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Enhancement of Echocardiographic Images of Rheumatic Heart Disease using Median filtering and Histogram Equalization Techniques

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***Abstract*—Rheumatic heart disease is a disease commonly occurring in the adults below 10 years, infants and mainly in pregnant ladies. In order to control the disease and for its proper treatment the images obtained through ultrasound must be tested using better values. In this approach first step is to filter the speckle noise from the image using median filtering, which limits the reading capability of the images obtained and once removed the speckle noise then image was enhanced using CLAHE, Typical HE, Local HE and Global HE methods. The experiments conducted using different image enhancement techniques on the image have resulted in better values like 7.35 Entropy using CLAHE, 28.82 PSNR using CLAHE, 15.94 AMBE using Local HE, 68.68 Contrast using Typical HE, MSE value of 84.54 using Local HE, SSIM .307 using CLAHE, PMSE 12.486 using CLAHE, SC .794 using CLAHE and ME -22.631 using CLAHE.**

Keywords*—*rheumatic heart disease, echocardiographic images, speckle noise, median filtering, CLAHE, typical HE, local HE, global HE

I. Introduction

Rheumatic heart disease is a cardiovascular disease that mainly occurs in the human heart. It is an effect of maltreatment of the disease Rheumatic fever found in joints and knee pains. If not treated properly rheumatic heart disease leads to morbidity and mortality of the persons in developing countries. First step towards the eradication of the disease is to generate awareness among people to self-identify the symptoms of the disease. Once the people are able to identify the symptoms there must be proper facility for the treatment of the disease which was most difficult in developing countries in 1990's. Providing facilities available like in developed countries is still a major challenge to developing countries even though some development occurred in the form of echocardiography. [1]

Echocardiography is a method to obtain the images related to the disease. The ultrasound scans of the images results in echocardiographic images related to the disease. The use of the echocardiography was first experimented on school students of rural area. The problems the team of doctors faced were the lack of complete awareness of the symptoms and experience of the team on the disease. Whatever the results they got were classified into mild, average and severe cases. The results got were limited due to number of test cases which were not able to strongly recommend the occurrence of the disease. Later on with the invent of technology and more and more knowing the disease the echocardiographic scanning of the images lead to better results than the previous test cases and obtained images was started to give more information about the disease with proper analysis of the disease. [2]

The main part of analysis of the rheumatic heart disease is the analysis of the echocardiographic images which are filled with speckle noise. In presence of speckle noise whatever the analysis done will be biased and ambiguous and experiment results will not be justified. Speckle noise limits the analysis of the image and also limits the further exemption of the images. So for better results of the experiments speckle noise must be removed from the image and enhance it for better analysis. Removal of noise can be done through different filtering methods like mean, median, etc and enhancement through different enhancement methods present. The whole procedure of filtering the noise and enhancing the images requires some effort to understand the results obtained after conducting the experiments to measure the different values. [3]

In this paper, section 2 explains the comprehensive review of work carried out to remove speckle noise using different methods and different methods used to enhance the images. In Section 3, novel approach is introduces for mitigating speckle noise in images through median filtering and enhancing echocardiographic images using the Contrast Limited Adaptive Histogram Equalization (CLAHE), Typical HE, Local HE and Global HE methods in comparison with the previous work done on the enhancement of echocardiographic images. In section 4 experimental results obtained are discussed to derive at different parameters, used to boost the result. In section 5 overall analysis of the result is done with the impact of result and the interpretation of the result with the help of performance metrics. At last results are concluded to summarize the overall effect of the experiment conducted on the images used for analysis of the disease.

II. Related Work

In this section different research papers are gone through which motivated to do the research on the current field, which guide us through the work to be carried out for proper conduction of research. These papers help us to understand the objectives, methods employed and challenges they faced to come out with the paper and finally how they arrived the desired result. These papers act as boosting factor to do the research and analyse the situation in better way related to research.

Mohammad Jalali, Hamid Behnam and Maryam Shojaeifard have masked the image with cartoon part to reduce speckle noise leading to image quality enhancement. Using this method they obtain more accuracy in terms of segmentation of the image compared to original image. The average improvement in segmentation is 15.98 for Hausdorff distance and 0.0632 for the dice similarity coefficient. The images obtained after conducting experiment using proposed method had high dice similarity coefficient of 0.96 and Hausdorff Distance of 16.49, which were superior to other methods used. [4]

Kalpana Chauhan, Rajeev Kumar Chauhan, and Anju Saini employed a hybrid filter consisting of SRAD with a relaxed median filter, through which they were able to remove large spike noise generated from SRAD process. The modified nonlinear complex diffusion filter effectively addresses the noise in the imaginary part of the image, offering improved noise handling capabilities. The results obtained after applying the HSARD has better noise removal compared to original SARD method employed to despeckle the noise from the image. [5]

Parisa Gifani, Hamid Behnam, Farzan Haddadi, Maryam Shojaeifard, Zahra Alizadeh Sani extracted temporal information through intensity variation time curves (IVTC) for individual pixels. They subsequently formulated both low-resolution and high-resolution over complete dictionaries using a priori knowledge of temporal signals and a set of predefined functions. Employing the Bayesian composite sensing sparse recovery algorithm, they determined the sparse coefficients of the signals. Finally, by integrating new IVTC signals into the original IVTC, they successfully reconstructed the original echocardiography video with an increased number of frames. [6]

Xuli Zong, Edward A. Geiser, Andrew F. Lame, and David C. Wilson adopted a multiscale wavelet analysis framework for speckle reduction and feature enhancement. They combined the wavelet shrinkage method with nonlinear processing to improve contrast within structures and along object boundaries. In the algorithm shrinkage of wavelet co-efficients is done through soft thresholding. along the borders. [7]

C. Preethi, M. Mohamed Sathik, and S. Shajun Nisha conducted a comparative analysis of established despeckling filters for speckle suppression and feature enhancement. The evaluated despeckling filters included the Lee filter, Median filter, Crimmins Speckle filtering, Gaussian filter, and Fast non-local means filter. Additionally, the Contrast-Limited Adaptive Histogram Equalization (CLAHE) method effectively addressed low contrast in ultrasound frames at an optimal scale. In terms of cardiac view performance analysis based on PSNR and SSIM, Fast non-local filtering demonstrated favourable values. Furthermore, in terms of UQI and MSE, Fast non-local filtering exhibited superior performance. Overall, fast non-local filtering displayed commendable performance across all cardiac tests. [8]

With the presence of different methods to remove speckle noise and enhance the images, their exists certain limitations. Here in the next section different approach is proposed to filter noise form the image and enhance the image denoised.

III. PROPOSED METHOD

In this section, the methodology employed for eliminating noise from the image is discussed. Then approach used to enhance the denoised image is discussed. Then different image parameters are computed to the validity of the denoised and enhanced image. Here techniques used and solutions got are discussed in detail In previous work on the enhancement of echocardiographic images using Adaptive Brightness Transfer Function algorithm which is one of histogram technique is based on curve fitting cine loop's gray level histogram to the sum of 3 Gaussian functions. The test was done on the 10 patients with 23 different cine loops, showing result of different echogenicity. The algorithm used was mainly dependent on the gray level of the image and parameters used were not real. The main drawback of the algorithm was that the image was noisy and the results obtained were analysed using artificial parameters. [9]

In the proposed method echocardiographic image is taken as the input obtained from ultrasound scanning of the patients upon obtaining the echocardiographic images, then speckle noise are mitigated through the application of the median filtering method. Subsequently, after obtaining the denoised image. Typical HE, Contrast Limited Adaptive Histogram Equalization (CLAHE), Global HE and local HE method are used to enhance the image. After employing the different histogram equalization methods results are compared using quality metrics. The working of each histogram equalization is discussed below and quality metrics output are discussed in section 4. This enhancement aids in the clear identification of symptoms related to rheumatic heart disease, facilitating further analysis. Figure 1 depicts the block diagram illustrating the proposed method for speckle noise removal from the initial noisy image.

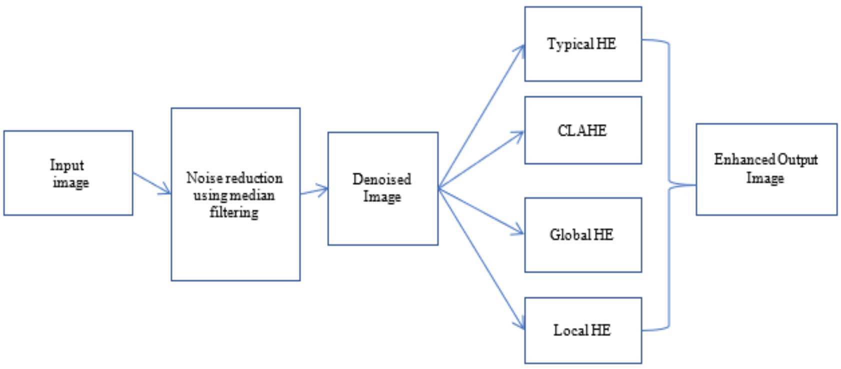

Fig. 1. The block diagram of our proposed method for filtering speckle noise and enhancing the denoised image is depicted in Figure 1, outlining the sequential steps involved in the comprehensive processing approach.

A. *Median filtering*

A median filter operates as a nonlinear filter, determining each output sample as the median value within a window of input samples. The outcome corresponds to the middle value after sorting the input values, typically employing an odd number of taps. Primarily employed for noise reduction in images or signals, median filtering enhances the quality of processing results. Notably, it excels in preserving edges while effectively removing noise, making it a valuable tool in signal processing applications.

The median filter operates on the principle of substituting the gray level of each pixel with the median of the gray levels within a designated neighbourhood, deviating from the typical average operation. In the process of median filtering, a specified kernel size is employed, encompassing pixel values within the kernel. The median level within this kernel is then determined. The application involves scanning through the signal entry by entry, with each entry being replaced by the median of neighbouring entries within a "window." This window slides entry by entry throughout the signal. It's worth noting that the number of windows to slide is generally fewer in one-dimensional signals compared to two-dimensional signals, which are constrained by regions or boundaries. [10]

Let f(x, y) represent the pixel value of the noisy image, for a window of size n*n cantered at pixel(x,y). The median filter computes the median value of the pixel intensities within the window and assigns this value to the corresponding pixel in the output image.

Mathematically the formula for the median filter operation can be written as

$$g(x,y) = median(f(x+k, y+l) \quad (1)$$

Where –n/2<=k, l<=n/2 and g(x, y) represents the denoised pixel value at position (x, y).

This operation is applied to many pixels in the image, excluding the borders where the window size extends beyond the image dimensions. [11]

B. CLAHE

Adaptive Histogram Equalization (AHE) is a computer image processing technique designed to enhance contrast in images. It deviates from standard histogram equalization by employing an adaptive method that calculates multiple histograms, each corresponding to a distinct section of the image. These histograms are then used to redistribute the lightness values of the image. This approach is particularly effective for improving local contrast and refining edge definitions in specific regions of an image. However, AHE has a tendency to overly amplify noise in relatively homogeneous regions of an image. To address this issue, a variant of adaptive histogram equalization known as Contrast Limited Adaptive Histogram Equalization (CLAHE) is employed. CLAHE mitigates the over amplification of noise by imposing limits on the amplification process, providing a more controlled and balanced enhancement of contrast.

However, when there are regions in the image that significantly differ in brightness from the majority, the contrast in those areas may not be adequately enhanced. Adaptive Histogram Equalization (AHE) addresses this limitation by employing a different approach. It transforms each pixel using a unique transformation function derived from a localized neighbourhood region. Originally developed for use in aircraft cockpit displays, AHE ensures that contrast enhancement is tailored to the characteristics of each pixel's immediate surroundings. In its basic form, each pixel undergoes transformation based on the histogram of a square surrounding that pixel. This adaptive approach allows for more nuanced contrast improvements, particularly in regions with varying brightness levels.[12]

By applying the redistribution recursively, the algorithm can fine-tune the contrast enhancement while ensuring that the effective clip limit aligns more closely with the specified limit. This iterative refinement helps strike a balance between effective contrast control and preventing excessive amplification in regions where the histogram is clipped. The reason to use median filtering is that it reduces the variance of the intensities in the image and it also uses 2D mask for each pixel in the image. The reason to use CLAHE is that it overcomes the limitation of global approaches by enhancing local contrast.[13]

C. Typical HE

Histogram equalization is a technique used in image processing to enhance the contrast of an image by redistributing the intensity values. The typical process for histogram equalization is Compute Histogram by calculating the histogram of the image by revealing the distribution of pixel intensities. Then calculate Cumulative Distribution function, then apply histogram equalization transformation to ensure compatibility with the pixel intensity range and lastly implement transformation across each pixel in the image to enhance the contrast and visual characteristics. [14]

D. Global HE

This method is most suitable for the images which are either dark or light. The main merit of this method is that the image is either completely or not at all enhanced. The image is treated here as photo which is in dark and later enhanced to light. This method is suitable for scientific images which are of low intensity and requires more enhancements for further analysis. For every set of pixels acquired from identical positions across all input single-channel images, the function assigns the histogram bin value to the corresponding location in the destination image. The coordinates of the bin are determined by the pixel values within this input pixel group. In statistical terms, the resulting pixel value in each output image represents the likelihood that the associated input pixel group pertains to the object defined by the histogram in use. [15]

For any grayscale image the parameters considered are cdf(x), max_hist and Max_cdf.

To show the trend of cdf relative to intensity value, normalized cdf is

$$cdf\_normalize = (Max\_hist * cdf(x))/max\_cdf \quad (2)$$

E. Local HE

Local histogram equalization is a contrast enhancement technique applied to images by performing histogram equalization independently in smaller, localized regions instead of globally across the entire image. This approach aims to mitigate the risk of over-amplifying noise, which can occur when applying histogram equalization to the complete image. By adapting the equalization process to specific regions, variations in contrast and lighting across the image can be addressed more effectively, resulting in improved visual quality and detail preservation. Here's a brief explanation of the process:

First the image is divided into non-overlapping blocks or regions, then local HE is applied and at last bocks are combined to form final enhanced image. Sometimes smoothing operation is used to reduce artifacts at the boundaries of the blocks. This method is particularly useful in situations where there are variations in lighting or contrast across different parts of an image. [15]

IV. Results

In previous approach they have used gray level histogram in order to identify the pixels with high and low level intensity. In order to identify pixels the algorithm has been divided into 3 sections with each assigned a Gaussian function. Here they have compressed and stretched the image with help of histogram equalization. After identifying the types of pixels they enhanced the high intensity pixels to get better view of tissues related to the cardiac muscle and low intensity pixels contained textual information. The results displayed better images of tissues related to cardiac muscle. The main drawback of the algorithm was the presence of noise in the echocardiographic image. [08]

In the proposed approach, speckle noise was eliminated from the image and later on image quality was. Step by step approach for speckle noise removal and image enhancement is discussed in this section along with visual representation.

Fig. 2. Original image

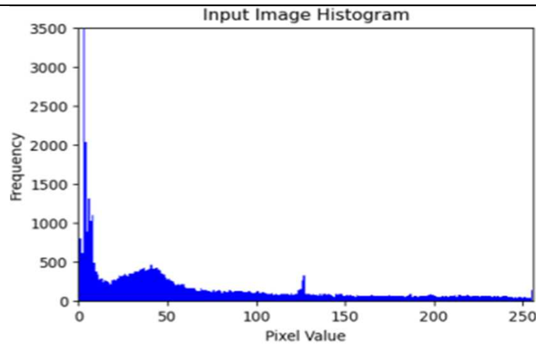

Fig. 3. Input Image histogram

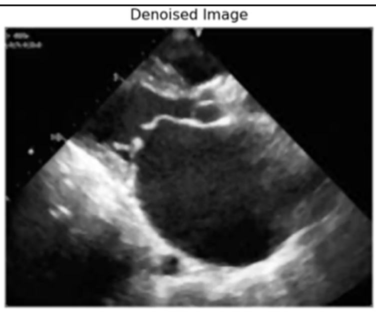

Fig. 4. Denoised image obtained after applying median filtering

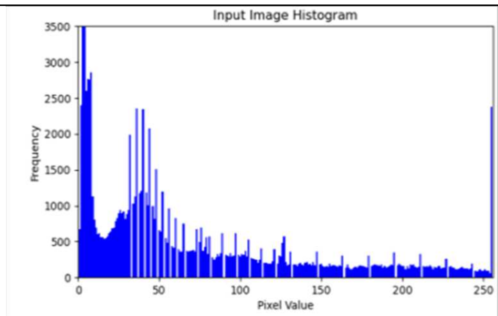

Fig. 5. Denoised Image Histogram

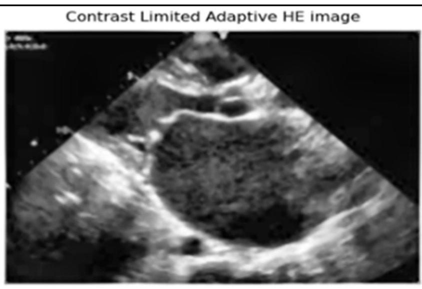

Fig. 6. Contrast Limited Adaptive HE Image Adaptive HE Image

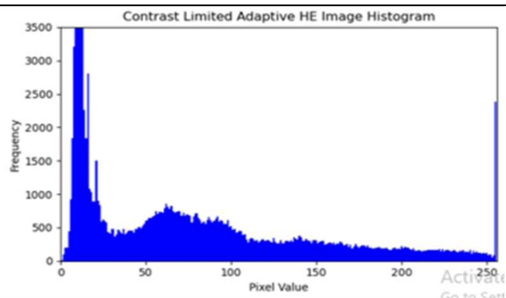

Fig. 7. Contrast Limited Histogram

Fig. 8. Typical HE Image

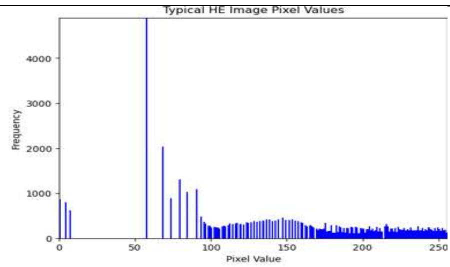

Fig. 9. Typical Histogram

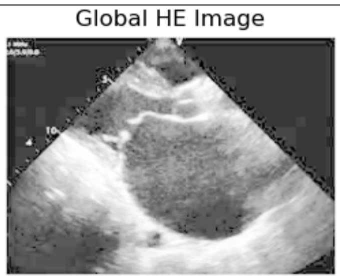

Fig. 10. Global HE image

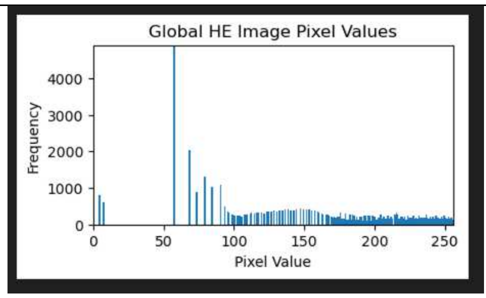

Fig. 11. Global HE Histogram

Fig. 12. Local HE Image

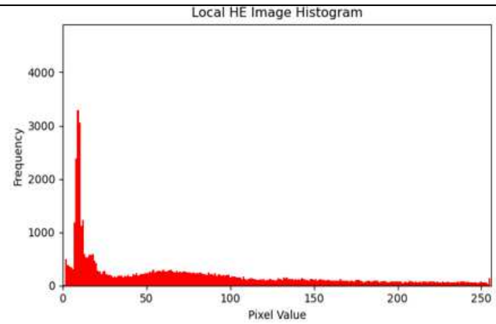

Fig. 13. Local HE Histogram

In figure 2 echocardiographic image obtained from the ultrasound scanning of the rheumatic heart disease patient is taken. In figure 3 displays the graph representing the histogram of original echocardiographic image. In figure 4 a denoised image obtained after applying the median filtering is considered, then histogram for denoised image is displayed in figure 5, as it is clear that histogram graph of input image and denoised image vary in their values.

Figure 6 displays the enhanced image obtained using CLAHE image enhancement technique and in figure 7 displays the histogram for the enhanced image obtained using CLAHE. In figure 8 displays the enhanced image obtained using Typical HE Image enhancement technique and in figure 9 displays the histogram for the enhanced image obtained using Typical HE. In figure 10 displays the enhanced image obtained using Global HE Image enhancement technique and in figure 11 displays the histogram for the enhanced image obtained using Global HE. In figure 12 displays the enhanced image obtained using Local HE Image enhancement technique and in figure 13 displays the histogram for the enhanced image obtained using Local HE.

System Requirements

Operating System	Windows 10 & Above
Processor	Intel Core i5 & above.
RAM	At least 8GB of RAM. HDD and above.
Storage	500GB.
Graphics Card	A dedicated graphics card with CUDA.
Monitor	Minimum resolution of 1920*1080 pixels.
I/O	Standard Keyboard and Mouse.

Software Requirements

Programming Language	Python 3.8
IDE	Anaconda with Jupyter Notebook.
Libraries	OpenCV with Python.
Algorithms	Median filtering and Histogram Equalization algorithms.
Version	GitLab
Documentation and reporting tools	Microsoft Word.
Knowledge and Skills	Image Processing concepts, algorithms and techniques, skills to develop algorithm effectively.

As it is visible that from the result that the images obtained after applying histogram equalization techniques very in contrast and also see that the graph plotted for different image enhancement techniques also vary in their presentation. From the image and histogram obtained it is clear that the contrast obtained is more in CLAHE compared to other 3 histogram equalization techniques. So it can justify that the better histogram equalization technique out of 4 is CLAHE. In this paper speckle noise have been removed from the image using median filtering, and contrast of the of the denoised image has been increased using different histogram equalization techniques.

V. Discussions

In this research paper initially speckle noise has been removed from the image using median filtering method. Then denoised image has been enhanced using different histogram equalization techniques like CLAHE, Typical HE, Local HE and Global HE. In these 4 methods varying presentation in histogram equalization has been observed and level of contrast obtained is more in CLAHE compared to other 3 methods. This implies that the CLAHE is the best histogram equalization technique to be applied for enhancing image contrast. The limitations of the paper is that the enhanced image obtained is used only for echocardiographic images which are result of ultrasound scan and these images contain minute information's which may not be enhanced.

Then performance metrics like Entropy to measure amount of uncertainty present in the image, Peak Signal-to-Noise Ratio (PSNR) to measure the quality of processed image to a reference image by quantifying the amount of noise introduced during processing, Absolute Mean Brightness Error(AMBE) to quantify the difference in brightness between

2 images, contrast referring to the difference in luminance or color, Mean Squared Error (MSE) quantifies the average squared difference between the pixel values of a processed image and a reference image, Structural Similarity Index(SSIM) used to access the similarity between 2 images processed and referenced image, Predictive Mean Squared Error(PMSE) quantifies the average squared difference between the predicted values, Structural Content(SC) is used to access the structural similarity between 2 images and Mean Error(ME) represent a measure of the average difference between corresponding pixel values in a processed image and a reference image were computed. Then values obtained were displayed in the Table 1 and identified the best result for different in age enhancement techniques.

TABLE I. THE PERFORMANCE METRICS

Image Enhancement Technique	Entropy	PSNR	AMBE	Contrast	MSE	SSIM	PMSE	SC	ME
Typical HE	6.223	27.901	75.368	68.679	105.430	0.217	8.853	0.762	-72.177
Global HE	6.224	27.901	128.723	68.680	92.663	0.125	6.101	0.426	-89.155
Local HE	7.204	28.160	15.943	67.764	84.537	0.298	10.674	0.688	-24.340
CLAHE	7.347	28.816	21.643	68.198	90.227	0.397	12.486	0.794	-22.631

Then we displayed the performance metrics values computed were displayed for different image enhancement techniques graphically in the figure.

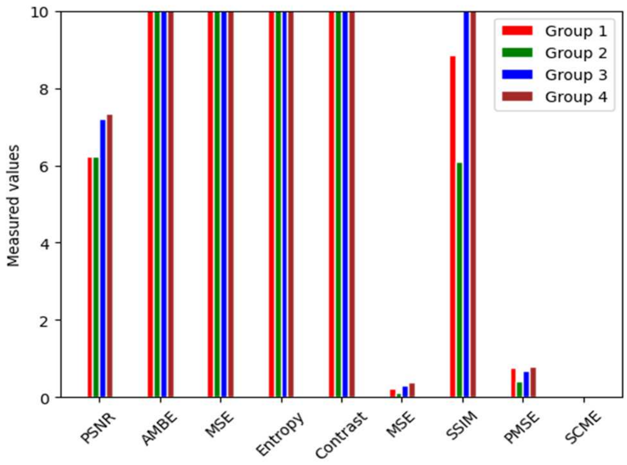

Fig. 14. Comparison Graph

From the figure 14 it can be inferred that Group 1 refers to Typical HE, Group 2 refers to Global HE, Group 3 refers to Local HE and Group 4 refers to CLAHE. It is clearly visible in the graph that CLAHE has better values for all the performance metrics used to measure the quality of enhanced image.

VI. CONCLUSION

In this research paper effort has been made to remove the speckle noise form the noisy echocardiographic image which is obtained from the ultrasound scanning. These speckle noise must be handled in better way for proper analysis of the image. We have used median filtering method to remove the speckle noise which is one of the most efficient methods for image denoising. The methods used for image enhancement and contrast enhancement are CLAHE, Typical HE, Global HE and Local HE which are variants of the HE used for contrasting image. It is mainly used for low contrast images. The result obtained from the experiments lead to further analysis of the image. The result obtained motivates us to do further study of the images so that we can derive at different analysis from different methods used to filter and enhance the image.

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