success is caused by the brightness of every part of image are evenly, so that the thresholding value of image binarization at every part are similar.
4. Conclusion
Brightening process at Gaussian pattern is success to evenly the image that intensity distribution is not evenly. The leptokurtic model is the worst model to evenly brightness. Leptokurtic type enlightenment process reaches 95%, but it has effective on binarization is as good as other patterns. Brightening process using Gaussian pattern is effective to increase 32% the success value of binarized from 61% to 92%.

References
[1] R D Atmaja, M A Murti, J Halomoan, F Y Suratman 2016 Journal of Electrical Engineering and Computer Science Vol. 3 No. 2, August 2016, pp. 377 ~ 382, DOI: 10.11591/ijeecs.v3.i2.pp377-382
[2] T R Singh, S Roy, O I Singh, T Sinam, K M Singh 2011 IJCSI International Journal of Computer Science Issues, Vol. 8, Issue 6, No 2, November 2011, ISSN (Online): 1694-0814, p271-277
[3] T M S Mulyana 2016 International Conference on Information & Communication Technology and Systems (ICTS) Proceedings 12-12 Oct. 2016, IEEE, DOI: 10.1109/ICTS.2016.7910287
[4] Moreno, Ivan & Tsai, Chang-Yu & Bermudez, David & Sun, Ching-Cherng 2007 Proceedings of SPIE - The International Society for Optical Engineering. art. no. 66700H p 6670. doi: 10.1117/12.735820.
[5] T R M Filho, K M Weig, M M Werneck, C A C Neto, M F da Costac 2015 Journal of Biomedical Optics May 2015 • Vol. 20(5) p.055005-1:055005-5
[6] Feng Lu, Y Matsushita, I Sato, T Okabe, and Y Sato 2015 IEEE Transactions on Pattern Analysis and Machine Intelligence Volume: 37 , Issue: 10 , Oct. 1 2015 (DOI: 10.1109/TPAMI.2015.2389841) Page(s): 1999 - 2012
[7] I Sato, T Okabe, Y Sato, K Ikeuchi 2005 Proceedings of the IEEE International Conference on Computer Vision - ICCV 2005 October 2005 pp. 325-332,
[8] Y Xu, Y Li and Y Qiu 2009 Journal of Modern Optics - J MOD OPTIC. 56. 2329-2334. 10.1080/09500340903398440.
[9] S Schoenecker and T Luginbuhl 2016 IEEE Signal Processing Letters Volume: 23 , Issue: 5 , May 2016 ) Page(s): 644 - 647 (DOI: 10.1109/LSP.2016.2537981)
[10] E. L. A. Picasso and J. M. P. Fortes 2008 in Electronics Letters, vol. 44, no. 3, pp. 194-196, 31 January 2008) (doi: 10.1049/el:20082550)
[11] E. A. Aronson 1974 IEEE Transactions on Aerospace and Electronic Systems, vol. AES-10, no. 5, pp. 609-614, Sept. 1974 (doi: 10.1109/TAES.1974.307853)
[12] E. Wong 1966 SIAM Journal on Applied Mathematics, 1966, Vol. 14, No. 6 : pp. 1246-1254
[13] Petar Cisar and Sanja Maravic Cisar 2010 Acta Polytechnica Hungarica Vol. 7, No. 2 p 95
[14] I T. DeCarlo 1997 Psychological Methods, Vol. 2, No. 3,292-307 1082-989X/97
[15] A. Mansour and C. Jutten 1999 IEEE Signal Processing Letters, vol. 6, no. 12, pp. 321-322, Dec. 1999 doi: 10.1109/97.803435
[16] A H Monahan 2013 J. Climate, 26, p:5563–5577, https://doi.org/10.1175/JCLI-D-12-00424.1
[17] G Marsaglia 2006 Journal of Statistical Software May 2006, Volume 16, Issue 4. http://www.jstatsoft.org/ p1-10
[18] S Mitra, D Mazumdar, K G Corresp., K Bhaumik 2018 PeerJ Preprints 6 Apr 2018 https://doi.org/10.7287/peerj.preprints.26831v1
[19] S.A.T.I, Vidisha, M Prades, Y K Jain, G Silakari 2013 International Journal of Emerging Technology and Advanced Engineering Volume 3, Issue 2, February 2013 p:321-327
[20] K R Babu, K.V.N.Sunitha, W G Dist, A Pradesh, G.Narayanaamma, Shaikpet 2011 IJCSIT - International Journal of Computer Science and Information Technologies, Vol. 2 No. 1 ISSN:0975-9646 p. 504-511
[21] P A Yirenkyi, J K Appati, I K Dontwi 2016 Open Journal of Applied Sciences, p478-488, http://dx.doi.org/10.4236/ojapps.2016.7048

[22] G Lee, Y Ji Hyun, S Y Ohm, and G C Min 2012 ICHIT, LNCS 7425, pp. 365–372, 2012. © Springer-Verlag Berlin Heidelberg 2012 p:139-774