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Digital Image Enhancement in Matlab: An Overview on Histogram Equalization and Specification

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***Abstract*—This paper has two major parts. In the first part histogram equalization for the image enhancement was implemented without using the built-in function in MATLAB. Here, at first, a color image of a rat was chosen and the image was transformed into a grayscale image. After this conversion, histogram equalization was implemented on the grayscale image. Later on, in the same image for each RGB channel, histogram equalization was implemented to observe the effect of histogram equalization on each channel. In the end, the histogram equalization was implemented to this specific color image of a rat. In the second part, for the grayscale image in part 1, the desired histogram of another colored image of a rat was introduced and histogram specification was implemented on the original colored image.**

***Keywords*—Digital image processing, color image, grayscale image, histogram equalization, histogram specification, image enhancement, RGB channel**

I. Introduction

In the modern age, image enhancement technique becomes a vital tool to facilitate with the improvement in image quality in various sectors like identifying anything in images as well as medical imaging [1, 2], computational photography, forensic analysis [3], and pattern recognition [4] in machine vision applications. Main motive of this technique is to make the images discernible by correcting the color hue and brightness imbalance [5] as well as contrast adjustment [6]. As the background of an image may hide structural information of an image [7], the technique to prolong the image temperament, enhances the foreground information, while retaining the background information and thus increases the overall contrast of an image [8, 9]. Several algorithmic techniques such as Artificial Neural Network [10], Convolutional neural Network [11], and K-nearest Neighbors [12] can also be applied in image processing techniques such as segmentation, thresholding and filtering. Though there are several image enhancement techniques has been developed over the past decades, the histogram based image enhancement techniques specifically; 1) Histogram equalization, 2) Histogram specification are utilized vastly for their high efficiency and simplicity of algorithm [5].

The counterbalance process of Histogram improves the contrast of an image through the propagation of effectively spreading out the most uniform values throughout the histogram of an image [13]. As the active spreading of intensity values makes the dark pixels appear darker and the white pixels lighter, the histogram equalization improves the visual appearance of an image. In short, histogram equalization corresponds to the uniform distribution of a histogram [14]. Histogram equalization can be applied both in grayscale as well as RGB color images for contrast enhancement.

The histogram specification is the alteration of an image so that its histogram matches a particular desired histogram [15]. In the histogram specification, cumulative frequency distributions (CDFs) are calculated from the histogram of an image to adjust the shape of the source image's histogram to be suited the expected image's histogram. Histogram specification is a handy technique for image contrast enrichment and thus improving visual image quality.

In this paper, histogram equalization and specification techniques are implemented for image enhancement. At first, a color image of a mouse is transmuted to the grayscale image. Then, histogram equalization is applied to the grayscale image. Histogram equalization is also implemented on red channel, green channel and blue channel separately and lastly, combined them to find histogram equalized color image. Lastly, histogram specification is also performed on the same color image given a desired image's histogram.

II. Literature Review

Histogram equalization has been showing its vast contribution in improvement of image quality in numerous sectors like medical images [16], pattern imaging [4] and so on. Previously, the performances of different types of histogram equalization such as; Global Histogram Equalization, Local Histogram Equalization and Fast Quadratic Dynamic Histogram Equalization in peak signal to noise ratio was performed [17]. To improve the contrast of images of MRI (Magnetic resonance imaging) tests for sensitive treatments (e.g. cancer, soft tissue, stroke etc.) the performances of four types of histogram equalizations were granted [16]. Though the quality in enhanced color images are no better than the gray scale enhanced image quality, approaches were made with 3-D Color Histogram Equalization method [18]. Recently, cohesion of 1-d and 2-D Histogram based method was analyzed in researches [19]. Again, another version of histogram called histogram of compressed scattering coefficients (HCSC) was proposed to get salvation from low-level hand-crafted features in images [20]. Conversely, instead of the generosity in histogram enhancement and specification method, there are a bunch of drawbacks in this method to improve the contrast level in the images. Due to inappropriate contrast, proper images are often not detected in X-rays or lung cancer etc [21]. Two of

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the image enhancement methods; Histogram equalization (HE) as well as Contrast Limited Adaptive Histogram Equalization (CLAHE) left unrealistic images after enhancement in embedded system [22]. Our proposal regarding Histogram Equalization and Specification method provides a uniform response in contrast improvement which gives an appropriate image in the output. On top of that, analyze was performed by MATLAB coding without any built-in function.

III. Histogram Equalization and Specification Basics

Like any other unsupervised methods such as Fuzzy C-Means [23] and ADBSCAN [24] clustering, histogram equalization is also unsupervised. The histogram of a digital image with L total possible intensity levels in the range [0, G] is defined as the detached function:

$$h(r_k) = n_k \text{ ...... (1)}$$

The value of G is 255 for images of category uint8. Often, it is useful to work with normalized histogram as follows:

$$p(r_k) = \frac{n_k}{n} \text{ ...... (2)}$$

The normalized range of the predominance level is [0, 1]. In the probability density function, difference of the PDFs of the input and output images are denoted by the subscript. The following metamorphosis on the input levels is performed to attain output (processed) intensity levels, s,

$$s = T(r) = \int_0^r p_r(w)dw \text{ ...... (3)}$$

Here,

$p_r(r)$ = The probability density function (PDF) of the severity levels in the original image the intensity.

An image is produced by the former transformation that contains similar intensity levels. On top of that it transcends the whole range [0, 1]. The genuine outcome of this equalization process for intensity level is an image which contains onward progressive range as well as better contrast. The transformation function is nothing over than the cumulative distribution function (CDF).

For discrete quantities the equalization transformation becomes:

$$s_k = \sum_{j=1}^{k} \frac{n_j}{n} \text{ ...... (4)}$$

An adjustable transformation function is generated by histogram equalization in the histogram equalization process of the original image. Though the transformation function for an image is flexible, it does not get changed once it is calculated. Specification of the shape of the histogram is necessary to get the processed image for some distinctive implementations. Histogram specification is the process in which an image having a particular histogram is brought forth.

$$H(z) = \int_0^z p_z(w)dw = s \text{ ...... (5)}$$

s could be found from the input image (this is the histogram-equalization transformation), so it follows that the following equation could be used to detect the altered levels z whose PDF is the specified, $p_z(z)$ [15, 25].

$$z = H^{-1}(s) = H^{-1}\left[T(r)\right] \text{ ...... (6)}$$

IV. Implementation and Discussion of Results

The following image was used to implement histogram equalization and specification.

Fig. 1. The image of a mouse

In Figure 2 the resolved grayscale image is represented after the conversion to the grayscale image.

Fig. 2. The grayscale image of figure 1

Then histogram equalization was implemented on the image without using the built-in function in MATLAB. After the implementation the obtain histogram equalized image is made known in figure 3 along with the genuine grayscale image. The histograms of the genuine grayscale image in addition to histogram equalized image are also shown.

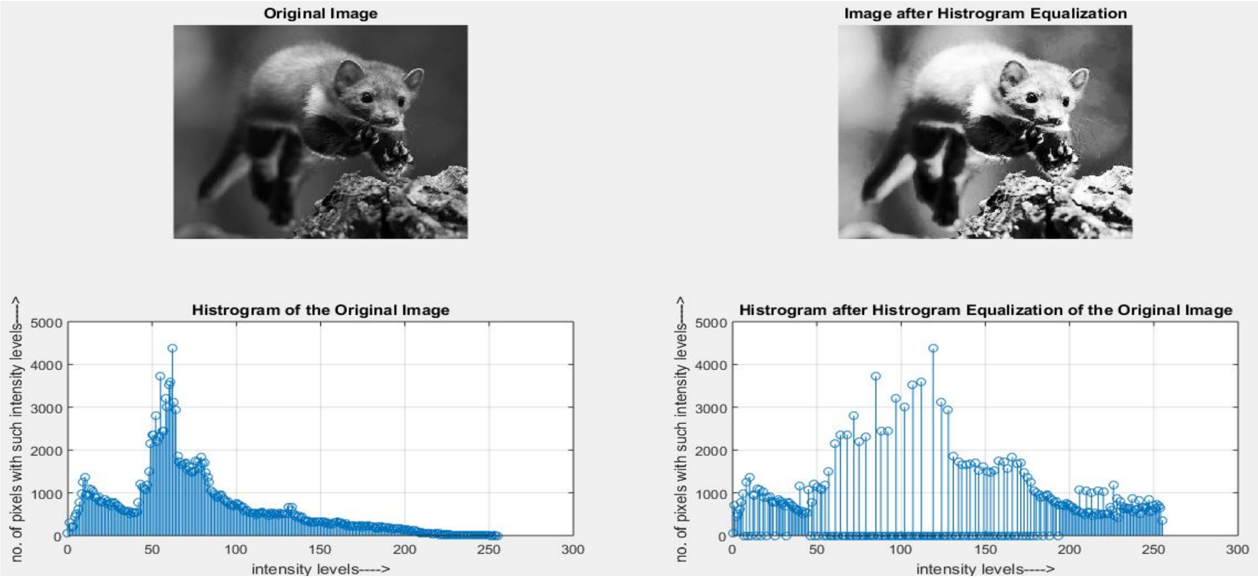

Fig. 3. The original grayscale rat image along with image after histogram equalization with their respective histograms

From the figure above, it is evident that the original image has most of the pixel clustered in a specific range of intensity. However, after histogram equalization, the intensity spread throughout the total intensity range which causes the raise in the sharpness of the image.

Afterwards, 3 RGB channels were prepared in the original image, and for each channel, the histogram equalization was applied.

Here, Figure 4, Figure 5 and Figure 6 demonstrate the obtained images for three different channels named Red, green and blue channel respectively after the standardization by histogram. The histograms of original RGB channels grayscale images, in addition to histogram after histogram equalization of RGB channel images, are also shown.

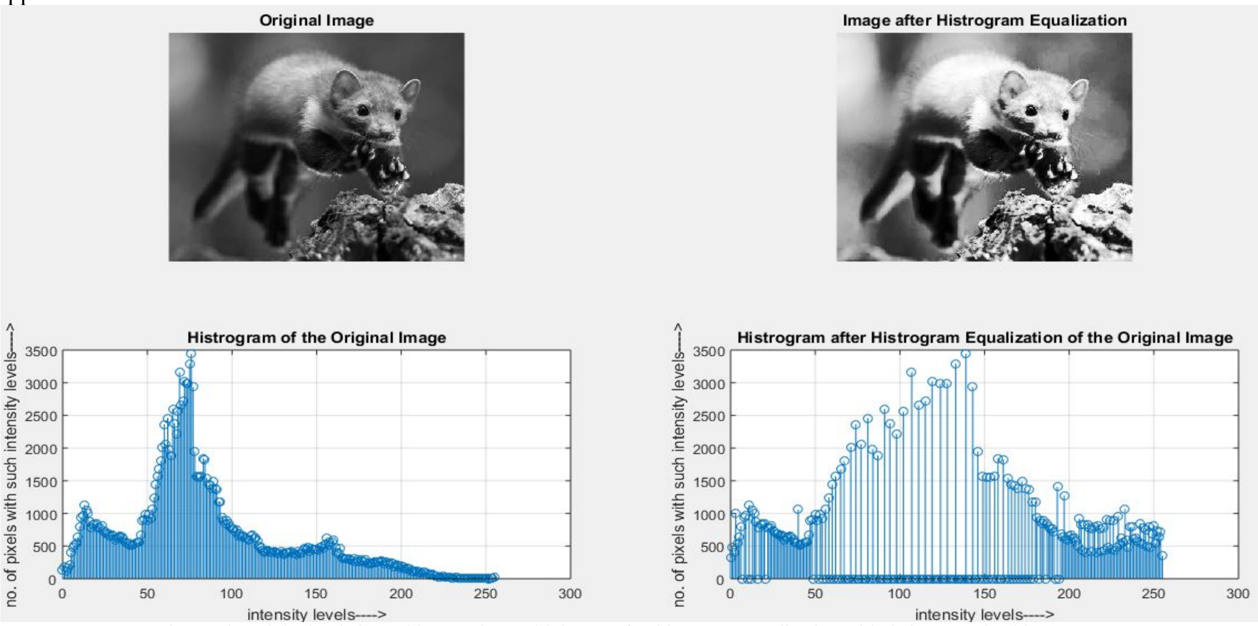

Fig. 4. The original red channel image along with image after histogram equalization with their respective histograms

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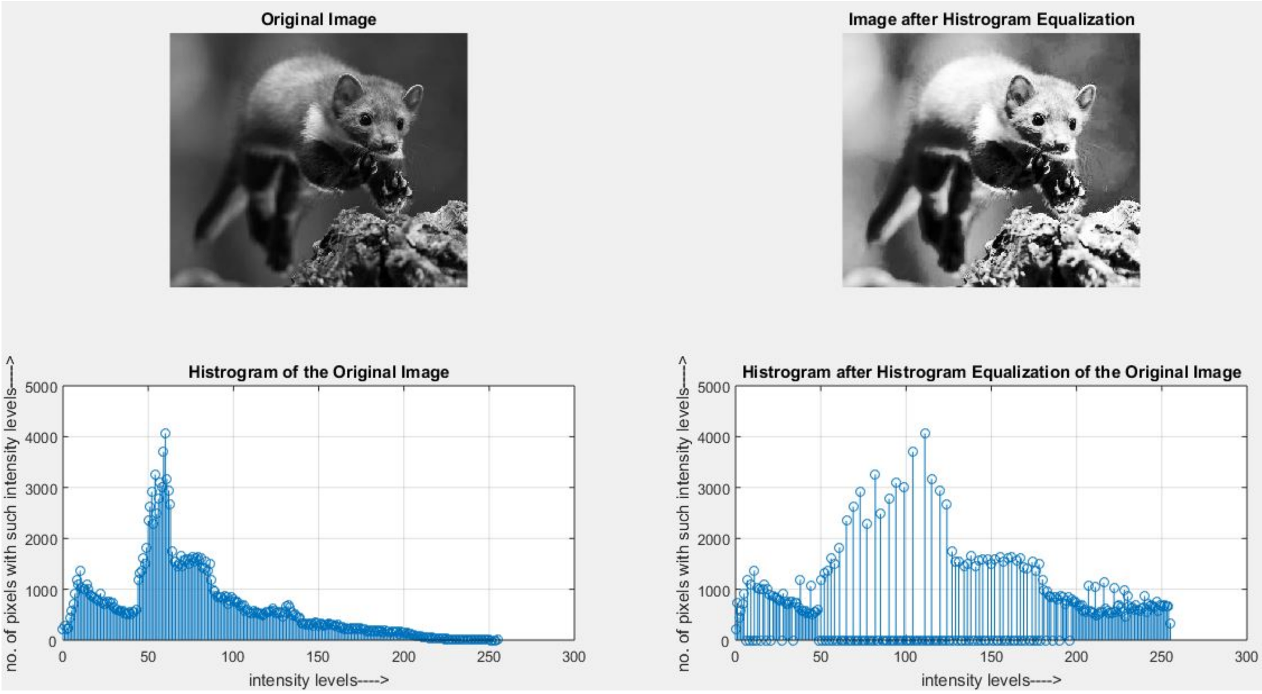

Fig. 5. The original green channel image along with image after histogram equalization with their respective histograms

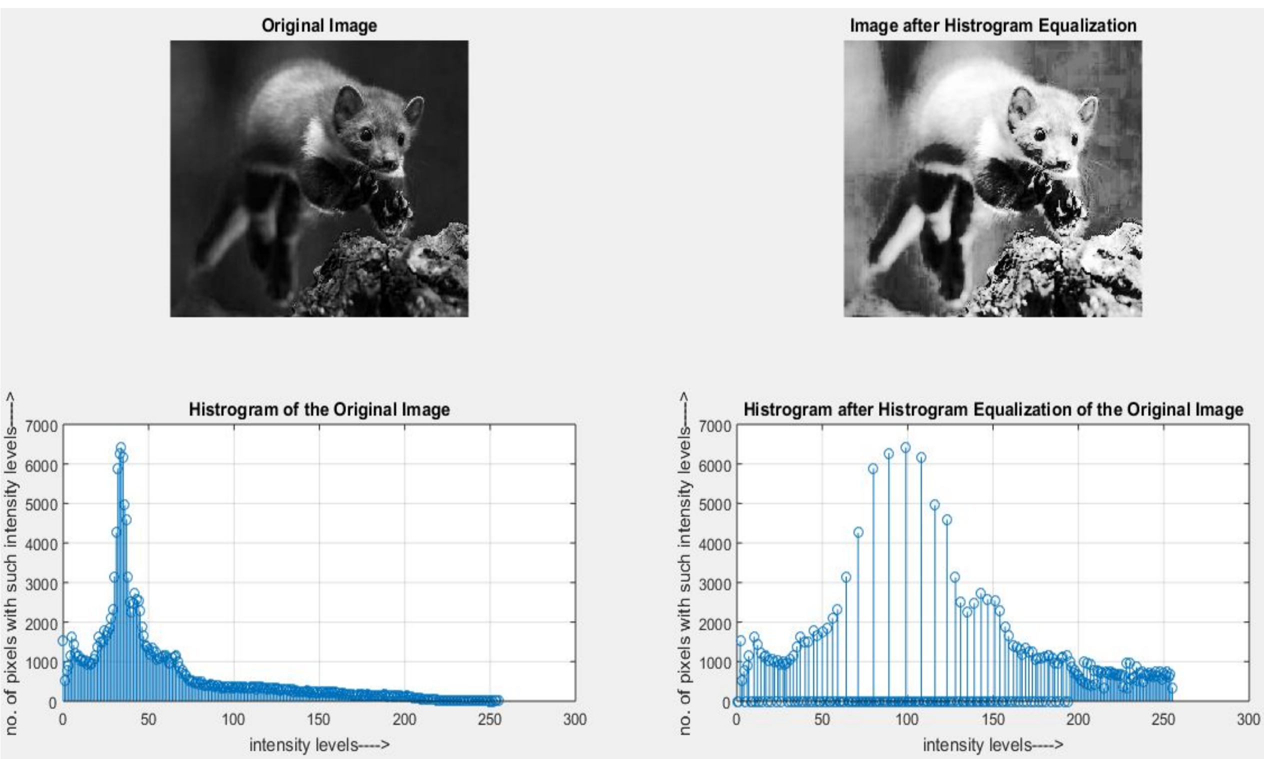

Fig. 6. The original blue channel image along with image after histogram equalization with their respective histograms

Here, it is detected that each channel shows different contrast enhancement patterns. Then the three channels were added, and the equalization process was implemented for the real color image.

By doing so, the obtain image after histogram equalization is depicted in figure 7 along with the original color image. The histograms of original color image, and the histograms of histogram equalized image, are also shown.

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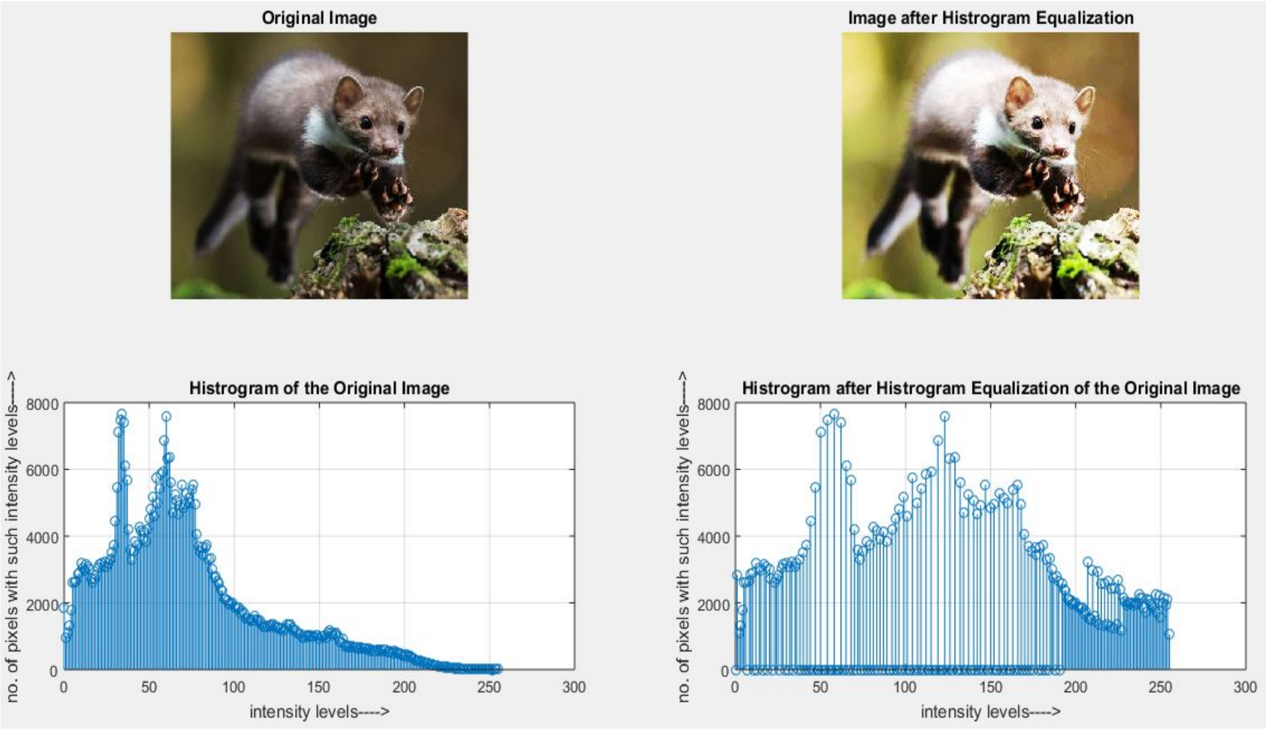

Fig. 7. The original color image along with image after histogram equalization with their respective histograms

In the figure above, the original image is shadier than the histogram equalized image.

For histogram specification, the image in Figure 8 was considered to extract the desired histogram for the image in Figure 1.

Fig. 8. Desired image for histogram specification

At first, the histograms of both of the images (original and desired images) were extracted. Then the histogram equalization was applied to the original image and the histogram of the original image was matched to the desired histogram through histogram specification process. Finally, the output of the histogram specification is publicized in Figure 9.

Here, it is noticed that at first, the images had histograms of a different pattern. However, after the histogram specification, the histogram of the actual image took a similar appearance to the specified image histogram.

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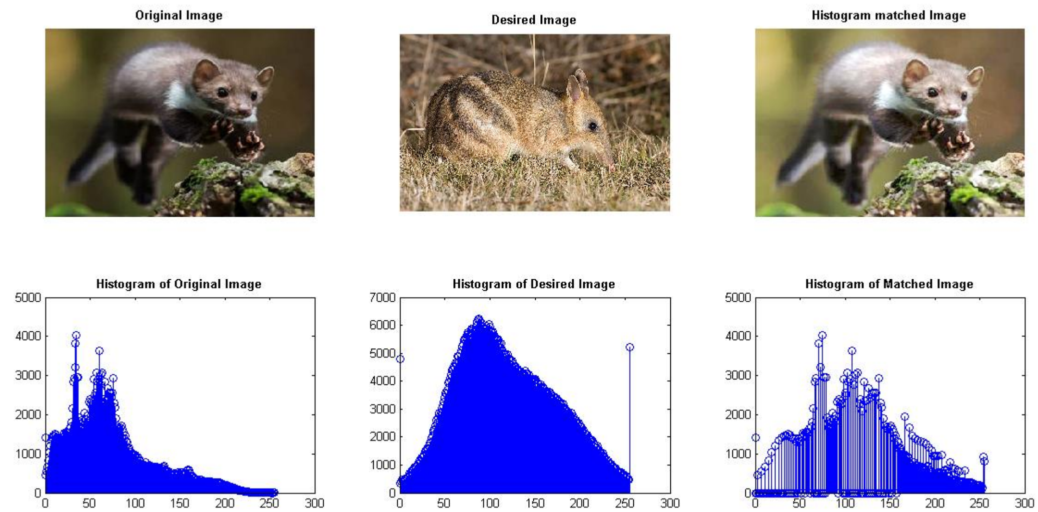

Fig. 9. The original color image along with desired image and image after histogram specification with their respective histograms

V. Conclusion

This paper presents equalization and specification of histogram techniques' practical implementation on some images for image contrast enhancement. It is observed that these techniques work quite well to improve pictures visual quality. In future works of this series, some other improved image enhancement techniques will be discussed.

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