International Journal of Latest Engineering Science (IJLES) E-ISSN: 2581-6659

DOI: 10.51386/25816659/ijles-v7i5p101

Volume: 07 Issue: 05 September to October 2024 www.ijlesjournal.org

Improving a New Global Thresholding Algorithm Based on Gray Average for Binaryizating Image

Trung Nguyen Tu

Department of Information Technology, Thuyloi University, Hanoi, Vietnam

***Abstract**: Threshold separation is an effective technique for binary encoding. The choice of threshold separation technique is crucial in the binarization process. There are two approaches to threshold separation: global and local. One of the most popular and effective global binary algorithms today is Otsu's method. However, Otsu's method suffers from very slow execution speeds with large images, complicated threshold calculations, and in some cases, loss of object detail. This study proposes several algorithms to determine globally optimal thresholds based on maximum, minimum, and average gray-level values. Experimental results demonstrate that the proposed algorithms often preserve object details better and achieve significantly higher speeds compared to the renowned Otsu's algorithm.*

Keywords - *Binarization, Image Binarization, Otsu, Global Binarization, Local Binarization, Grayaverage.*

I. INTRODUCTION

Binary images are useful in many image processing applications due to their simplicity and efficiency. Binarization typically involves two steps including determining the gray threshold according to some objective criteria and assigning each pixel to a background layer or object. The main issue in the Binarization process is the choice of thresholding technique [1]. Several threshold algorithms have been researched and proposed to determine the optimal threshold value. Thresholding algorithms can be classified into six classes: histogram shape-based methods, clustering-based methods, entropy-based methods, object attribute-based methods, spatial methods, and The local formula is based on the local characteristics of each pixel [2]. Among these classes, many thresholding algorithms are based on a minimum variance [3]. Otsu's thresholding technique is a classification-based method that seeks to find a threshold that minimizes the internal variance, defined as the weighted sum of the variance of two classes [4]. Gaussian Otsu's method is an extension of the Otsu method and it uses the maximum variance between classes as the optimal threshold value. In [4], the authors tested and compared two binary algorithms Otsu and Gaussian Otsu. In [5], Sauvola and his colleagues proposed an adaptive document binarization algorithm based on local approach, called Sauvola binary algorithm. The Isauvola algorithm is an improvement of the Sauvola algorithm [6]. In [7], the authors presented a parallel algorithm for edge detection in images based on the Otsu-Candy operator. Senthilkumaran and colleagues also applied the thresholding algorithm in medical image segmentation.

With the global approach, the Otsu algorithm still takes a lot of time when working with large images. Additionally, in some cases, the Otsu threshold does not preserve object granularity.

This paper presents a new binary threshold finding algorithm based on the gray level average. The remaining parts of the article are presented as follows: part II presents the Otsu algorithm, part III presents the proposed algorithm, part IV presents some experiments on large-sized image data. Finally the conclusion.

II. THE RELATED KNOWLEDGES

A. *Global binarĩation approach*

- Input: Gray image
- Output: Binary image

In principle, global binary algorithms consist of two main steps:

- Step 1: Find the global threshold
- Step 2: Binarize the image

According to the global binary algorithms will be different Step 1 - how to find the threshold and the same in Step 2. One of the famous global binary algorithms is the Otsu binary algorithm.

B. *Otsu binarization algorithm*

Otsu is the name of a Japanese researcher [4] who came up with the idea of automatically calculating thresholds based on the pixel values of the input image to replace using fixed thresholds.

1) Step 1: Calculate the Histogram representing the frequency of gray levels:

$$p_i = \sum_{i=0}^{L-1} \frac{n_i}{M*N} \quad (1)$$

Wherein:

- n_i is the number of pixels with value i.
- L = 256.
- $p_o + p_1 + p_2 + \ldots + p_{L-1} = 1$

2) Step 2: For every threshold T_k = k, (0<k<L-1) to divide the input image into 2 classes C_1 (set of pixels with value ≤k) and C_2 (set of pixels has a value greater than k)
   - Step 2.1: Calculate $P_1(k)$ and $P_2(k)$ respectively as the ratio of the number of pixels of layers C_1 and C_2 to the total number of pixels:

$$P_1(k) = \sum_{i=0}^{k} p_i \quad (2)$$
$$P_2(k) = \sum_{i=k+1}^{L-1} p_i \quad (3)$$

   - Step 2.2: Calculate the average value m1, m2 of classes C_1, C_2:

$$m_1(k) = \sum_{i=0}^{k} iP\left(\frac{1}{C_1}\right) = \frac{1}{P_1(k)} \sum_{i=0}^{k} ip_i \quad (4)$$
$$m_2(k) = \sum_{i=i+1}^{L-1} iP\left(\frac{1}{C_2}\right) = \frac{1}{P_2(k)} \sum_{i=k+1}^{L-1} ip_i \quad (5)$$

   - Step 2.3: Calculate σ_B as the variance of two classes C_1 and C_2:

$$\sigma_B^2 = P_1(m_1 - m_G)^2 + P_2(m_2 - m_G)^2 \quad (6)$$
$$\sigma_B^2 = P_1 P_2 (m_1 - m_2)^2 \quad (7)$$

   Wherein:

   ✓ m_G is the average value of the image:

$$m_G = \sum_{i=0}^{L-1} ip_i \quad \text{or } m_G = P_1 m_1 + P_2 m_2 \quad (8)$$

   ✓ m_k s the average value up to threshold k:

$$m_k = \sum_{i=0}^{k} ip_i \quad (9)$$

3) Step 3: According to Otsu, we will calculate the threshold k* at which the difference between the two segments (background color and character color) reaches the maximum value, denoted $\sigma_B^2(k^*)$ is calculated:

$$\sigma_B^2(k^*) = \max_{0 \ll k \ll L-1} \sigma_B^2(k) \quad (10)$$

Attention: If there are many equal largest σ_B^2 values, we will choose k with the largest value among them as the threshold k*.

4) Step 4: Binary the image according to threshold k*.

$$g_{Out}(x,y) = \begin{cases} 1 & \text{Nếu } g_{In}(x,y) > k^* \\ 0 & \text{Nếu } g_{In}(x,y) < k^* \end{cases} \quad (11)$$

Wherein:

✓ $f(x,y)$ is the input pixel value.
✓ $g(x,y)$ is the output pixel value.

III. PROPOSING A NEW BINARIZATION ALGORITHM BASED ON UPPER AND LOWER BOUND VALUES

Although the Otsu algorithm is very effective in image binarization, it still has limitations: The execution speed is very slow with large images, the threshold calculation is still quite complicated and in some cases it also loses the detail of the image. object.

In this section, the article proposes a binary algorithm based on the gray level average BUA as follows:

- Step 1: Find the average value of the gray level in the entire image:

$$\text{agvGrey} = \frac{\sum_{m=1}^{M} \sum_{n=1}^{N} I_{m,n}}{MxN} \quad (12)$$

- Step 2: Find the average gray level deviation value in the entire image:

$$\text{agvDev} = \sqrt{\frac{\sum_{m=1}^{M} \sum_{n=1}^{N} (I_{m,n} - agvGrey)^2}{MxN}} \quad (13)$$

Where, $I_{m,n}$is the gray level at row m, column n in the input image matrix I.

- Step 3: Calculate threshold T

$$T = \text{agvGrey} * \left(1 + \alpha * (\text{agvDev}/128 - 1)\right) + 15 \quad (14)$$

Where, the coefficientα ∈ [0.2,0.5].

DOI: 10.51386/25816659/ijles-v7i5p101

Volume: 07 Issue: 05 September to October 2024 www.ijlesjournal.org

- Step 4: Binary the image according to threshold k
  Similar to step 4 of the Otsu algorithm.

Obviously, the threshold finding procedure of this algorithm is much simpler than the Otsu algorithm and the execution speed is likely to be much better than the Otsu algorithm.

IV. EXPERIMENTS

The author tested the proposed BUA binary algorithm and compared it with the famous Otsu binary algorithm. Experimental data includes two types of images: Documents and Landscapes. Due to the limited scope of the article, the author presents the testing of a number of different image samples as illustrated in Figures 1 and 2. In this test, the author uses VS.NET and C# tools to install Otsu and BUA algorithms.

From the experiments in Figures 1 and 2, we see that the detail (distinction between objects) of objects on the post-binary image of the BUA algorithm is better than that of the Otsu algorithm. This is especially evident in experiments 2 and 3. In other words, the binary image from the Otsu algorithm loses more information than the proposed BUA algorithm.

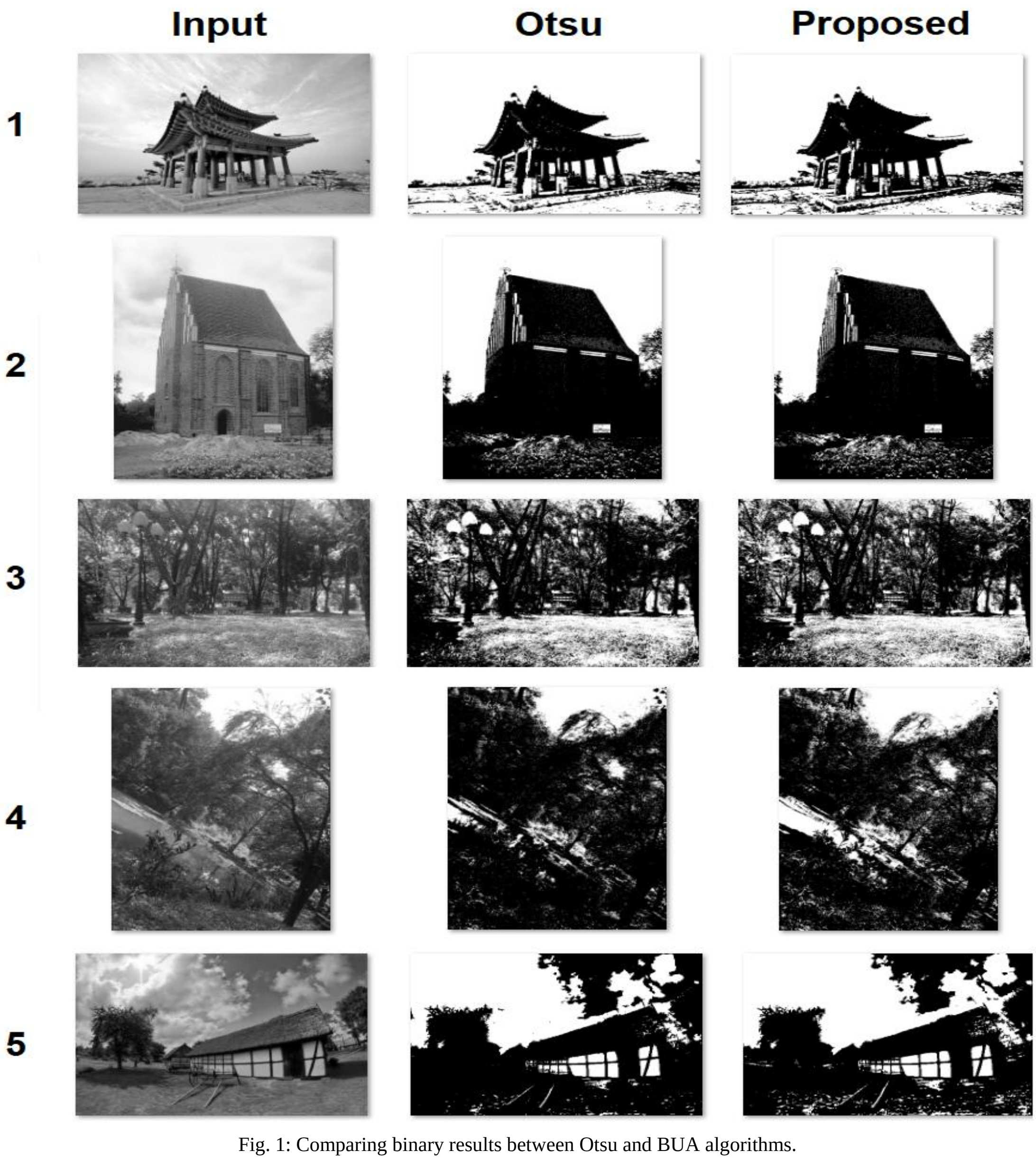

Fig. 1: Comparing binary results between Otsu and BUA algorithms.

International Journal of Latest Engineering Science (IJLES) E-ISSN: 2581-6659

DOI: 10.51386/25816659/ijles-v7i5p101

Volume: 07 Issue: 05 September to October 2024 www.ijlesjournal.org

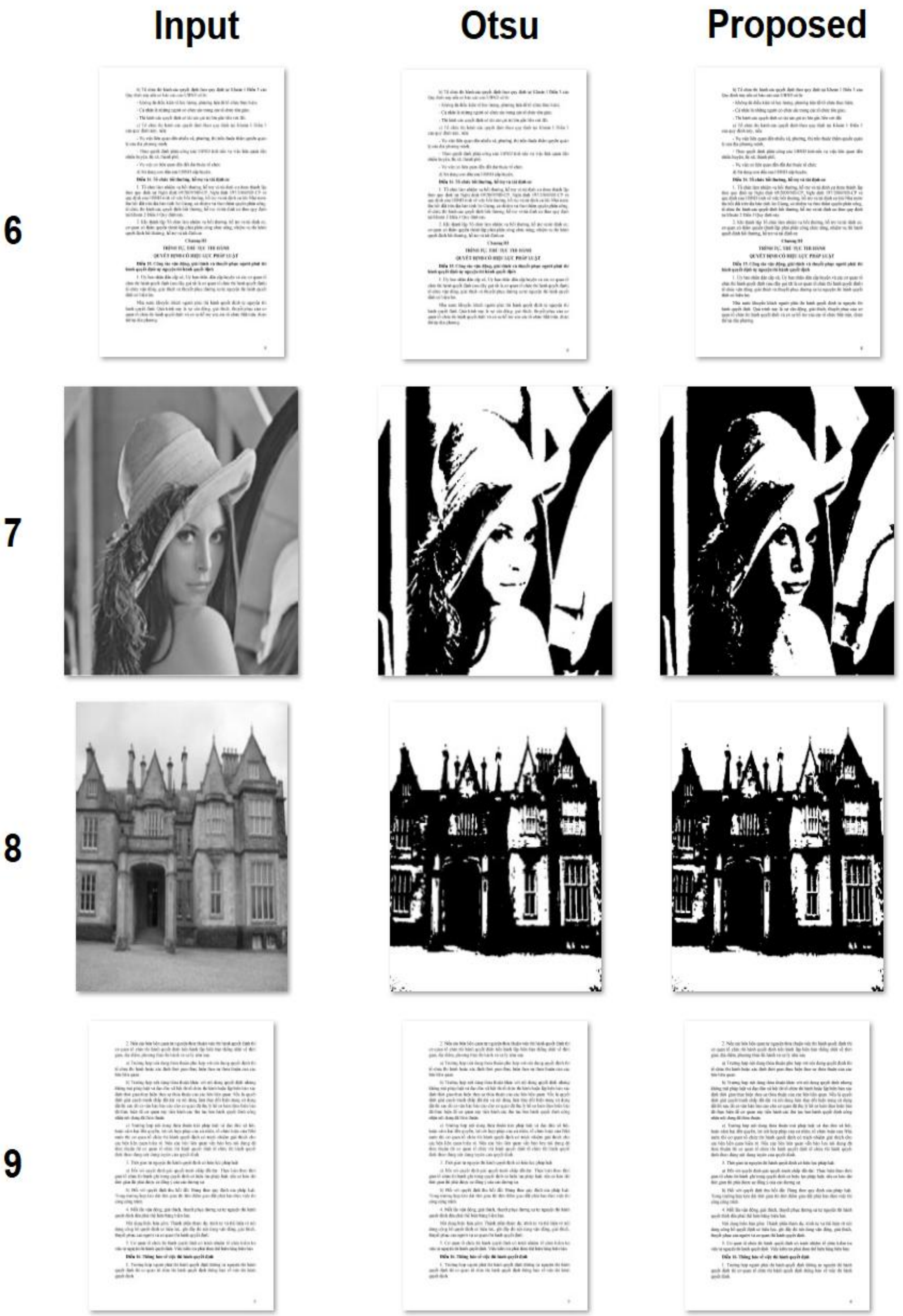

Fig. 2: Comparing binary results between Otsu and BU algorithms.

Table 1. Comparing the executive time of Otsu and BULB.

TN	width	height	Otsu (ms)	BUA (ms)	Ratio Ot/Bu
1	729	480	220	25	**8.8**
2	720	960	417	44	**9.5**
3	640	480	185	496	**9.7**
4	3264	2448	4806	496	**9.5**
5	2448	3264	4691	13	**8.3**
6	512	341	108	480	**13.1**
7	2479	3508	6301	18	**8.2**
8	466	518	148	15	**8.7**
9	420	516	130	463	**13.5**
10	2479	3508	6260	25	**8.8**
Average Ratio					**10.23**

Comment: From table 1 above we see:

- The biggest time difference between Otsu and BUA is 13.5.
- The smallest time difference between Otsu and BUA is 8.2.
- The average time difference between Otsu and BUA is 10.23.

In short, the execution time of the BUA algorithm is much smaller than that of the original Otsu algorithm.

V. CONCLUSIONS

In this paper, the author proposed two new global binary algorithms. Algorithm 1 is based on maximum and minimum values across the image while Algorithm 2 utilizes the gray level value and average deviation. Experimental results on two different types of images show that the two proposed algorithms preserve object details better after segmentation compared to Otsu's method. In addition, the execution speed of the two proposed algorithms increases on average by approximately 100 and 10 times, respectively, compared to the Otsu algorithm. In the next research, the author will continue to study binary algorithms, image classification, and image retrieval.

REFERENCES

[1] Melgani F. Robust image binarization with ensembles of thresholding algorithms. *J. Electron. Imaging*, 15, 2006.

[2] B. S. Sezgin. A survey over image thresholding techniques and quantitative performance evaluation. *Journal of Electronic Imaging*, 13:146{165, 2004.

[3] Z. H. Nowinsk. On minimum variance thresholding. *Journal of Pattern Recognition Letters*, 15:1732{1743, 2006.

[4] Yousefi, Jamileh. *Image Binarization using Otsu Thresholding Algorithm*, 2015. 10.13140/RG.2.1.4758.9284.

[5] Sauvola, J., Seppanen, T., Haapakoski, S., and Pietikainen, M.: 'Adaptive document binarization'. Proc. 4th Int. Conf. on Document Analysis and Recognition, Ulm Germany, 1997, pp. 147–152.

[6] Zineb H. and et. al, "ISauvola: Improved Sauvola's Algorithm for Document Image Binarization", ICIAR 2016, LNCS 9730, pp. 737–745, 2016, DOI: 10.1007/978-3-319-41501-7_82.

[7] Jianfang Cao et el., *Implementing a Parallel Image Edge Detection Algorithm Based on the Otsu-Canny Operator on the Hadoop Platform*, Computational Intelligence and Neuroscience, May 2018.

[8] Senthilkumaran N and Vaithegi S, IMAGE SEGMENTATION BY USING THRESHOLDING TECHNIQUES FOR MEDICAL IMAGES, Computer Science & Engineering: An International Journal (CSEIJ), Vol.6, No.1, February 2016.