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Narzullo Mamatov ✉; Nilufar Niyozmatova; Malika Jalelova; Abdurashid Samijonov; Shaxzoda Tojiboyeva

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Methods for Increasing the Contrast of Drone Agricultural Images

Narzullo Mamatov[1, a)], Nilufar Niyozmatova[1, b)], Malika Jalelova[1, c)], Abdurashid Samijonov[2, d)], Shaxzoda Tojiboyeva[3, e)]

[1] *"Tashkent Institute of Irrigation and Agricultural Mechanization Engineers" National Research University, Tashkent, Uzbekistan*
[2] *Tashkent University of Information Technologies named after Muhammad al-Khorazmi, Tashkent, Uzbekistan*
[3] *Namangan State University, Namangan, Uzbekistan*
[a)] *Corresponding author: m_narzullo@mail.ru*
[b)] *n_nilufar@mail.ru*
[c)] *jalelova97@mail.ru*
[d)] *an_samijonov@mail.ru*
[e)] *tojiboyevashaxzoda25@gmail.com*

Abstract. Given the significant time investment required for manual execution and oversight of various agricultural tasks, the adoption of modern technologies emerges as the most efficient solution to address this issue. Nowadays, the interest in the images taken by unmanned aerial vehicles (drones) in the field of agriculture is also increasing. In contemporary times, there is a growing fascination with images captured by unmanned aerial vehicles (drones) within the agricultural sector. However, in certain instances, the quality of these drone-captured images may not meet the stipulated criteria necessary for performing specific tasks. One of the common problems with images is low image contrast. This situation complicates the identification of objects, distinguishing important elements such as agricultural crops and machinery. This study is devoted to determining the optimal pair of contrast enhancement method or sequence of methods and reference contrast evaluation criteria, and a new approach for automating image processing is proposed.
Keywords. algorithm, contrast, criterion, drone, histogram, image, indicator, method, PSNR, reference evaluation, UAVs.

INTRODUCTION

Today, modern technologies have become an indispensable tool in various fields of agriculture and provide an opportunity to quickly obtain current information [1]. Drones (Dynamic Remotely Controlled Navigation Device), commonly known as unmanned aerial vehicles (UAVs), are now widely used in agriculture for tasks such as vegetation monitoring, comprehensive soil analysis, land resource management and threat detection, as they are cheaper than satellite remote sensing. Although such devices have many advantages, they are not without disadvantages. Variables like adverse weather conditions and inadequate image contrast obtained from drones can diminish the quality of the data. Contrast is a crucial parameter for assessing image quality. An image with low contrast may not provide enough information and cause various difficulties in recognition [2]. In such scenarios, it becomes imperative to improve the image's contrast.

Improving image contrast is a traditional problem in image processing [3]. In realm of image processing [4-7], many researchers have developed their own approaches to enhance image contrast. Among these approaches, it is worth noting that histogram equalization, contrast limited adaptive histogram equalization (CLAHE), contrast stretching and morphological contrast enhancement methods are effective. As a result of the use of the listed methods, image contrast changes, and the details hidden in the image are more clearly visible, and the image quality is improved [8]. An image with adequate contrast is taken as input to some automated processing systems. Therefore, low-contrast images should be brought to the required level.

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When an image is processed for visual interpretation, the final judge of how well the method has worked is the human, that is, the expert. However, in order to automate image processing, the evaluation should be objectively quantified. Objective methods are generally divided into two types, namely reference and no-reference. Reference methods compare two images, original and contrast-enhanced images. Due to the high accuracy of these methods, experiments were conducted using reference evaluation criteria in this research work.

LITERATURE REVIEW

Reference indicators for image quality assessment cited in foreign literature on image contrast change are analyzed below.

The analysis of methods for improving the contrast of magnetic resonance imaging images and eliminating noise in them is given in the article [9]. In this work, it is emphasized that SSIM, PSNR and RMSE indicators are convenient and effective in evaluating the quality of images.

Algorithms for increasing the contrast of gray images were analyzed in detail in the research work [10], and the images obtained using different algorithms were compared by means of PSNR and AMBE (Absolute Mean Brightness Error) indicators. It was noted that the CLAHE method is the best method. For retinal images, histogram equalization, CLAHE and contrast stretching algorithms and median filter were used together in [11]. The images were then evaluated using MSE, PSNR and SSIM metrics. In this, CLAHE is recognized as the best algorithm.

Separate contrast enhancement experiments for both grayscale and color images were conducted in [12], and the results of the contrast enhancement algorithm applied to the gray image were evaluated by the PSNR indicator, and among them, the morphological contrast enhancement algorithm was found to give the best result.

MATERIALS

Following a comprehensive review of the literature, it was determined that PSNR proves effective in assessing the quality of images with enhanced contrast. As a result, it was selected as the fundamental indicator for conducting further experiments. In order to calculate this indicator, MSE of the reference image I_{org} of size $M \times N$ and the contrast of I_c at the point of coordinate (i, j) is calculated:

$$MSE = \frac{1}{MN} \sum_{i=1}^{M} \sum_{j=1}^{N} \left(I_{org}(i, j) - I_c(i, j) \right)^2 \tag{1}$$

Based on the MSE value, the PSNR is calculated by the following formula:

$$PSNR = 10 \log_{10} \frac{\left(2^n - 1\right)^2}{\sqrt{MSE}} \tag{2}$$

CONTRAST ENHANCEMENT METHODS

Histogram equalization, a method extensively examined in research studies [13-17], operates on the fundamental concept of evenly redistributing the image's intensity across the entire spectrum of gray levels. This method is rooted in the following formulas:

$$p(r_k) = \frac{n_k}{n}, k = 0,1,..., L-1 \tag{3}$$

$$s_k = T(r_k) = (L-1) \sum_{j=0}^{k} p(r_j) = (L-1) \sum_{j=0}^{k} \frac{n_j}{n} \tag{4}$$

where $r_k -$ initial brightness, $s_k -$ output brightness, $L -$ brightness range, $n_j -$ number of brightness points, $n -$ total number of pixels.

The following relationship is valid between r_k and s_k in formula (2):

$$r_k = T^{-1}(s_k), k = 0,1,..., L-1 \tag{5}$$

CLAHE. CLAHE and contrast stretching methods are detailed in [18]. CLAHE has an additional histogram fitting step, the histogram trimming step.

Contrast stretching. Contrast stretching, as a technique [18,19], involves expanding the contrast within an image to encompass the desired range of intensity values. Applying this method to the image I_{org} uses the following formula:

$$I_c(i,j) = 255\frac{I_{org}(i,j) - \min}{\max - \min}, i = \overline{1,M},\ j = \overline{1,N} \tag{6}$$

$\max-$ the image with the highest brightness value, $\min-$ the image with the smallest brightness value, M and $N-$ image sizes, I_c- the image with the resulting contrast.

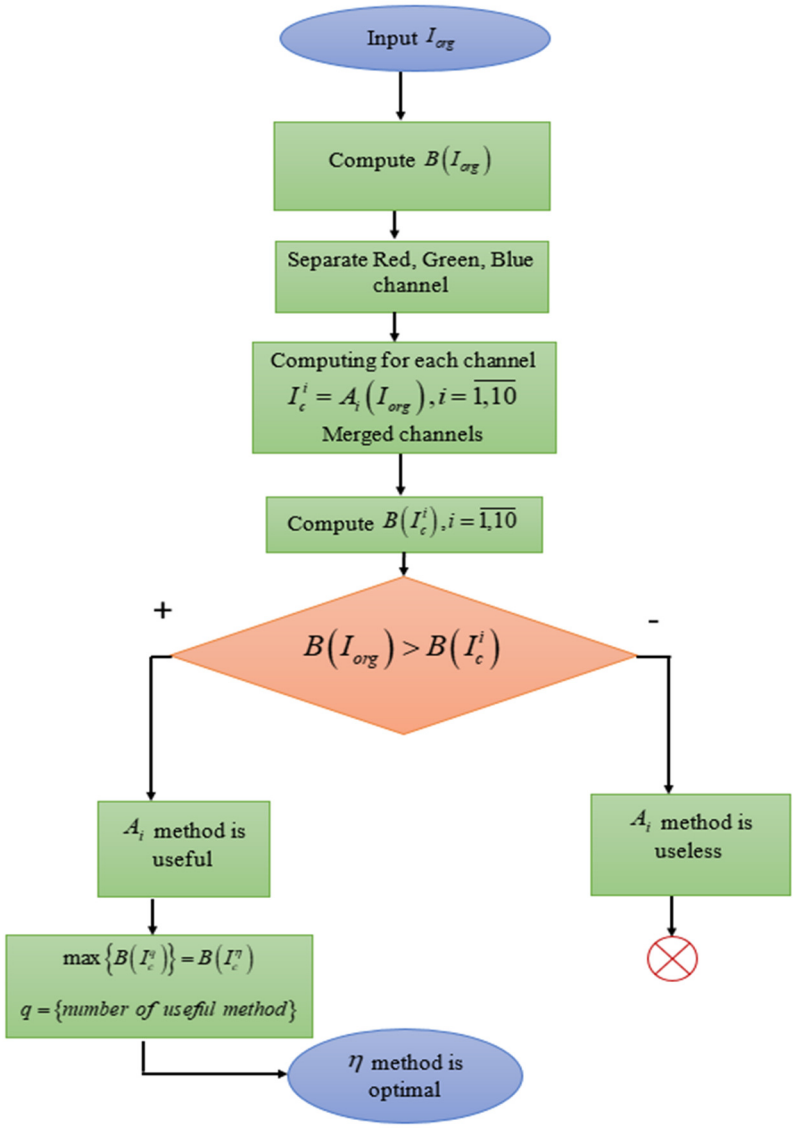


FIGURE 1. Algorithm for determining the optimal method

Morphological contrast enhancement. This method is thoroughly examined in [20], where it employs morphological filters to alter the shape and dimensions of objects within the image while maintaining the overall structure. The method basically changes image contrast by performing dilation and erosion operations. These operations are performed on the input image I_{org} using the structure element B as follows.

Erosion:

$$E(x,y) = \min\{I(x+i, y+j) | (i,j) \in B\} \tag{7}$$

Dilation:

$$D(x,y)=\max\left\{I(x+i,y+j)\middle|(i,j)\in B\right\} \tag{8}$$

A morphological contrast image $C(x,y)$ is obtained as the difference between the dilation and erosion images:

$$C(x,y)=D(x,y)-E(x,y) \tag{9}$$

METHODS

The experimentally selected PSNR is denoted by B as the operator. We define histogram equalization, CLAHE, contrast stretching, and morphological contrast enhancement methods, which are popular contrast enhancement methods, and their various combination sequences, respectively, as follows:

A_1 : Histogram Equalization, A_2 : CLAHE, A_3 : Contrast stretching

A_4 : Morphological Contrast Enhancement, $A_5: A_1 \to A_2$, $A_6: A_1 \to A_3$

$A_7: A_1 \to A_4$, $A_8: A_2 \to A_3$, $A_9: A_2 \to A_4$, $A_{10}: A_3 \to A_4$

In that case, the algorithm for determining the optimal method is implemented as in Fig.1.

In this work, the optimal method of increasing the contrast of the image obtained by drones is determined, and in order to automate the image processing process, it is necessary to evaluate the initial image contrast using a no-reference evaluation indicator. In this case, the images taken from the drone are in the RGB color model, that is, since they are color images, the GCF (global contrast factor) indicator without reference is used. Because this indicator provides an assessment close to the subjective opinion of a person when evaluating the contrast of a color image [21].

RESULTS

In this work, 122 image samples from the database of drone images were used for the computational experiment [22]. Figures 2-3 shows examples of the resulting images after applying different contrast enhancement methods to the base images.

TABLE 1 shows the PSNR value of histogram equalization, CLAHE, contrast stretching, and morphological contrast enhancement methods for the base image set [22].

According to Table 1, 64 images in A_3 method, 58 images in A_1 received the highest PSNR value, so it was found that the A_3 method is optimal when the GCF value of the original image is in the range $[7;14]$. However, since the A_3 method did not give the expected result in all images, different sequences of the 4 methods were tested (TABLE 2).

TABLE 1. PSNR value of contrast enhancement methods A_1, A_2, A_3, A_4

Image name	GCF value	PSNR value of methods				$\max_i\{B(A_i)\}$, $i=\overline{1,4}$
		$B(A_1)$	$B(A_2)$	$B(A_3)$	$B(A_4)$	
Image1.jpg	5.626	23.719	23.048	22.819	22.812	1
Image28.jpg	4.912	23.826	23.072	22.755	22.815	1
Image45.jpg	4.331	22.773	22.520	22.193	22.310	1
Image59.jpg	8.990	27.773	28.097	43.111	27.901	3
Image65.jpg	9.635	27.832	28.287	43.922	27.940	3
Image85.jpg	12.279	27.781	28.367	44.365	27.864	3
Image97.jpg	10.111	27.730	28.271	44.739	28.019	3
Image111.jpg	11.530	27.664	28.068	44.750	27.911	3
Image120.jpg	11.356	27.652	28.148	44.378	27.952	3
...	...	…	…	…	…	…

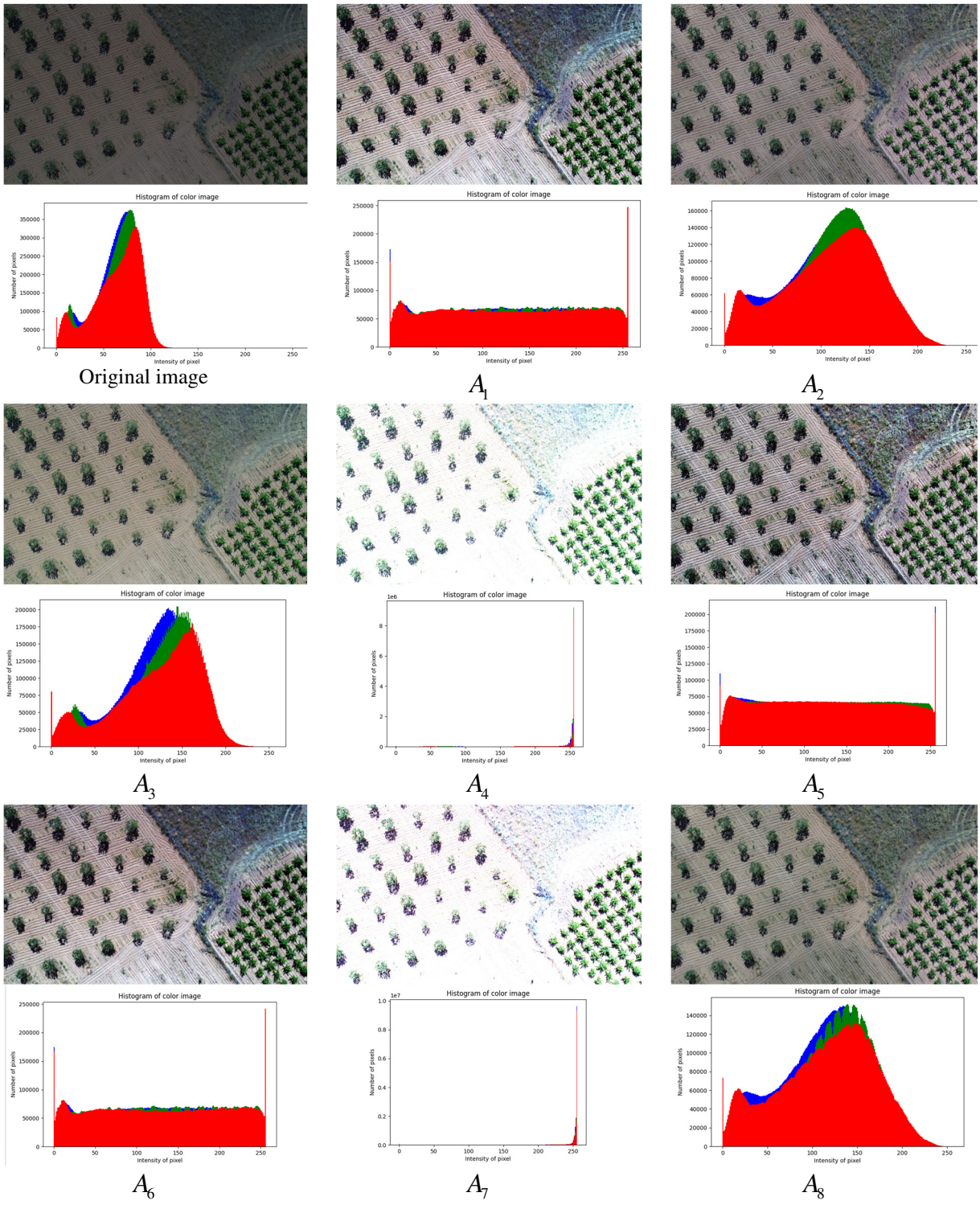
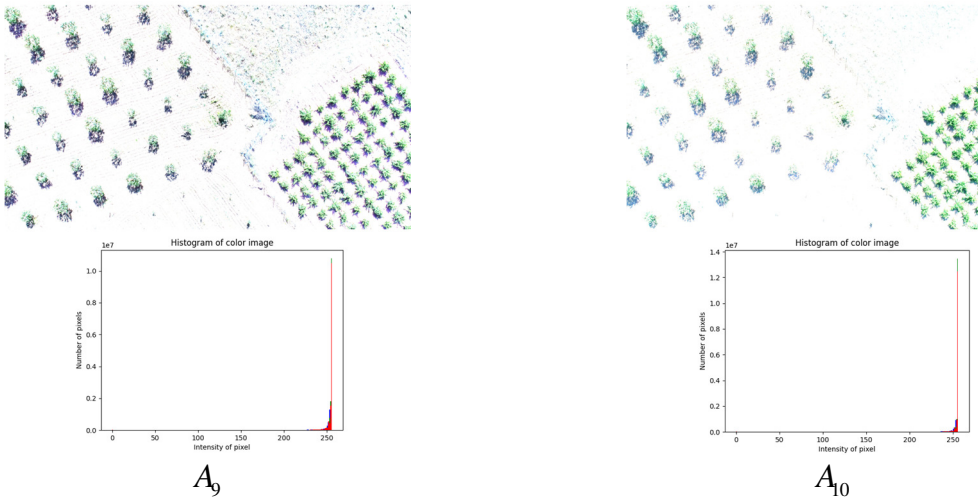


FIGURE 2. Resulting images and their histograms



A_9 A_{10}

FIGURE 3. Resulting images and their histograms

According to the results of Table 2, it was found that 7 images in A_5, 51 in A_6, 24 in A_7, and 40 images in A_8 have the highest PSNR value. It was found that the initial image is the most effective method when the GCF value is in the range $[0;6]$.

TABLE 2. PSNR value of contrast enhancement methods $A_5, A_6, A_7, A_8, A_9, A_{10}$

Image name	GCF value	PSNR value of methods						$\max_i \{B(A_i)\}, i = \overline{5,10}$
		$B(A_5)$	$B(A_6)$	$B(A_7)$	$B(A_8)$	$B(A_9)$	$B(A_{10})$	
Image4.jpg	5.86	23.13	23.29	22.33	22.57	22.27	22.26	6
Image15.jpg	5.33	23.28	23.46	22.48	22.67	22.39	22.37	6
Image32.jpg	5.86	23.07	23.29	22.22	22.44	22.15	22.13	6
Image49.jpg	4.65	23.24	23.25	22.55	22.64	22.45	22.41	6
Image58.jpg	4.43	22.73	23.07	22.13	22.31	22.07	22.03	6
Image70.jpg	9.52	27.93	27.77	28.04	28.29	27.93	27.93	8
Image84.jpg	12.59	28.20	28.23	27.84	28.56	27.83	27.84	8
Image96.jpg	9.70	27.83	27.74	28.26	28.20	28.12	28.08	7
Image109.jpg	13.54	28.21	28.11	27.88	28.43	27.86	27.85	8
...	...	…	…	…	…			…

CONCLUSION

The processing of drone images for crop evaluation is critical in improving agricultural productivity. Based on the images obtained by drones, farmers can identify and analyze the affected areas of crops in large areas.

In this research, the contrast of drone images was enhanced by 4 methods and their different sequences, and the resulting images were evaluated by the PSNR value. The following conclusions were drawn from the results of the calculation experiment:

- as a result of the separate application of histogram equalization, CLAHE, contrast stretching and morphological contrast enhancement methods to increase the contrast of the drone image, it was determined that the contrast stretching method is the most optimal method;
- the contrast stretching method failed to increase the contrast of all images, so a different sequence of 4 methods was tested. In this case, a sequence of histogram equalization and contrast stretching methods was chosen as the optimal method;
- it was recommended to use a sequence of histogram equalization and contrast stretching methods when the image contrast GCF value is in the range $[0;6]$, and to use the contrast stretching method when it is in the range $[7;14]$.

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