Multiple Regions Based Histogram Equalization

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Abstract— **Image contrast enhancement is required to improve the visual appearance of the image. Histogram is an important tool for image processing. By equalizing the histogram the contrast of an image can be increased. A widely known contrast enhancement technique is histogram equalization (HE). In this paper, a histogram equalization technique has been proposed for image contrast enhancement. The input image is divided into multiple regions and each region is mapped into output region to get the equalized histogram. The proposed method is capable of preserving and maintaining the brightness and the quality of the image. The proposed method also brings out the edges which were not in the input image. Using some performance measuring tools, the proposed technique has been compared with other existing methods. From the experimental results it can be seen that the proposed technique dominates over other existing methods.**

Keywords—contrast enhancement, histogram, histogram equalization, image brightness.

I. INTRODUCTION

Image contrast enhancement technique improves the quality of an image which is better than the input image. This technique brings out the details those have been obscured in the original image. Therefore in various applications it is required to improve the contrast of an image.

Histogram is an important tool by which the brightness or the contrast of an image can be increased. Usually a histogram of a digital image represents the frequency of occurrence of gray-levels in the image. The histogram in which the components are concentrated in the low side represents a dark image. The component of high side represents a bright image and almost a uniform histogram except some of the components represents an enhanced image. Therefore histogram equalization (HE) is a well- known technique to enhance the contrast of an image [1]. It is a simple and effective technique which can be applied on various applications. In case of medical image processing HE technique can be used to enhance the contrast of x-ray images. Although HE technique is suitable for various applications, it does not preserve the brightness of the image. The operation of HE technique is global therefore it fails to preserve the image brightness.

Later various methods have been published to remove the drawback of HE technique. Brightness preserving bi-histogram equalization removes the drawback of HE technique [2]. It divides the histogram of input image into two parts according to the mean value of the image. It gives low value of average mean brightness error (AMBE) compared to HE technique. Depending on median of the image a histogram can also be divided into two parts and this concept is applied on Equal area dualistic sub-image histogram equalization (DSIHE) [3]. Minimum mean brightness error bi-histogram equalization (MMBEBHE) [4] and Minimum mean brightness error dynamic histogram equalization (MMBEDHE) [5] have been proposed to preserve the brightness of the image. These two methods are the extension of BBHE method and provide maximal brightness preservation. Based on the local mean values, recursive mean separate histogram equalization (RMSHE) [6] divides the histogram into several subsections and equalizes each subsection independently. To preserve the naturalness of the image Range Separate Histogram Equalization (DRSHE) has been proposed which is presented in [7].

To adapt the local brightness of the input image adaptive histogram equalization methods have been proposed [8], [9]. Contrast limited adaptive histogram equalization (CLAHE) [10] is another AHE technique. Since this technique has no computation complexity, it is known as time consuming procedure.

Image enhancement also plays an important role in medical images. X-ray image enhancement technique is required to make diagnostic decision by observing the x-ray images [11]. Magnetic resonance image (MRI) enhancement also plays an important role in medical image processing. Using stochastic resonance in Fourier domain enhanced magnetic resonance images can be obtained [12]. The contrast of infrared image can also be enhanced by using plateau histogram algorithm [13]. Region based algorithms also have been proposed [14], [15]. In these algorithms the input image is at first divided into multiple regions and each region is mapped into the output histogram.

In this paper, a multiple regions based histogram equalization technique has been proposed. At first, the image has been divided into two subsections based on the threshold value of the image. Then each subsection has also been divided into several regions based on pixels of minimum and maximum probabilities. This technique brings out the edges which were obscured in the input image. It also preserves the brightness of the image and gives better quality output image than the original image.

The rest of the paper is organized as follows- section-II represents the proposed method algorithm. Experimental results and comparison part is described in section-III. Finally, section-IV concludes the paper.

II. Proposed Algorithm

For a given digital image I(x, y) with N pixels and gray level ranges of [0, L-1], the proposed algorithm is given below step by step-

(1) Firstly, the image is sharpened by using Unsharp Contrast Enhancement Filter to reduce the noise.

(2) The threshold value (T) of the image is calculated using Otsu's global threshold method.

(3) Then the image is divided into two subsections based on the threshold value.

Subsection-1 if Pixels <= Threshold value

Subsection-2 if Pixels > Threshold value

(4) After dividing the image into two subsections, the probability of each pixel of each subsection is obtained by-

$$P_k = n_k / n \quad k = 0, 1 \ldots L-1 \tag{1}$$

where in k is the k^{th}-gray level and n_k is the total number of pixels a subsection with gray level k, n is total number of pixels in each Subsection.

(5) Then from Section-1, the pixel which has minimum probability (M1) is calculated. At the same time, the pixel which has maximum probability (M2) is also calculated. After calculating these two pixels (M1, M2), the average of these two pixels is calculated.

(6) After that the subsection-1 is divided into four regions using the following conditions-

If M2 > M1, Subsection-1 is divided into four regions shown below-

Region-1: if I(x, y) <= M1

Region-2: if M1 < I(x, y) <= A1

Region-3: if A1 < I(x, y) <= M2

Region-4: if M2 < I(x, y) <= T

If M1>M2, Subsection-1 is divided into four regions shown below-

Region-1: if I(x, y) <= M2

Region-2: if M2 < I(x, y) <= A1

Region-3: if A1 < I(x, y) <= M1

Region-4: if M1 < I(x, y) <= T

(7) Then from Subsection-2, the pixel containing the minimum probability (M3), the pixel containing the maximum probability (M4) and the average of these two pixels M3 and M4 denoted by A2 are calculated.

(8) After that the subsection-2 is divided into four regions using the following conditions-

If M4 > M3, Subsection-2 is divided into next four regions shown below-

Region-5: if T < I(x, y) <= M3

Region-6: if M3 < I(x, y) <= A2

Region-7: if A2 < I(x, y) <= M4

Region-8: if I(x, y) > M4

If M3>M4, Subsection-2 is divided into next four regions shown below-

Region-5: if T < I(x, y) <= M4

Region-6: if M4 < I(x, y) <= A2

Region-7: if A2 < I(x, y) <= M3

Region-8: if I(x, y) > M3

(9) The output intensity range of each region among 8-regions are determined by using the following eq.-

$$OR_K = (N_K / N_T) \times (L-1) \tag{2}$$

for k=1, 2, 3……8.

OR_K = output intensity range of k region

N_K= total number of pixels in k region

N_T = total number of pixels in the original image.

(10) After determining or mapping the range, the cumulative distribution functions of each region are calculated.

(11) The pixels of each region are distributed in output histogram according to the output intensity range of each region by using the general histogram equalization eq. is given below.

$$E'(x, y)=\left\{\left(\frac{cdf(v)-cdf(\min)}{cdf(\max)-cdf(\min)}\right)\right\}_k \times (OR_k) \tag{3}$$

where, k represents the regions and k=1, 2, 3……8

$$E(x, y) = \text{round}\,(E'(x, y)) \tag{4}$$

where, *cdf(v)* = cumulative value of a pixel in region k; *cdf(min)* and *cdf(max)* = minimum and maximum cumulative value of region k.

Finally, the equalized histogram of enhanced image E(x, y) can be obtained by applying the proposed method.

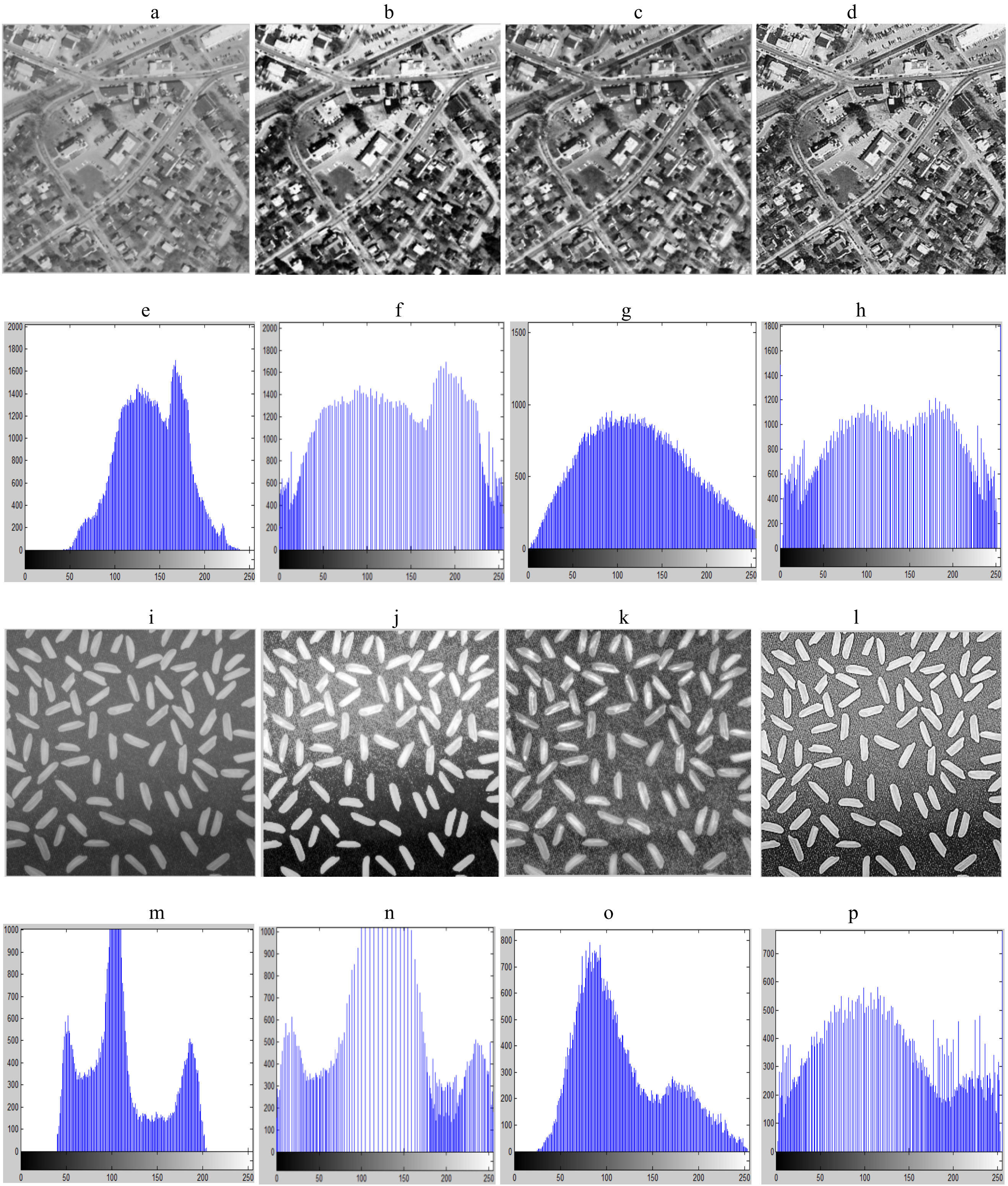

Fig. 1: (a),(i)-original images and (e),(m)-corresponding histograms;(b),(j)-HE results and (f),(n)-corresponding histograms;(c),(k)-CLAHE results and (g),(o)-corresponding histograms;(d),(l)-results of proposed method and (h),(p)-corresponding histograms.

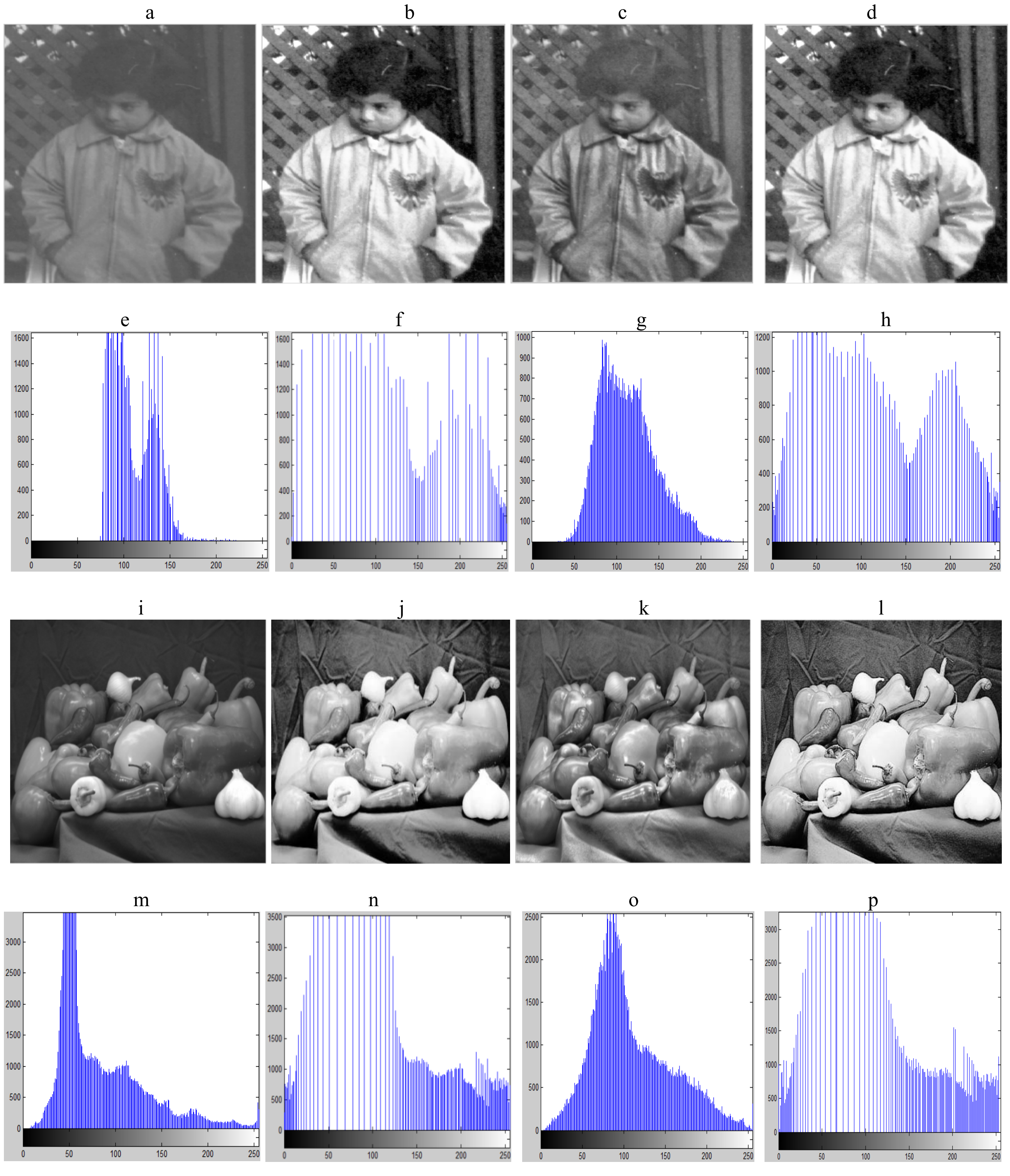

Fig. 2: (a),(i)-original images and (e),(m)-corresponding histograms;(b),(j)-HE results and (f),(n)corresponding histograms;(c),(k)-CLAHE results and (g),(o)-corresponding histograms;(d),(l)-results of proposed method and (h),(p)-corresponding histograms

III. EXPERIMENTAL RESUTS AND COMPARISON

In this section, the results of the proposed method have been compared with other existing methods. To demonstrate the performance of proposed algorithm, the presented method was implemented by using MATLAB. Four performance parameters have been used to demonstrate the performance of the proposed method. The performance parameters are– (1) average mean brightness error (AMBE), (2) mean square error (MSE), (3) peak signal to noise Ratio (PSNR) and (4) number of detected edges

The mean brightness of the input image in its output image is measured by the performance parameter AMBE. AMBE is obtained from the subtraction of average intensities of input and output images. The AMBE is obtained by-

$$AMBE = |X'-Y'| \quad (5)$$

where, X' and Y' are the average intensities of input and output images. Low value of AMBE is required for good enhancement.

The quality of the image is measured by using two performance parameters, MSE and PSNR. If I(x, y) is the original image and the enhanced image is E(x, y) of size M×N then MSE can be obtained by-

$$MSE = [\Sigma_x \Sigma_y \{I(x, y) - E(x, y)\}^2] / (M\times N) \quad (6)$$

where, x is from 0 to M-1 and y is from 0 to N-1. M and N are the dimensions of the images.

The peak signal to noise ratio (PSNR) is calculated from the MSE and can be obtained by-

$$PSNR = 10 \times \log_{10}(MAX^2 / MSE)$$

$$= 20\times \log_{10}(MAX) - 10 \times \log_{10}(MSE)\ (dB) \quad (7)$$

where, MAX is the maximum gray level of the image.

For good enhancement, low value of MSE is desired. High value of PSNR indicates that the high quality of image affected by low quality of noise. Therefore, high value of PSNR is desired for good enhancement.

TABLE I shows the results of AMBE of the proposed method compared with HE method and BBHE method. Investigating TABLE I, it can be seen that the low values of AMBE can be obtained from the proposed method compared to HE and BBHE method for all given images. Therefore, from this table, it can be said that the proposed method is capable of preserving the brightness of the image.

TABLE II shows comparison results of MSE between the proposed method and other exiting HE and BBHE methods. It can be seen from TABLE II that the MSE of the proposed method is lower than other existing methods. Therefore, investigating this table, it can be said that the proposed method maintains the quality of the image.

TABLE III shows the results of PSNR of the proposed method compared with HE and BBHE methods. It can be seen from TABLE III that the PSNR of the proposed method is better than other existing methods. Therefore, investigating this table, it can be said that the proposed method maintains the quality of the image which is affected by low quality of noise.

TABLE I. COMPARISON RESULTS OF AMBE

Images	HE method	BBHE method	Proposed method
Aerial	12.733	6.4736	6.0129
Rice	17.3449	9.3328	8.1591
Baby	20.0793	2.8954	2.6318
Peppers	47.4633	6.5139	3.4968

TABLE II. COMPARISON RESULTS OF MSE

Images	HE method	BBHE method	Proposed method
Aerial	1.69×10^3	1.54×10^3	0.80×10^3
Rice	1.49×10^3	0.93×10^3	0.70×10^3
Baby	2.92×10^3	2.89×10^3	2.74×10^3
Peppers	3.64×10^3	3.59×10^3	3.29×10^3

TABLE III. COMPARISON RESULTS OF PSNR

Images	HE method	BBHE method	Proposed method
Aerial	15.852	16.258	19.094
Rice	16.393	18.441	19.655
Baby	13.471	13.521	13.756
Peppers	12.514	12.635	12.954

TABLE IV. NUMBER OF DETECTED EDGES (CANNY EDGE DETECTION)

Images	Original	HE method	CLAHE method	Proposed method
Aerial	18493	18970	19433	22706
Rice	4826	4935	5261	7981
Baby	6201	6943	6895	8149
Peppers	11245	15485	16816	22261

TABLE IV shows the results of number of detected edges (where edge detection is the canny edge detection) in case of the proposed method and also of HE method and contrast limited adaptive histogram equalization (CLAHE) method. From TABLE IV, it can be said that the number of detected edges of the proposed method is more than HE and CLAHE methods.

IV. Conclusion

In this paper, a multiple regions based histogram equalization technique has been proposed to enhance the contrast of an image. Four performance parameters have been used to demonstrate the performance of the proposed technique. Investigating the experimental results, it can be said the proposed method gives low value of AMBE which means the method is capable of preserving the brightness of the image. From the experimental results, it can also be said that the proposed method maintains the quality of the image by giving low value of MSE and high value of PSNR. The number of detected edges of the proposed method is also higher than the existing methods. Therefore, the proposed method is effective for image enhancement technique.

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