A simple approach to determine the best threshold value for automatic image thresholding

Article · January 2009

DOI: 10.1109/ICSIPA.2009.5478623

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A SIMPLE APPROACH TO DETERMINE THE BEST THRESHOLD VALUE FOR AUTOMATIC IMAGE THRESHOLDING

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***Abstract*— Image thresholding is a powerful yet simple method to highlight the subject from its background in image scene analysis. Lots of methods have been proposed around the globe while some researchers regard this matter as a non-trivial problem. This paper proposes a simple approach for fast calculation of the threshold value for automatic image thresholding based on gradient analysis of the image histogram. The method manages to successfully differentiate the subject from the background. The proposed approach is validated by illustrative examples. Satisfactory results were acquired with other methods that use more complex algorithms.**

I. Introduction

Searching for best threshold value for automatic image thresholding is a tedious task, especially when dealing with complex data, which is often the case in image processing. In image processing, the object intensity value sometimes has a different value in its own region due to the object shadows and lighting inconsistency. A histogram plot of the frequency of occurrence of pixels intensities clearly shows this matter. Fig. 1(a) shows the histogram of the plantlets image as shown in figure 1(b).

From the histogram, many points of local minima clearly exist that are likely to distract the calculation for finding the best threshold value indicated by dashed-red line. The best threshold value will successfully segment the image where the subject will be highlighted compared to the background, as well as the shadows and noises.

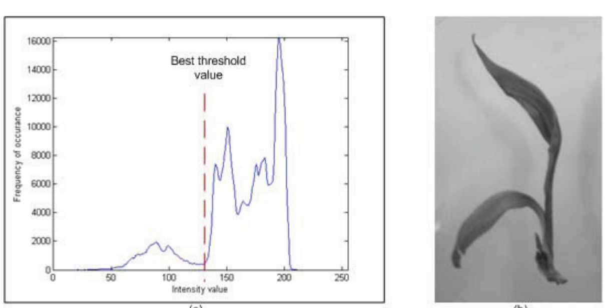

Fig. 1: A histogram of associated image.

Literature [1] has proposed a revolutionized algorithm to calculate the optimal threshold value based on the statistical information of the image by analyzing the discriminant criterion by measuring the separability of the resultant classes in gray levels. The method has inspired other researchers as in survey by [2-4]. Many of the methods however, still require complex statistical information and are quite iterative-based. Thus, time consumption during the threshold value calculation is undeniably hard to achieve on real-time basis or near real-time processing time.

Histogram-based thresholding is one of the common methods used in image thresholding and segmentation. It is simple because it is easier to visualise yet accurate enough to differentiate the target from the background. Thus, many methods used this ability to calculate the best threshold value by using methods such as histogram smoothing, iterations, rectangular approximation, etc [2]. Also, a review by [5] reveals that histograms can be regarded as a probability distribution function (PDF) and more statistical analysis can be done in order to find the best threshold value.

II. Methodology

Fig. 2 shows the flow chart of the proposed method. It is intended to calculate the best threshold value on grayscale or luminance images. The proposed method can be extent to color image thresholding provided that the color is $(2^8)^3$ bit as in RGB color space where every space is 2^8 bit. The RGB image is however is easily converted to grayscale image using commonly used formula of weighted sum of the R, G, and B, components [9];

$$I(x,y) = [0.2989\ 0.5870\ 0.1140] \times \begin{bmatrix} R(x,y) \\ G(x,y) \\ B(x,y) \end{bmatrix} \tag{1}$$

From the grayscale image, $I(x,y)$ the histogram function could be formed. Forming the histogram is rather easy by indexing the same pixel values into their corresponding bins, where in this case a total of 255 bins for a grey level image.

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The histogram function was then differentiated before gradient analyses are done to determine the best threshold value for automatic image segmentation.

A. Histogram Differentiation and Gradient Analysis

As the histogram function, $h(x)$ is formed, further step is to differentiate the function, using a commonly used differentiation function, $g(x) = \partial h(x) / \partial x$. Differentiation of a histogram with bins of 2^8-1 will result in $(2^8$-1)-1 where the last value has no pair to differentiate with. Therefore, for the last value $g(255)$, it is initialise to 0. This last value can be set to 0 because it does not hold any significant meaning for image thresholding, meaning that the best threshold value is impossible to be located at $h(x = 255)$.

Fig. 3 shows the histogram plot in blue while the differentiation in dashed-red. The gradient analysis is done such a way that the zero-crossing in *g(x)* is acknowledged. Hence, the sign change rules is introduced. The sign chance rule is basically a concept to identify the peaks and valleys [8]. Generally, the differentiation change from positive to negative indicates a peak while from negative to positive indicates a valley.

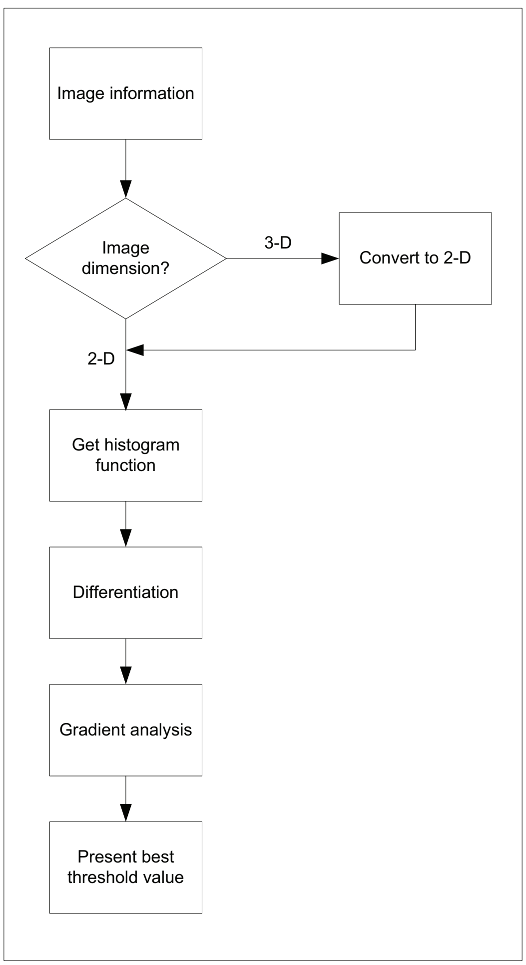

Fig.2: Flow chart of the proposed method

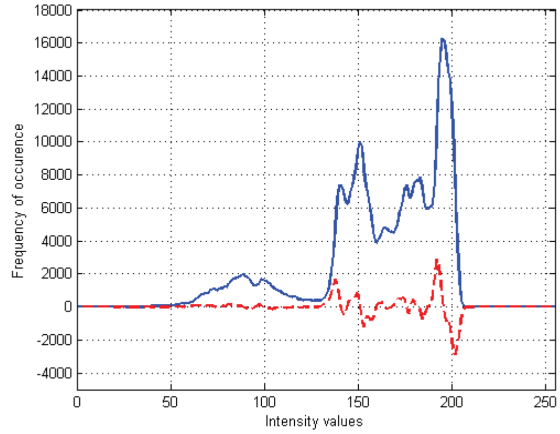

Fig. 3: A histogram function and its differentiation function

III. Best Threshold Value Determination

A. Sign Change Rules

A non-statistical analysis is used in determining the best threshold value. The histogram differentiation is used instead. As mentioned before, the sign change rules is introduced based from gradient analysis of the differentiation function. Before the sign change rules applied, $g(x)$ is transformed into $g_2(x)$ ranging from -1 to 1 as stated in (2). This step is to ensure mathematical stability and calculation easiness.

$$g_2(x) = \begin{cases} 0 & ,if\ g(x) = 0 \\ 1 & ,if\ g(x) > 0 \\ -1 & ,if\ g(x) < 0 \end{cases} \tag{2}$$

Afterwards, the sign change rules is applied to $g_2(x)$. In the if-else pseudo language, the sign change rules in this works concurrent with the general zero-crossing representation can be written as;

If the value of $g_2(x)$ is equal to $g_2(x+1)$, then nothing happened. Else if it is larger, then it is a possible peak, and else if it is smaller, then it is a possible valley.

Therefore, all x where the transition value is larger can be acknowledged as possible peaks while all x where it is smaller can be acknowledge as possible valleys. Then, it comes to the final step in the process which is to determine the best threshold value x_{th} at x in the index of possible valleys.

B. Calculation of Threshold Value

Let x_v be the index of all possible valleys and x_p the index of all possible peaks of the image histogram. Logically, the best threshold value x_{th} will be among the values in x_v. Equations (3) and (4) are used in order to determine x_{th}. The idea is to calculate the mean of $h(x_v)$ and replace them into eq. (4), where n is the total number of possible valleys found. Equation (4) is basically the customized distance measurement of each possible valleys x_v from the raw histogram to its differentiation based on the frequency of occurance at y-axis. By including the mean terms in the equation and consideration of squared differentiation negative values, the variances of the possible valleys are controlled and ensuring proper results. Therefore, the threshold value x_{th} is selected such a way that it has the minimum value in $D(x_v)$ that can be also rewritten as $D(x_{th})$.

$$\mu(x_v) = n^{-1}\sum h(x_v) \tag{3}$$

$$D(x_v) = \left| h(x_v) - \mu(x_v) + g(x_v)^2 \right| \tag{4}$$

In order to ensure the selected x_v is the correct best threshold value x_{th}, it can be compared with the possible peaks x_p. The selected x_{th} should be between x_p and never to be occurred at the very first or end of a histogram.

IV. Result and Discussion

The proposed method is applied to grayscale images such as the one shown in Fig 1(b) previously, the 'Lenna' image, and the 'Cameraman' image. The result is satisfactory enough and comparable to the Otsu method [1] and iterative Riddler and Calvard method [6]. This comparison is made to prove that the proposed method produce a satisfactory result and is able to differentiate the subject from the background in scene analysis and not for performance comparison.

Fig. 4 shows the result of thresholding of the plantlets image using the proposed method, Otsu method, and iterative Riddler and Calvard method. The proposed method successfully escapes the local minima and results in a perfect value for image thresholding. The Otsu method also results in a good thresholding value but some noise has occurred at the left-bottom of the image. This is probably due to the fact that the gray level of the plantlet shadows appears to be slightly the same with the plantlet shadows. However, a simple pre-processing algorithm could remove the noise. On the other hand, the iterative Ridler and Calvard method shows an example of a calculation that is stuck at the local minima with no way to escape it. The result is not convincing and fails to differentiate the subject from the background.

Fig. 5 shows the result of image segmentation performed on the Lenna image. The histogram plot shows that multiple local minimums and maximums exist and indeed no subject is present to be highlighted from the background in Lenna image. The proposed method yields the thresholding value at the global minima, which is the valley right after the first peak. Meanwhile, other methods result in fair thresholding values and are likely to segment the image successfully.

The cameraman image was also successfully segmented using the proposed method as well as the Otsu algorithm and Ridler and Calvard methods. Fig. 6 shows the convincing results. The cameraman image histogram plot shows that this is an ideal case of bi-modal histogram and there should be no problem for any methods to differentiate the person who's holding the camera from its background. The proposed method as well as the other two methods, yields satisfactory results with almost the same threshold value acquired. Table 1 summarises the calculated threshold values for all three images using the proposed method, Otsu method, and iterative Ridler and Calvard method.

Table 1: Summary of threshold value for image segmentation, 8-bit grayscale image

	Automatic thresholding value		
	Plantlets image	Lenna image	Cameraman image
Proposed method	122	82	91
Otsu method	131	117	88
Ridler and Calvard method	155	116	87

V. Conclusion and Recommendation

The proposed method is proven to produce satisfactory results comparable to other methods. The method is simple yet effective for automatic image thresholding and segmentation. The time consumption during the best threshold value calculation is surprisingly low, as only simple mathematical formulas i.e. gradient analysis are used. The proposed method also does not have any problem in escaping the local minimums as no iterative calculations are involved. The method also does not have any problem to calculate the best threshold value in any bi-modal histograms.

A fuzzy approach could be applied to sign change rules for faster and intelligent processing in order to recognize the zero-crossing in the differentiation function. The fuzziness is believed to be more accurate and reliable in searching for the best threshold value and the comparison with possible peaks may not be required.

References

[1] N. Otsu, "*A Threshold Selection Method from Gray-Level Histograms*", IEEE Trans. on Systems, Man, and Cybernetics, vol. 9(1), pp. 62-69, 1979.

[2] M. Segzin and B. Sankur: "*Survey over Image Thresholding Techniques and Quantitative Performance Evaluation*", Journal of Electronic, vol. 13(1), pp.146-165, 2004.

[3] P.K. Sahoo, S. Soltani and A.K.C. Wong, "*A Survey of Thresholding Techniques*", Computer Vision, Graphics, and Image Processing, vol. 41, pp.233-260, 1988.

[4] R. Guo and S. M. Pandit, *"Automatic Threshold Selection Based on Histogram Modes and a Discriminant Criterion",* Machine Vision and Applications, vol.10, pp.331-338, 1998.

[5] R.C. Gonzalez, and R.E. Woods, "*Digital Image Processing*", 2nd ed, Prentice Hall, 2002.

[6] T.W. Ridler and S. Calvard, "*Picture Thresholding Using an Iterative Selection Method"*, IEEE Trans. on Systems, Man, and Cybernetics, vol. 8(8), pp. 630-632, 1978.

[7] M.K. Quwaider, J.D. Scargle, and B. Jackson, "*Grey Level Reduction for Segmentation, Thresholding and Binarisation of Images based on Optimal Partitioning on an Interval*", IET Image Processs., vol 1(2), pp. 103-111, June 2007.

[8] Sezan, Mohammed, Ibrahim, "*A Method for Automatically Detecting Peaks in the Grey-Level Histogram of a Digital Image*", International Application Published under the Patent Cooperation Treaty, PCT/US87/00656, 22 Oct. 1987.

[9] Charles A. Poynton (2003), *Digital video and HDTV: Algorithms and Interfaces*, Morgan Kaufmann Publishers, pp. 88, 313-321.

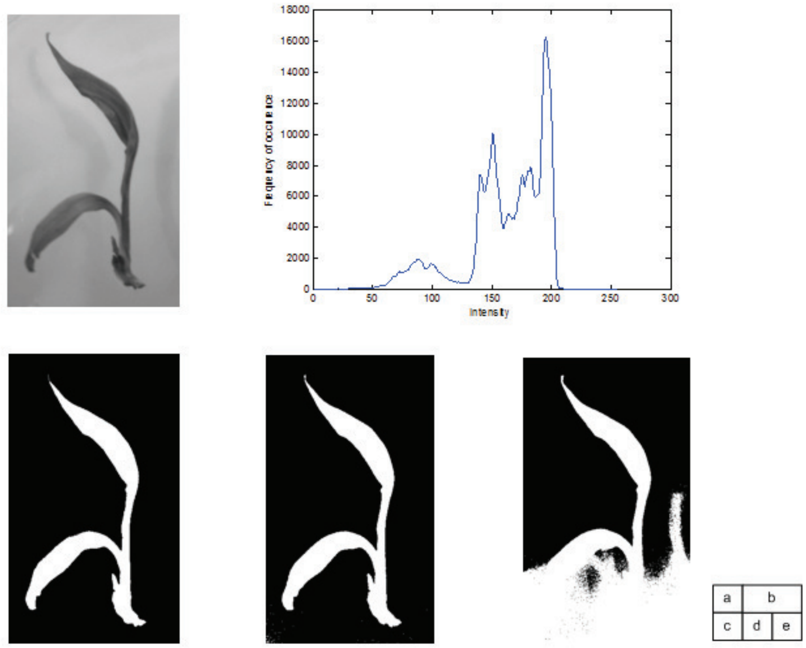

Fig. 4: (a) Original tissue culture plantlets image, (b) Histogram representation of the image,
(c) Thresholding result of proposed method, (d) Result using Otsu method, and (e) Result of iterative Ridler and Calvard method.

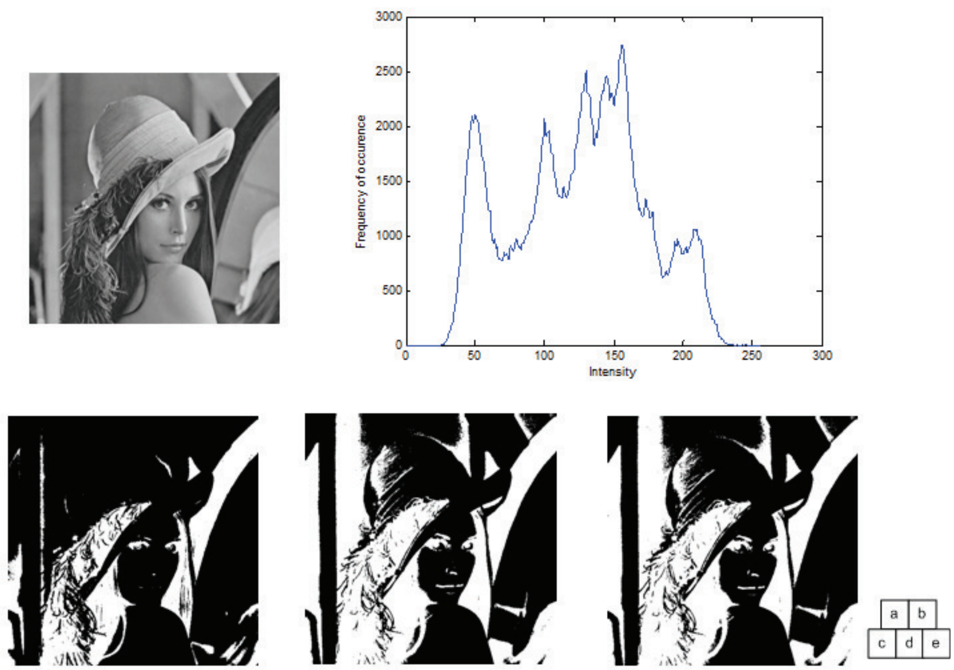

Fig. 5: (a) Original 'Lenna' grayscale image, (b) Histogram of the image,
(c) Thresholding result of proposed method, (d) Result using Otsu method, and (e) Result of iterative Ridler and Calvard method.

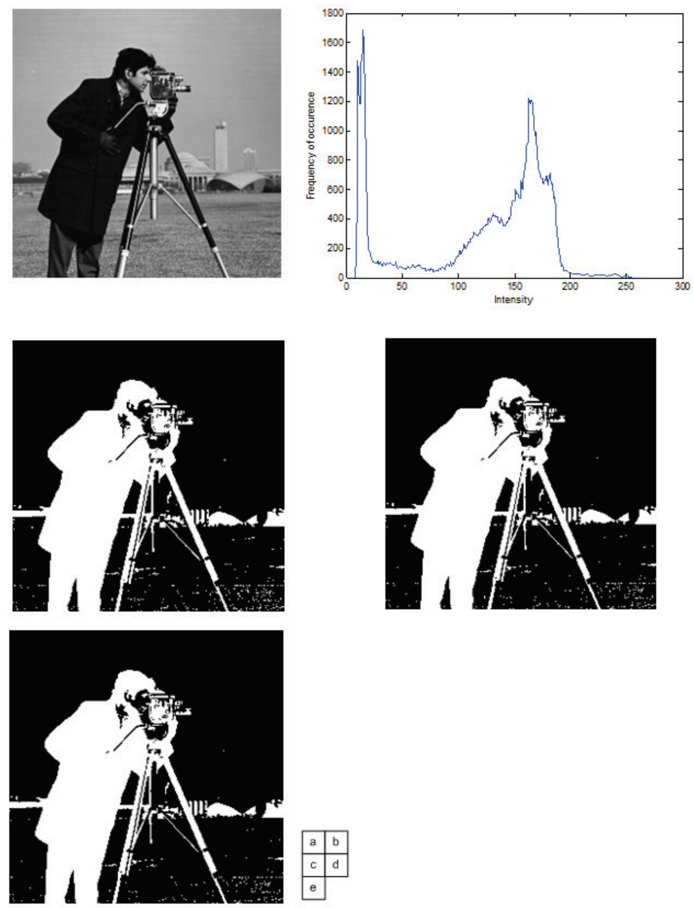

Fig 6: (a) Original grayscale of ‘cameraman’ image, (b) Histogram plot of the image,
(c) Thresholding result of proposed method, (d) Result using Otsu method, and (e) Result of iterative Ridler and Calvard method.