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An Improved Approach for Grayscale Image Enhancement Based on k-means Clustering and Averaging of Filters

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Abstract: In this research work, a technique for enhancement of grayscale images has been proposed without distorting the local image information. Histogram equalization algorithm is generally used for image enhancement. Its limitations include over-enhancement of certain pixel values as well as poor enhancement of the images having noise values. The proposed method helps to overcome these issues. In this proposed work, the grayscale image is clustered using k-means clustering based on the pixel intensity values and then the clusters are segmented with respect to the number of clusters. Then the mean-median filter averaging method is used on each of the clusters, to improve the contrast in the images and also eradicate noises in the image. In the subsequent step all the individually segmented and modified images are combined and we get the enhanced image as a result. This technique is compared to other enhancement techniques like histogram equalization, mean and median filtering in the spatial domain. Furthermore, the enhanced image is threshold and High-Pass Filter is mapped with this thresholded value. On calculating the Peak Signal to Noise Ratio, PSNR values, it has been shown that the experimental outcomes for the method which is proposed yields a better result when it comes to contrast enhancing the image and removing the unwanted salt and pepper noise than the traditional histogram equalization method.
Keywords: Image enhancement, K-means, Segmentation, Noise Removal, Averaging filters, Histogram Equalization

I. INTRODUCTION

Images form a crucial source of knowledge and information, thus it is important to improve the quality of images so that more insights can be drawn from it. This can be achieved using various image processing and enhancement techniques. To improve the quality of an image so that it is suited for a particular application, image enhancement is deployed. One such image enhancement technique is the Histogram Equalization (HE) technique. It is one of the most widely used methods for image enhancement but the problem with histogram equalization is that it over enhances the image. This can lead to the cause of erroneous results in the case of using images that provide sensitive and vital information, such as medical images. One of the major factors that degrade the image quality is noise. Noise can be of many categories including salt and pepper noise, Poisson noise, Gaussian noise, Speckle noise and so on. Enhancement method like Histogram Equalization, contrast enhances the image, but fails to eliminate the noise. Along with enhancement, image segmentation is also very important, if we desire to modify a part of the image, rather than the entire image. Thus a new approach has been proposed through this paper so that the image is first segmented by applying k-means clustering algorithm that can be categorized as an unsupervised learning algorithm and then the image is enhanced so that these issues that occur in the traditional approaches can be overcome.

II. RELATED WORK

The major research work related to this field are listed in the following paragraphs. In their paper, Govind, Vijeesh, and Arun A. Balakrishnan uses averaging method to enhance medical images. This helps in overcoming the over-enhancement problem that occurs in the case of histogram equalization. Firstly, the gray levels are clustered depending on a certain criteria and then the transform function is applied to each of the clusters. This transformation function can be calculated by finding the Probability Density Function (PDF), then using this value the cumulative Density function (CDF) is calculated. The transform function for Histogram equalization (HE) is calculated using this and finally the transform function for averaging method is calculated using transform function for HE and an Identity function, I. It is then compared with respect to histogram equalization and transform domain technique based on the Peak Signal Noise Ratio values. In the proposed method, the cluster weight value is taken as 2, and this is fixed throughout the entire experiment. The cluster number can be diminished with the increase in the weight value. On comparing averaging method with the other methods, the experimental results show that its performance is much better than other approaches that are spatial and transform based for enhancing an image and also eliminates noise and contrast enhances the image.

In the paper by Kaur, Hardeep, and Jyoti Rani, a Magnetic Resonance Imaging (MRI) image is taken and the aim of this is to eliminate noise and improve contrast of a particular image. For achieving this, various Histogram equalization techniques, including the traditional approach for Histogram Equalization is deployed. Image enhancement is done to adjust and change the image in such a way so that it is more suitable for certain applications by improving contrast ratio, changing the brightness, removing the noise and making image identification easier. MRI images are largely used in the medical industry to detect, identify and gain more information and insights on various diseases and including Human brain soft tissues, strokes ,tumour and cancer, and so on. In this paper the various techniques like histogram equalization, Local Histogram Equalization, Adaptive Histogram Equalization and Contrast Limited Adaptive Histogram Equalization techniques are applied and compared with the help of certain parameters. In this paper, in the algorithm followed firstly the input image that is an MRI image is taken and then it is converted into Gray Level MRI image. Then for contrast enhancement of the input image, Histogram Equalization procedure is applied and the histogram is taken. Then the same procedure is performed on the image, for other techniques like Local histogram equalization (LHE), the Adaptive Histogram Equalization (AHE), and Contrast limited adaptive histogram equalization (CLAHE) and the corresponding histogram is computed. Then all the techniques are compared and contrasted based on metrics parameter.

For diagnosis in the medical field, the local contrast enhancement of images is important. The method proposed by Yang, Hsueh-Yen, Yu-Ching Lee, Yu-Cheng Fan, and Hen-Wai Taso in their paper, proposes a method that overcomes the problem which exists for local enhancement such as over-enhancing and increased complexity, thus resulting in the loss of valuable information. In this technique, weighted calculation and local bi-histogram equalization (LBHE) has been proposed to avoid the unexpected effects that appear. Here, the pixel-matching scheme used in the case of similar value search and also interlaced data flow for algorithm implementation have been used. A mechanism for automatic modification is established using constraint curve. From the experimental results, it is proven that this method is more efficient for enhancing the organic structure of heart in MRI by eliminating local noise. The implementation in the proposed method is efficient for complexity reduction and also provision of a scalable mechanism for enhancing the contrast. Its application is correction of local contrast in medical electronics. The steps followed in the algorithm includes estimation of local mean using block matching flow. This is followed by bilinear mapping, thus enhancing the image and efficiently reducing the artefacts of local image enhancement.

In the paper by Das, Jayanta, et al, a selective median filter is proposed for the restoration of grayscale images, which are affected by salt and pepper noise. Using this filter, firstly noisy pixel is identified and replaced by an appropriate value. Until suitable median value is found for the replacement, the window size increases automatically. On evaluating this with respect to other algorithms like standard, weighted, switching mean median filter and bilateral filter, it is shown that it gives better results in terms of Peak Signal-to- Noise Ratio (PSNR), Mean Square Error (MSE) and Structural Similarity Index (SSIM). The performance of this filter depends on spatial processing where it is seen whether salt and pepper noise affects each pixel or not, if it does then it compares with the surrounding noisy pixels. The steps for this technique include initialization of the maximum window size, determining a noisy pixel and initializing a 3*3 window and computing minimum, median and maximum such that max>median> min, otherwise increase the window size by 2. The process is repeated till a suitable output pixel is obtained. Then PSNR, MSE and SSIM is computed for this algorithm with respect to other median filter algorithms and it shows that this algorithm yields a comparatively better result.

In medical science, magnetic resonance imaging (MRI) is a method used for evaluating brain tumour. In the paper, "Efficient detection of brain tumour from MRIs using K-means segmentation and normalized histogram", for de-noising the additive noises like Gaussian, speckle, salt and pepper noise median, adaptive, averaging, Gaussian and un-sharp masking filter. The performance is compared using PSNR and MSE. With the help of normalized histogram and k-means for segmentation an idea for brain tumour identification is proposed. To obtain accurate prediction and classification of the MRI, Naïve Bayes Classifier and Support Vector Machine (SVM) have been used. In this paper, the steps followed include considering an MRI image, then removing the noise using filters, after that the histogram of the image is normalized, then it is classified as tumour image or non-tumour image. If it is a tumour image, then it is segmented using k-means and the tumour region is detected. On comparing the results, it has been shown that Median filter works best for noise removal and averaging filter gives best result for MSE, and SVM is more efficient than Naïve Bayes Classifier.

III.PROPOSED METHOD

In the proposed method, firstly a salt and pepper noise affected grayscale image has been used for testing purpose. In this regard a noisy image can be considered or the noise can also be externally added where the parameters range from 0 to 1. Then this noisy image is clustered with the help of k-means clustering algorithm. In this particular experiment, the number of clusters is considered to be 3, but this algorithm effectively works for any number of clusters. As a grayscale image is considered, there as 256 pixel values, and the pixel intensity value ranges from 0 to L where L is 255. So the first, second and third cluster formed are in the range 0 to L/3, L/3+1 to 2L/3 and 2L/3+1 to L consecutively. In other words, pixels belonging to the intensity value 0 to L/3 come under cluster 1, pixels belonging to the intensity value L/3 to 2L/3 come under cluster 2 and pixels belonging to the intensity value 2L/3 to L come under cluster 3 respectively. If the number of clusters is 2, then the range would be 0 to L/2 for cluster 1 and L/2+1 for cluster 2 and so on.

So considering the number of clusters equal to 3 we proceed to cluster the image, then the pixels under each of the clusters are separately extracted. Therefore, we get three separate segments, wherein in segment 1, segment 2 and segment 3, only the pixel intensity values that comes under clusters 1, 2 and 3 respectively are individually extracted. This is done because in some of the cases, we do not wish to enhance or modify the entire image, we are just interested in modifying a part or a segment of the image. Thus, we can achieve that by extracting that particular segment based on a particular criterion.

After separately extracting each of the clusters, mean filter is applied on the first segment where the pixels belonging to cluster 1 is present, similarly it is applied on the second and third segment. Then the three segments are combined and when we get the entire modified image, it is shown that the image has been smoothened. The same process is performed but in this case instead of mean filter, median filter is applied. It is noticed that on combining the three segments, in the image which is obtained, the noise is reduced on application of median filter.

Then, on the noisy image, the new technique which is the mean-median filter averaging technique is applied. In this technique, the average of mean and median filter is considered. It can be given by the function,

F= (Mean_filtered_image + Median_filtered_image)/2 equation (1)

For a better result and efficient noise removal, the mean_filtered_image pixels are multiplied with the co-efficient 0.2 and median_filtered_image pixels are multiplied with the co-efficient 3.The co-efficient can be changed and the values can be compared. Thus the new equation, we get is

F= (Mean_filtered_image * 0.2 + Median_filtered_image*3)/2 equation (2)

Then on the modified image, thresholding is applied such that the pixel values lesser than 1 are 0 and the values above 250 are 255. After thresholding the image, the image is sharpened. Then we get the final mean-median filter averaged enhanced image, which is noise-free.

Histogram equalization is applied on the original noisy image and the resultant image of histogram equalization is compared with the mean-median filter averaged image. On comparing the two techniques with respect to Peak Signal Nose Ratio (PSNR) [4], it is shown that the new approach yields a better result than the traditional histogram equalization technique.

For further enhancement of the image, high pass filter is applied on the mean-median filter averaged image and this helps in detecting the edges more prominently.

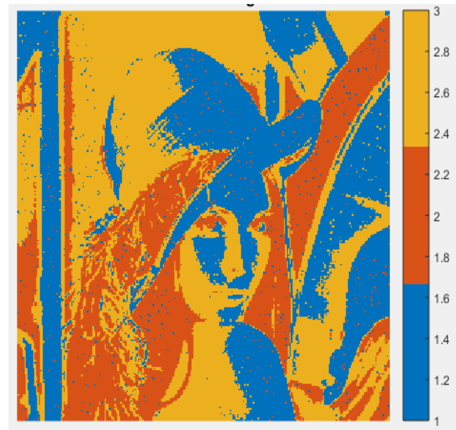
The resultant image is again mapped on the thresholded mean-median filter averaged image and we obtain a noise-eliminated enhanced image. On this histogram equalization or adjustments can be applied in order to get the desired and suitable image for a particular requirement.

IV. RESULTS

A. Effects of applying various image processing techniques on the original noisy image

The experiment has been carried out using the MATLAB tool. In this experiment, three images that are cameraman, Lena and fruit-grayscale are taken respectively. Cameraman and Lena are available in the MATLAB toolbox and fruit-grayscale image is obtained from a standard database which is available publicly. The images are first corrupted by addition of salt and pepper noise of density ratio ranging between 0 and 0.2. Then histogram equalization (HE) technique is applied on the noisy image and the new technique of mean-median filter averaging is applied on the noisy image. On comparing the Peak signal Noise Ratio or PSNR values on application of both the techniques, it is shown that the new approach produces a better result than the traditional histogram equalization approach.

1. (a)



1. (b)

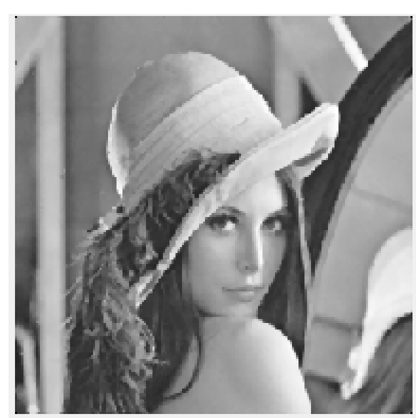
1. (c)

1. (d)

1. (e)

1. (f)

1. (g)



1. (h)

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1. (i)


1. (j)


1. (k)

Fig 1. (a)Original noisy image, (b) Clustered image using k-means (number of clusters=3), (c) Image under cluster 1, (d) Image under cluster 2, (e) Image under cluster 3, (f) Histogram equalization on the clustered image (g) Mean filtering on each of the cluster segments and then the combined image, (h) Median filtering on each of the cluster segments and then the combined image, (i)Image after applying mean-median filter averaging technique, (j)Image after applying high pass filter, (k) Image after mapping images (i) with (j)

B. Comparison of Peak Signal to Noise Ratio (PSNR) of Enhancement Techniques

The PSNR can be given by the following equation,

PSNR = 10.log10 (Maxi2/MSE) = 20.log10 (Maxi /√MSE) equation (3)

Here, Maxi is the maximum possible value for image pixel and the mean-squared error is represented by MSE.

TABLE I

COMPARISON OF THE PSNR VALUES OF THE HISTOGRAM EQUALIZATION DIFFERENT IMAGES WITH RESPECT TO THE NEW APPROACH OF MEAN-MEDIAN FILTER AVERAGING TECHNIQUE.

Serial Number	Images	Enhancement technique	PSNR value
1	cameraman.tif	HE	19.2279
2	cameraman.tif	New Method	22.5248
3	lena.png	HE	16.7899
4	lena.png	New Method	21.2036
5	fruit.bmp	HE	19.9959
6	fruit.bmp	New Method	23.2953

From the table it can be inferred that the new approach that is mean-median averaging technique produces a higher PSNR value than Histogram Equalization. Thus, the new approach can be concluded to be better than the traditional Histogram Equalization method.

V. CONCLUSIONS

The limitation with this technique is that it only works with gray scale images. Secondly, the new approach is applicable for de-noising images that are affected with salt and pepper noise having the ratio of noise density that ranges between 0 and 0.2 and it doesn't yield a good result for images with a very high noise density.

In future, the approach can be modified in such a way that it is applicable for coloured images also. In this case, only salt and pepper noise is considered, so the mean-median filter averaging technique can be enhanced such that it works for other noise affected images such as images corrupted by Gaussian noise, Speckle noise, and Poisson noise and so on.

The main objective of the proposed method is to eliminate the salt and pepper noise in gray scale images and also the enhancement of the contrast in the image. This is effectively achieved using the new approach of mean-median filter averaging. Since the image is first segmented by applying k-means clustering, this approach is also suitable for enhancing a part of the image and instead of the entire image as a whole. The new approach also overcomes the issue of over-enhancement which occurs in the case of histogram equalization and it also efficiently de-noises the image due to the application of median filtering, which the traditional histogram method fails to do. Thus, from the experimental results, it is also proved that this approach yields a better result in terms of the PSNR value with respect to Histogram equalization technique of image enhancement.

VI. ACKNOWLEDGMENT

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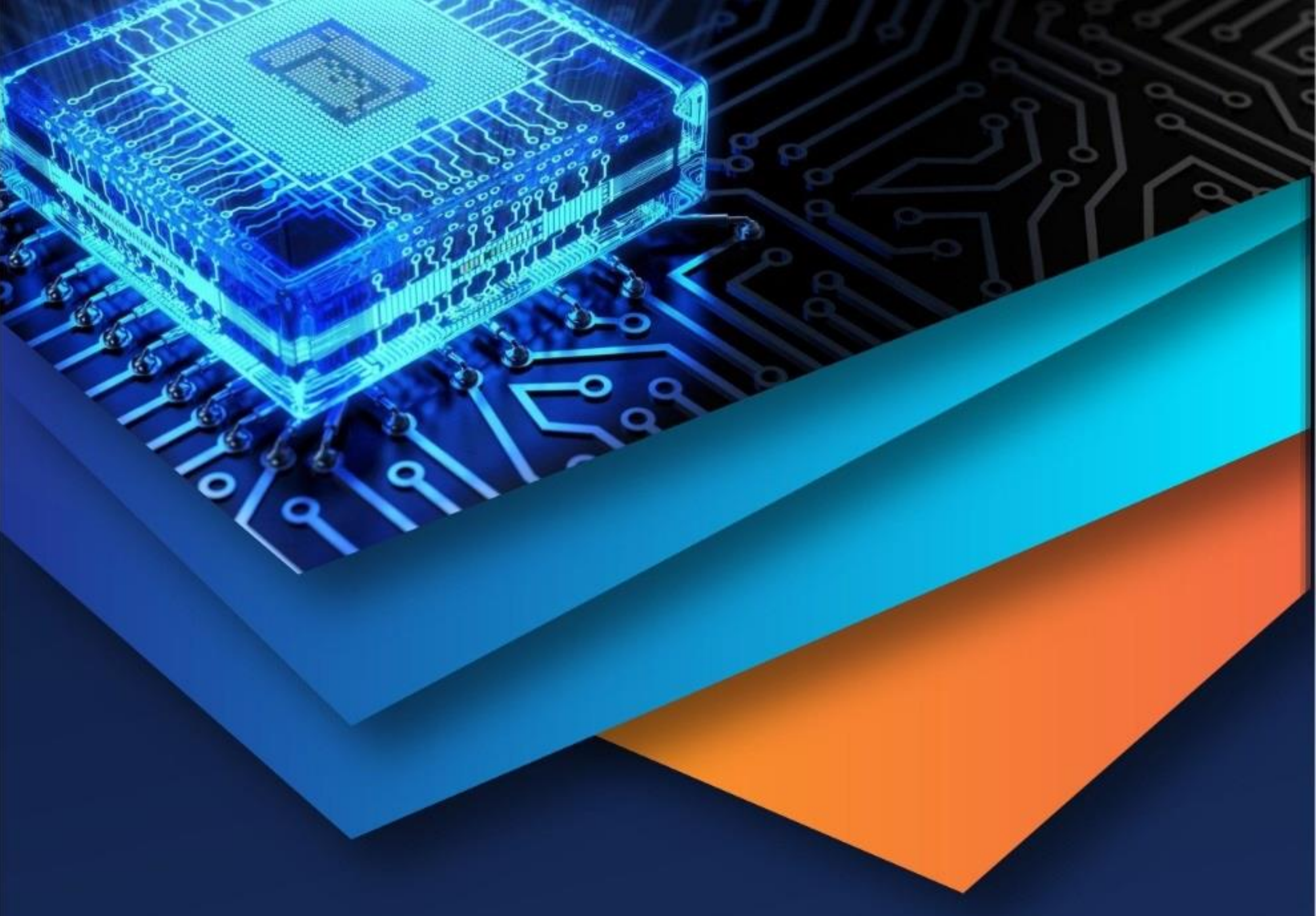

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