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Improving a New Global Thresholding Algorithm based on Upper and Lower Bounds for Binaryizating Image

Trung Nguyen Tu

Department of Information Technology, Thuyloi University, Hanoi, Vietnam

***Abstract**: Threshold separation is an effective technique in binary encoding. The choice of threshold separation technique is very important in the binarization process. There are two threshold separation approaches: global and local. Several threshold algorithms have been researched and proposed to determine the optimal threshold value such as Otsu (global) or Sauvola (local). In this study, the article proposes an algorithm to find a globally optimal threshold. Experimental results show that the proposed algorithm in many cases ensures better object detail and much better speed than the famous Otsu algorithm.*

Keywords —*Binarization, image binarization, Otsu, global binarization, local binarization, upper bound, lower bound.*

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 a global approach. 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 KNOWLEDGE'S

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*.

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

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 upper and lower boundary value BULB (The binary based on Upper and Lower boundary) as follows:

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

$$\text{lower} = low\_boudary(Grey\_Image) \quad (12)$$

- Step 2: Find the upper limit value of the gray level in the entire image..

$$\text{upper} = upper\_boudary(Grey\_Image) \quad (13)$$

- Step 3: Calculate threshold k

$$\text{k} = 0.5 * (\text{lower} + \text{upper}) \quad (14)$$

- 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 BULB 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 BULB 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 BULB 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 BULB algorithm.

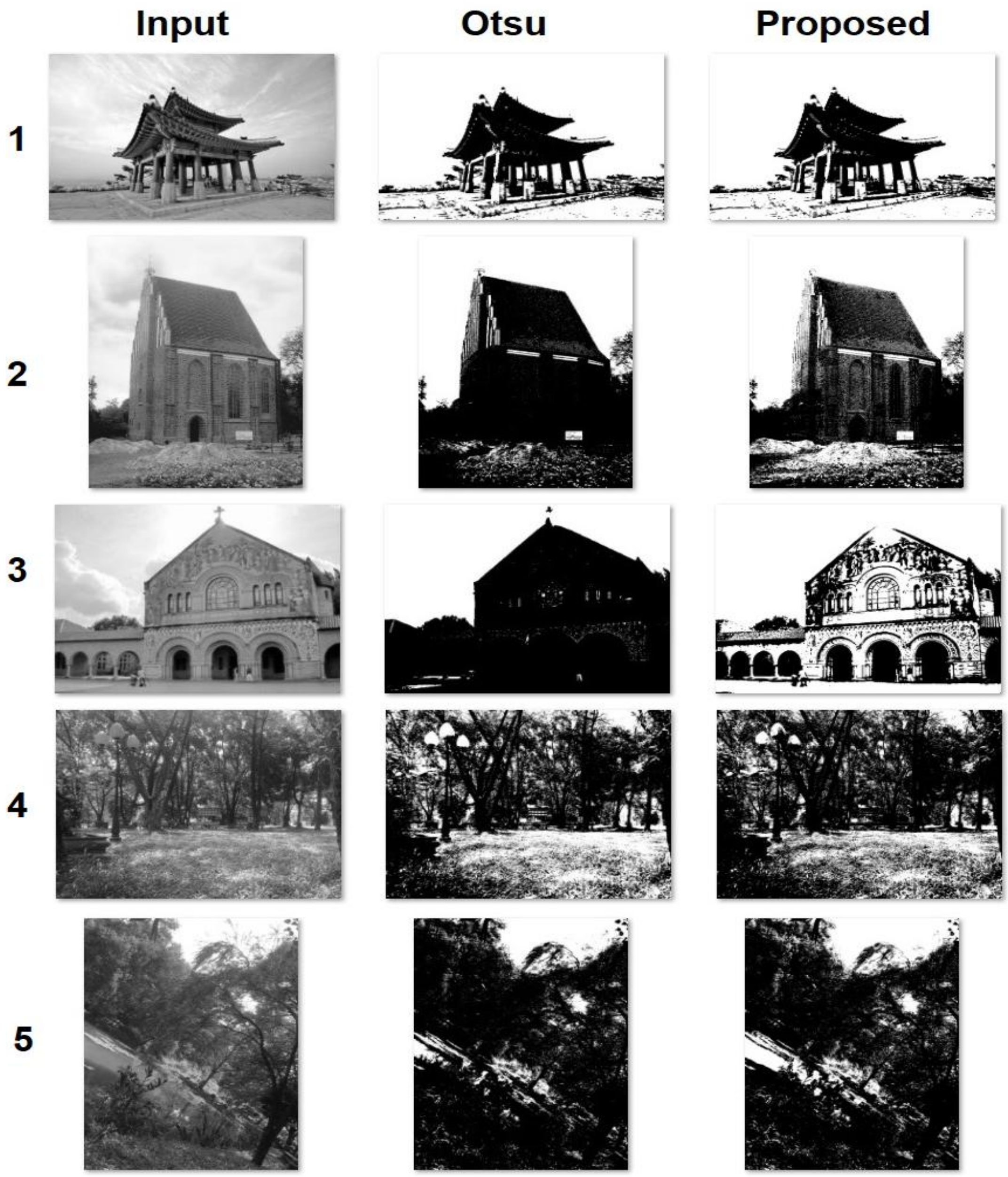

Fig. 1:Comparing binary results between Otsu and BULB algorithms.

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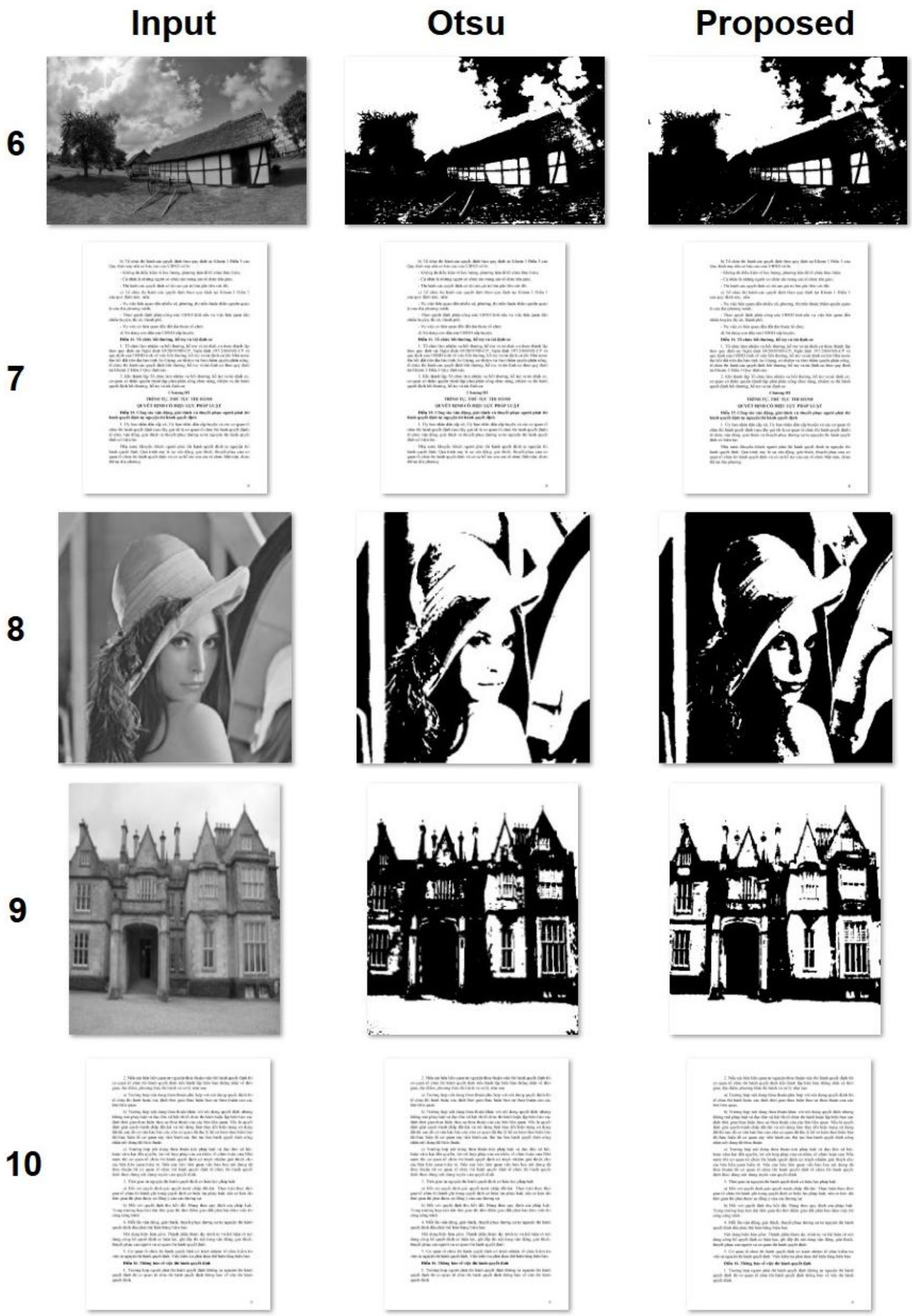

Fig. 2: Comparing binary results between Otsu and BULB algorithms.

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

TN	width	height	Otsu (ms)	BULB (ms)	Ratio Ot/Bu
1	729	480	220	3	**73,3**
2	720	960	417	4	**104,3**
3	640	480	185	3	**61,7**
4	3264	2448	4806	48	**100,1**
5	2448	3264	4691	48	**97,7**
6	512	341	108	1	**108**
7	2479	3508	6301	52	**121,2**
8	466	518	148	1	**148**
9	420	516	130	1	**130**
10	2479	3508	6260	51	**122,7**
Average Ratio					**110.3**

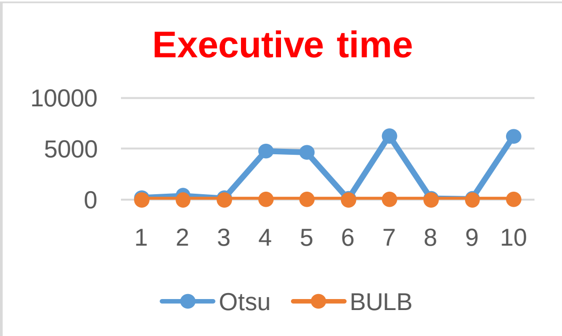

Fig. 3: Comparing the executive time of Otsu and BULB.

Comment: From table 1 and figure 3 above we see:

- The biggest time difference between Otsu and BULB is 148.
- The smallest time difference between Otsu and BULB is 61.7.
- Most tests show that the time reduction of MRO compared to Otsu is about 97 times or more.
- The average time difference between Otsu and BULB is 110.3.

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

V. CONCLUSIONS

In this paper, the author proposed a binary based on BULB upper and lower bound values. The BULB algorithm proposes a new binary threshold after finding the upper and lower limit values across the image. Experimental results on two different types of images show that the BULB algorithm ensures object detail after segmentation better than Otsu. In addition, BULB's execution speed increases on average by nearly 100 times compared to the Otsu algorithm. In the next research, the author will continue to study binary algorithms and image classification.

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