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A new operator of enhancing dark images and application in binarizing dark images

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Abstract. *Image enhancement is a very important topic in image processing and has achieved considerable success. However, dark image enhancement is still a difficult problem, needs further research. Binary plays an important role in digital image processing, mainly in applications of computer vision. The choice of thresholding technique is very important in the binaryization process. Some algorithms determine the optimal threshold value such as Otsu or Sauvola. To achieve good results, the input image needs to have good brightness and contrast first. However, this is not always possible as there are photos taken in very dark conditions. At this point, it is likely that the resulting binary image will lose a lot of information, making the identification of objects difficult and inaccurate. In this case, if it is possible to pre-process the image to improve the image quality first, it will certainly improve the resulting image binary. This paper introduces a dark image enhancement and its application to binary dark image. Experimental results show that dark image enhancement is better than some recent algorithms and gives better binary quality than the original algorithm.*
Keywords: Image binary, Otsu, Dark image enhancement, dark object, dark object enhancement operator.

1. **Introduction.** Image enhancement is one of the important jobs of image processing. The image enhancement methods are divided into 3 categories including histogram, fuzzy logic and optimization method [1]. Histogram-based contrast enhancement methods focus on histogram modification of an image. The fuzzy logic-based image enhancement methods make the image clearer quality than the traditional methods. Blur technique is used to enhance the image. In [2], the authors combine fuzzy logic and gray level adjustment formulas to enhance the contrast of the image. In [3], Yugander et al proposed an MR Image Enhancement algorithm that uses Adaptive Weighted Average Filtering and Homomorphic Filtering. In [4], Swarup et al proposed a New Approach to Retinal Image Enhancement using PSO system and opacity measurement. In [5], Pankaj et al proposed a new improvement of histogram equalization based on medical image contrast enhancement using swarm optimization. In [6], Malika et al. have proposed an image improvement technique based on artificial bee swarm on discrete wavelet domain (AIEDW). In [7], Mehwish Iqbal et al. proposed a white and color balance technique in enhancing images in low light conditions. In [8], Kai Liu and Yanzhao Tian presented research and analysis of deep learning image enhancement algorithm based on fractional differential. In [9], Junyi Xie et al. proposed a semantically guided low-light image enhancement algorithm. In [10], Z. Liang et al. propose a method to enhance single underwater image by guided color correction of attenuation map and preserved detail. In [11], Xueyang

Fu a, Xiangyong Cao proposes to enhance underwater images with local-local network and compressed gray histogram equalization. In [12], Himanshu Singh et al proposed a gamma-corrected gray histogram equalization method based on swarm optimization for dark image enhancement (SGHIE). Binary images are useful in many image processing applications due to their simplicity and efficiency. A binary image is created by quantizing the gray levels of the image into two values, usually 0 and 1. Binary usually involves two steps: Determining a threshold and assigning each pixel to the background layer or object. Several threshold algorithms have been studied and proposed to determine the optimal threshold value. Gaussian Otsu's method is an extension of Otsu's method and it uses the maximum variance between classes as the optimal threshold value. In [14], the authors tested and compared two binary algorithms Otsu and Gaussian Otsu. The Isauvola algorithm [16] is an improvement of the Sauvola algorithm [15]. In [17], Romen et al. proposed a locally adaptive binary algorithm based on the integral sum image whose running time does not depend on the local window size to calculate the mean in the local window. With H. Zeng and et al., they proposed a method of real-time photo enhancement by learning 3D Lookup Tables [19]. In [20], a image enhancement for is proposed that based on Robust Exposure Correction. Image enhancement studies are often based on the rule: If light, make it brighter, if dark, make it darker. However, for images with very dark domain objects, these rule-based methods will make the output image even worse at distinguishing those objects. In addition, image binary algorithms when applied directly on dark images will give very poor results. To overcome this problem, the paper proposes a new dark image enhancement algorithm and a binary image enhancement with image enhancement. The rest of the paper is presented as follows: Part II presents related studies, Part III presents the proposed algorithm, Part IV presents some experiments on large image data. Finally the conclusion.

2. **Related Work.**

2.1. **The binary algorithm Otsu.** Otsu is the name of a Japanese researcher [13] who came up with the idea of calculating threshold automatically based on pixel value instead of using fixed threshold.

- Step 1: Calculating Histogram of the input image:

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

  Where:
  - n_i: the number of pixels whole gray level is i.
  - : L = 256.
  - $p_0 + p_1 + ... + p_{L-1} = 1$
- Step 2: With every threshold $T_k = k$, $(0 < k < L - 1)$ to divide the input image into 2 classes C_1 (a set of pixels whole gray level is smaller than k) and C_2 (a set of pixels whole gray level is bigger than k)
  - Step 2.1: Calculating $P_1(k)$ and $P_2(k)$ corresponding is the ratio of the number of pixels in the class C_1 and C_2 that compared with the total number of pixels:

$$P_1(k) = \sum_{i=0}^{k} p_i \tag{2}$$

$$P_2(k) = \sum_{i=k+1}^{L-1} p_i \tag{3}$$

– Step 2.2: Calculating m_1, m_2 that are the mean values of the classes C_1, C_2:

$$m_1(k) = \sum_{i=1}^{k} iP(\frac{1}{C_1}) = \frac{1}{P_1(k)ip_i} \tag{4}$$

$$m_2(k) = \sum_{i=k+1}^{L-1} iP(\frac{1}{C_2}) = \frac{1}{P_2(k)ip_i} \tag{5}$$

– Step 2.3: Calculating σ_B is the variance of the two classes C_1 and C_2:

$$\sigma_B^2 = P_1(m_1 - m_G)^2 + P_2(m_2 - m_G)^2 \tag{6}$$

$$\sigma_B^2 = P_1P_2(m_1 - m_2)^2 \tag{7}$$

Where:

* m_G: mean value of the image:

$$m_G = \sum^{L-1} i = 0ip_i \tag{8}$$

hay $m_G = P_1m_1 + P_2m_2$

* m_k: the mean value to the threshold k:

$$m_k = \sum^{k} i = 0ip_i \tag{9}$$

- Step 3: According to Otsu, k* is calculated that the value of $\sigma_B^2(k^*)$, the difference between the two paragraphs (background color and character color), reaches the maximum value:

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

Note: If having the biggest values σ_B^2 that they are equal, k* is the biggest value k whole σ_B^2 is max.

- Step 4: Perform the image binarization according to threshold k*:

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

Where:

– $g_{In}(x, y)$: value of input pixel

– $g_{Out}(x, y)$: value of output pixel

2.2. **Combine images using principal component analysis.** In [18], Sonali Manel et al presented an image synthesis method based on principal component analysis (FIPCA), shown in figure 1.

3. Propose the algorithm of the dark image enhancement and binarizition.

3.1. **The algorithm of the dark image enhancement.** In this section, the paper proposes an dark image enhancement algorithm that named the algorithm of the dark image enhancement (ADIE). The algorithm includes the following steps:

- Step 1: Transform the gray level to the domain [0,1] according to the formula:

$$f_1(x) = \frac{x}{255} \tag{12}$$

So, we have:

$$R_1, G_1, B_1 = f_1(R), f_1(G), f_1(B) \tag{13}$$

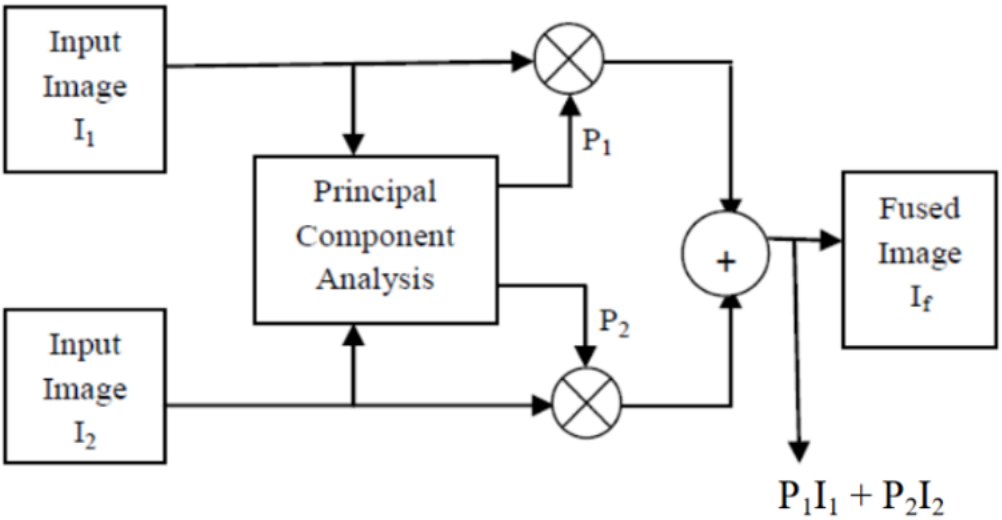

FIGURE 1. Image fusion using PCA.

- Step 2: Transform R1, G1, B1 according to the formula:

$$f_2(x) = x + 2 * (1 - x)^3 * x \tag{14}$$

So, we have:

$$R_2, G_2, B_2 = f_1(R_1), f_1(G_1), f_1(B_1) \tag{15}$$

- Step 3: Transform R2, G2, B2 to the domain [0,255] according to the formula:

$$f_3(x) = 255 * x \tag{16}$$

So, we have:

$$R_3, G_3, B_3 = f_1(R_2), f_1(G_2), f_1(B_2) \tag{17}$$

- Step 4: Generate output image using PCA-based transformation (section 2.2) where I1 is the image obtained after step 3, I2 is the image that increases the brightness of I1 as follows:

$$I_{new} = FIPCA(I_1, I_2) \tag{18}$$

$$I_2 = IncreaseBright(I_1) \tag{19}$$

3.2. **The algorithm of dark image binary based on ADIE.** The ADIE-based dark image binary algorithm (ADIE-DIB) is shown schematically in figure 2.

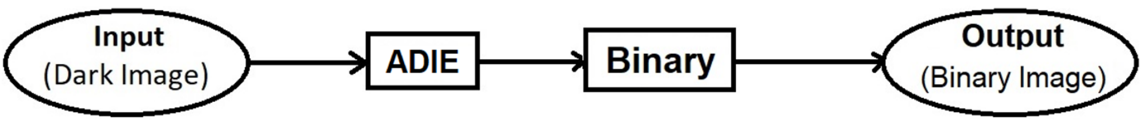

FIGURE 2. The chart of the dark image binary based on ADIE.

According to the diagram above, the ADIE-DIB dark image enhancement algorithm consists of 2 main steps:

- Step 1: Enhance the input image with the algorithm ADIE
- Step 2: Binary the result image of step 1 to get output image

3.2.1. *The main contributions.* The main contributions of this paper includes:

- Propose the new operator of dark image enhancement.
- Apply the new operator of dark image enhancement to binarize the dark image.

4. **Experiments.** Recent methods used for comparison include: AIEDW (2017) [6], SGHIE (2017) [12]. Dataset includes 500 dark images, obtained from internet and captured by mobiphones. Due to the limited scope of the article, some of the tests are illustrated in Figures 3 and 4. In which, Figure 3 contains the full image of the tests, Figure 4 is a partial image of the images in the tests for the purpose of more detailed observations. The images used for testing have poor contrast and are very dark. From Figures 3 and 4, visually, it can be seen that:

- The AIEDW method slightly improves the brightness and contrast compared to the original image.
- The SGHIE method better improves the AIEDW method in terms of brightness and contrast.
- The proposed method gives an output image that is noticeably brighter and contrasted than the original image and is much better than the AIEDW and SGHIE methods.

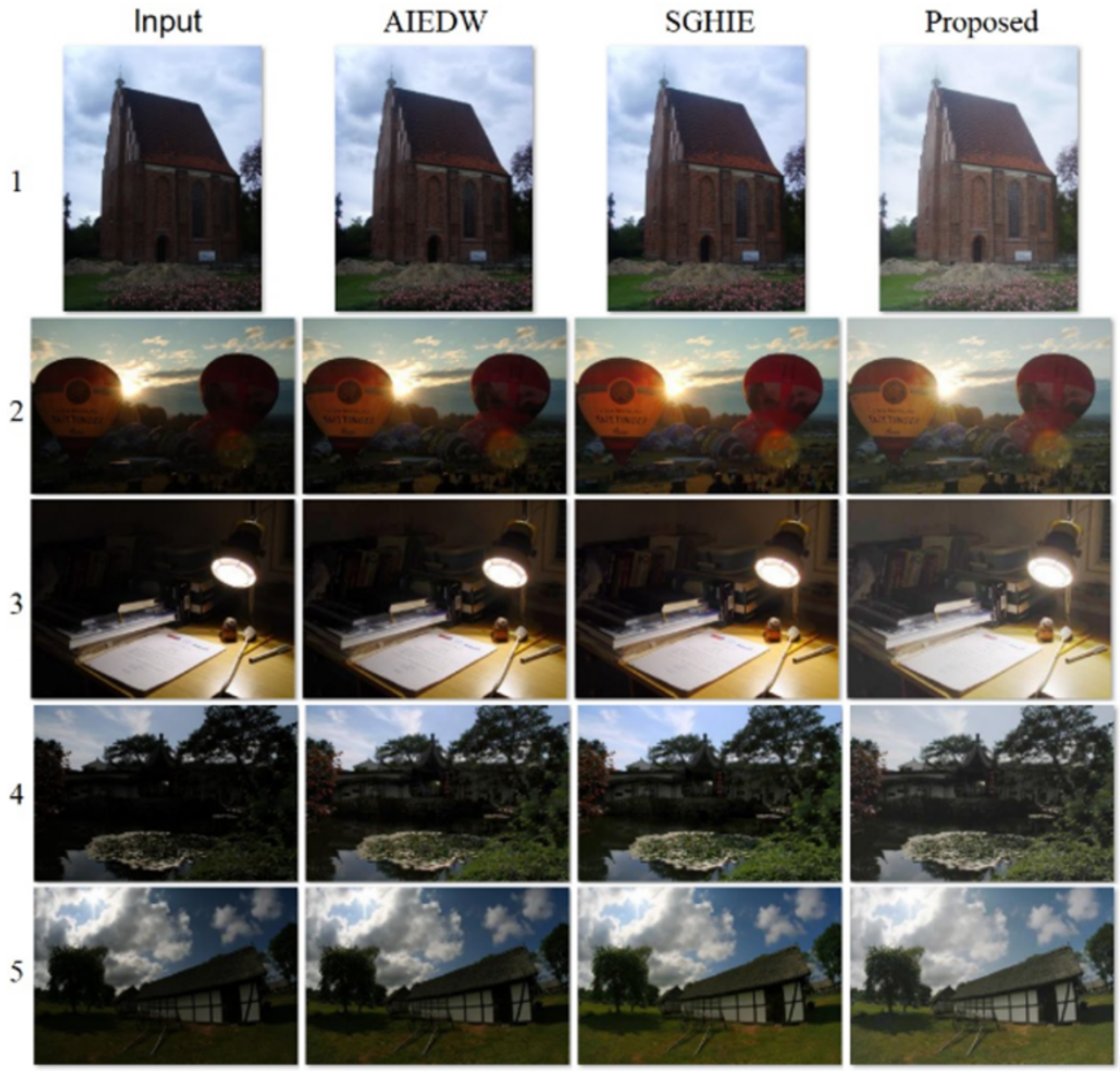

FIGURE 3. Some test results.

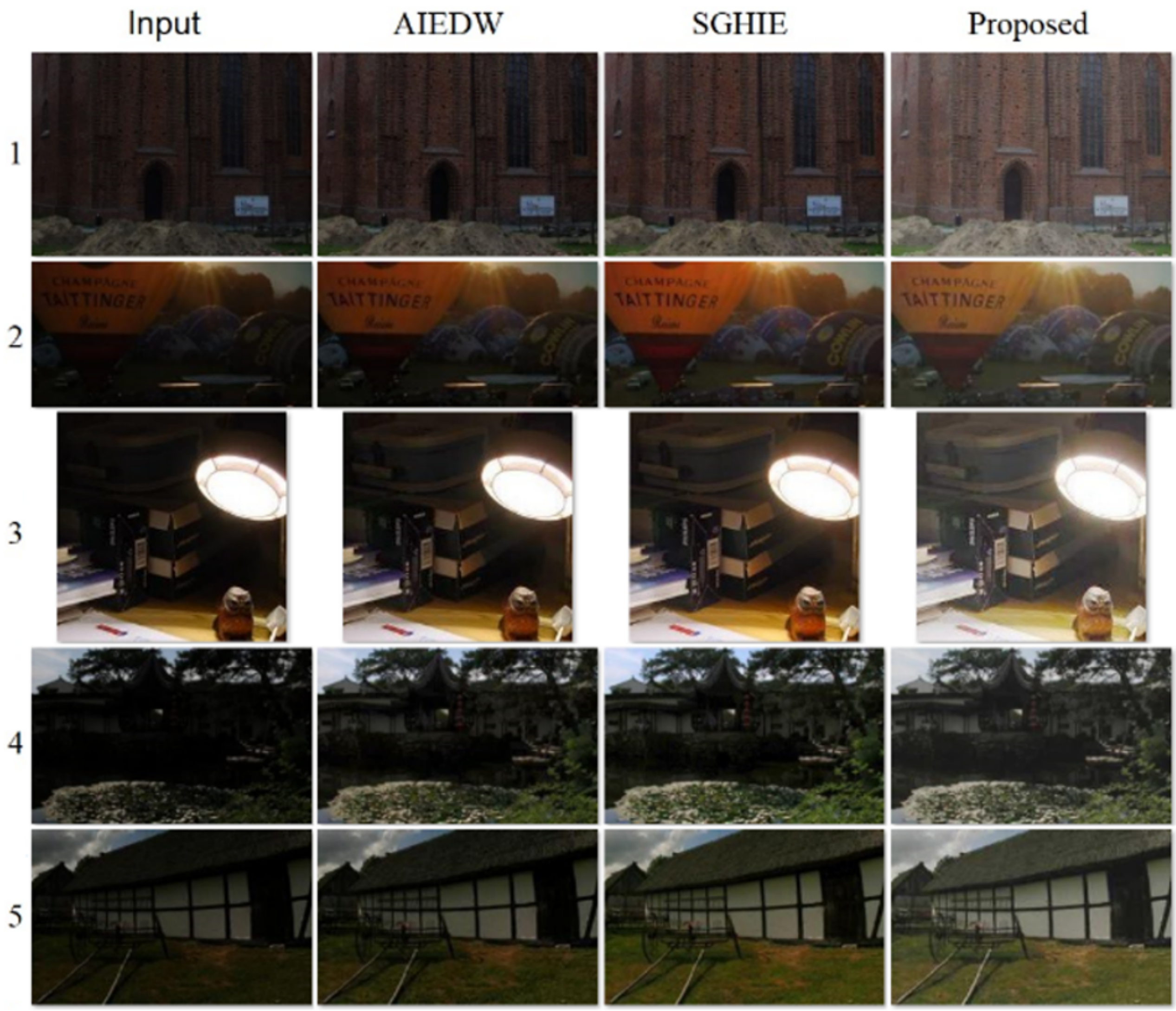

FIGURE 4. Some test results.

To evaluate the quality, the Sharp measure is used to measure the sharpness and contrast of the image after enhancement of the methods compared with the original image, presented in Table 1, Figure 4. From Table 1 and Figure 5, it can be seen that:

- AIEDW method has the smallest Sharp measure value of all three methods.
- The SGHIE method gives better performance with a larger Sharp measure value than the AIEDW method.
- The method has the largest Sharp measure value of all three methods.

TABLE 1. Compare image quality based on sharpness (contrast).

STT	AIEDW	SGHIE	Proposed
1	0.0483	0.0524	0.0576
2	0.0172	0.0188	0.0191
3	0.0219	0.0227	0.0232
4	0.0512	0.0592	0.0594
5	0.0189	0.0236	0.0266

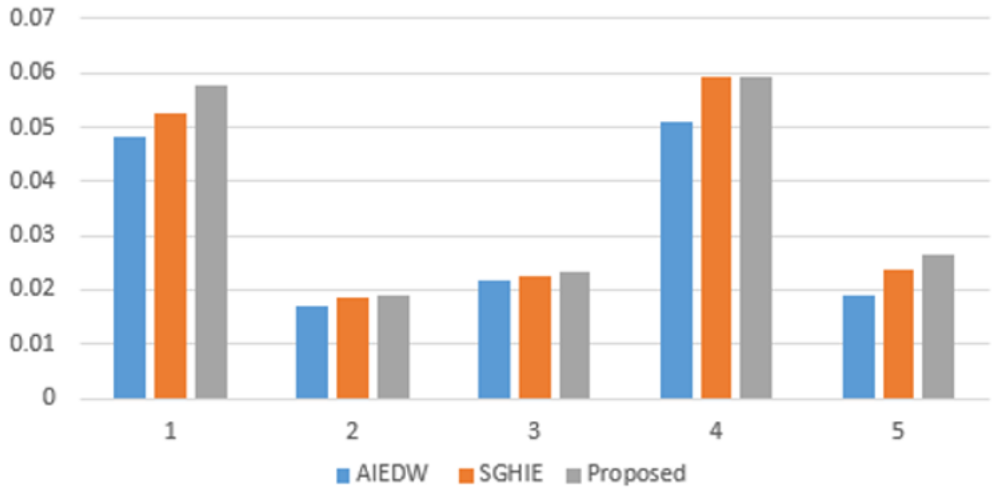

FIGURE 5. The chart for comparing image quality based on sharpness (contrast).

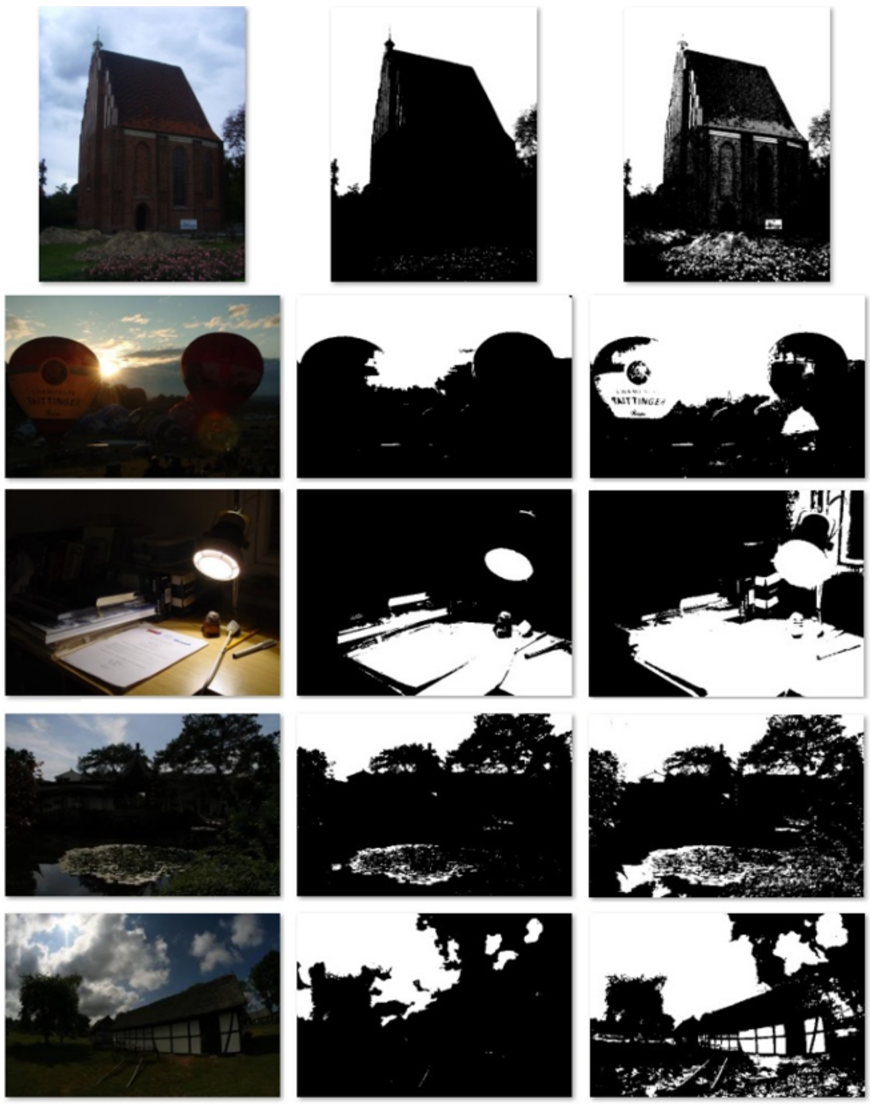

FIGURE 6. Compare the binary quality of the original binary algorithm and the algorithm ADIE-DIB.

From the above comments, it can be seen that the proposed method for the enhanced image has better brightness, contrast and similarity with the original image than the recently compared methods. To evaluate binary quality, the algorithm ADIE-DIB is tested and compared with the famous Otsu algorithm. The results are shown in figure 6.

Figure 6 shows that the binary image with the original algorithm lost a lot of information, almost the discrimination of objects was very poor. However, with binary image of the new algorithm, the objects can be distinguished quite clearly.

5. **Conclusions.** This paper introduces the ADIE dark image enhancement algorithm and its application in dark image binary. Experiments show that the following images enhanced by the proposed algorithm are better than some other recent methods when enhancing dark images. With the image enhancement support from this algorithm, the proposed binary algorithm gives better results than the original binary algorithm. In the next study, the author intends to continue with other problems of image processing.

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