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Novel Method for Contrast Enhancement of Digital Images using Image Fusion

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***Abstract* – Image Fusion gives a new perspective for contrast enhancement in digital images. Here we combine several input images taken at different time and formed a contrast enhanced single image. Most of the enhancement methods are concentrated on either global or local details enhancement. So, here we select the global details from one of the input image and local details from other input image and combine global and local details in an image using pyramid decomposition. The proposed method is well suited in any kind of digital images, especially for medical images. Fusion of two X-ray images is performed and applies a wiener filter to the resultant image. The proposed methods performance is evaluated by comparing the edge content based contrast metrics with other existing methods.**

Keywords-Contrast Metrics; Edge Content based Contrast metrics; Image fusion; Luminance metrics

I. INTRODUCTION

Image processing is needed for removing noise and blur from images. In the field of medicine to evaluate or to examine the inner body parts different scanning techniques such as X-ray, MRI can be used. The X-ray scan can show the images of the hard tissues like bones clearly but it cannot show the images of the soft tissues clearly. So, usually images taken at different time and analysed it separately. It's time consuming and costly. Image Fusion is a method can combine several input images and form a single image. In the proposed method, performs histogram equalization and contrast limited adaptive histogram equalization in the X-ray input images and the resultant image is a contrast enhanced fused X-ray image .For this we define image enhancement parameters from histogram equalized and contrast limited adaptive histogram equalized X-ray image. Histogram equalization is a global technique for overall enhancement, but local details are not highlighted. While contrast limited adaptive histogram equalization is a local contrast enhancement method, it reduces the over amplification of noise present in the image. So by using image fusion we can take the advantages from both methods and better visibility is possible by passing it through an average filter. Contrast difference between images can be analysed by human visual system itself. But in some cases in addition to qualitative evaluation, quantitative methods also needed. So here we compare the fused image from the source image by calculating the edge content based contrast metrics.

II. CONTRAST ENHANCEMENT METHODS

Image enhancement methods are based on global and local techniques. Histogram equalization is a global contrast enhancement method which is suitable for entire enhancement of the image [4]. It can be graphically plotted as the number of pixels for each gray level. It improves the contrast in an image by extending the number of pixels. Image histogram transforms to another suitable intensity values by calculating the cumulative distribution function of the entire image. A contrast enhanced image histogram shows all the feasible values in the gray scale by better distributing the intensity. However, it reduces the quality of original image and produces noise. The proposed method calculates the histogram equalization of the input X-ray image. It shows bone structure in X-ray image clearly than soft tissues in X-rays. CLAHE operates on small regions in the image, called tiles, rather than the entire image [2]. Each tile's contrast is enhanced, so that the histogram of the output region approximately matches the histogram specified by the distribution parameter. The neighbouring tiles are then combined using bilinear interpolation to eliminate artificially induced boundaries. The contrast, especially in homogeneous areas, can be limited to avoid amplifying any noise that might be present in the image. The CLAHE algorithm partitions the images into contextual regions and applies the histogram equalization to each one. This evens out the distribution of used grey values and thus makes hidden features of the image more visible. The full grey spectrum is used to express the image. Contrast Limited Adaptive Histogram Equalization, CLAHE, is an improved version of AHE.

III. CONTRAST ENHANCEMENT PARAMETERS

Next step is to compute quality determining parameters of image such as luminance and contrast which helps to achieve best fused image. Higher details preserving areas in the image should receive greater weight and regions of image having lesser details receive lower weight at the time of fusion. Image enhancements parameters of histogram equalized and contrast limited adaptive histogram equalized image weight map are calculated by combining contrast and luminance using multiplication operation.

A. Metrics for Contrast

By increasing the contrast of an image, shadows become enhanced and thereby details and quality improves. Image can be mathematically represented as a two-dimensional function f(x, y). Then perform histogram equalization in the image 1 and adaptive histogram equalization in the image 2 where x and y are the row and column coordinates, respectively. The gradient of an image f(x,y) at location (x,y) can be defined as a laplacian two-dimensional column vector .

$$\nabla f = \begin{bmatrix} G_x \\ G_y \end{bmatrix} = \begin{bmatrix} \frac{\partial f}{\partial x} \\ \frac{\partial f}{\partial y} \end{bmatrix} \qquad (1)$$

Magnitude of the gradient is represented by the first order derivatives of image. By taking the absolute value of the image gradient $|\nabla f|$ gives contrast metrics and can be used for computing weight map. Magnitude of this vector is given by

$$|\nabla f| = \sqrt{G_x^2 + G_y^2}$$
(2)

B. Metrics for luminance

Contrast enhancement often results in a significant shift in the brightness of the image giving it a washed out appearance [4], which is undesirable. So luminance metrics is an important factor which helps to attain contrast enhanced fused image. Calculating the luminance metrics [1] of histogram equalized and adaptive histogram equalized image .The gray scale image luminance metric is calculated by using a Gaussian kernel K

$$K(f; m_0, \sigma) = \exp\left(-\frac{(f-m_0)^2}{2\sigma^2}\right)$$
(3)

where σ is taken as 0.9, K represents luminance metric and m_0 is the average pixel value of the original image.

C. Weight map Computation

By applying laplacian filter and calculating the absolute value of filter response of gray scale image, contrast of image can be achieved. By calculating Gaussian kernel we can find the luminance of image. Obtaining scalar weight map using contrast and luminance of histogram equalized and adaptive histogram histogram equalized image of X-ray. It will enhance boundaries and textures in the fused image. At the time of fusion composition area having similar details will give low values and the diverse region will give higher contrast values. It will enhance boundaries and textures in the fused image. At the time of fusion composition area having similar details will give low values and the diverse region will give higher contrast values. Weight map can be written as

$$W_{i,j} = (C_{i,j})^{\alpha} (K_{i,j})^{\beta}$$
(4)

α and ß are scaling exponents. C and K are contrast and luminance respectively. By properly selecting this we can achieve best fusion results.

IV. PYRAMID DECOMPOSITION

A. Gaussian and Laplacian pyramid

Seamless stitching can be possible by using pyramids without reducing as much data in the images and possible to avoid boundary artefacts by smoothing the blurred boundary. In the case of an image pyramid, is a collection of images. They are arising from a single original image that is successively downsampled until some desired stopping point is reached. There are two common kinds of image pyramids. We use Gaussian and Laplacian pyramid for getting the fused pyramid.

Gaussian pyramid can be generated by convolving the HE or CLAHE image with a Gaussian kernel and scaled down [3]. This is same as passing the equalized image to a low pass filter and sub sampling by a factor of two. So area reduces to one-fourth of original area. It creates a sequence of images like pyramids which are decreased down in its size and quality. That is scaling down decreases the resolution and we lose the information.

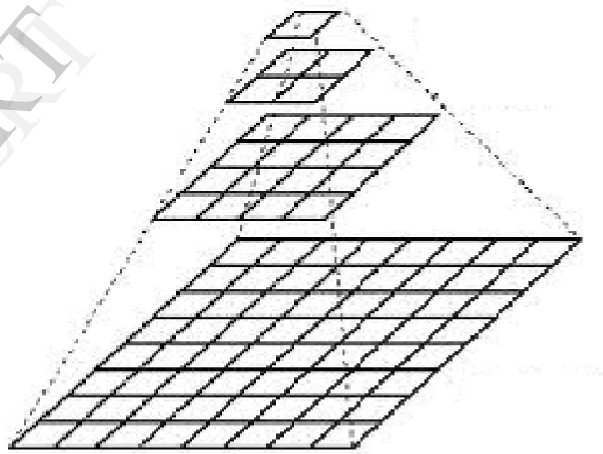

Fig. 1. The filtered images stacked one on top of the other to form a Gaussian Pyramid

The Laplacian pyramid can be obtained by subtracting the successive levels of Gaussian pyramid. This is same as convolving the Histogram equalized and contrast limited adaptive histogram equalized input image f_1, with a Gaussian kernel and then downsampled it to create a reduced version of input image f_2.Then subtract upsampled image f_2 from original image f_1. Further repetition of these steps generates the remaining Laplacian pyramid levels. Laplacian Pyramids are formed from the Gaussian Pyramids. Laplacian pyramid images are like edge images only. Most of its elements are zeros. level in Laplacian Pyramid is formed by the difference between that level in Gaussian Pyramid and expanded version of its upper level in Gaussian Pyramid.

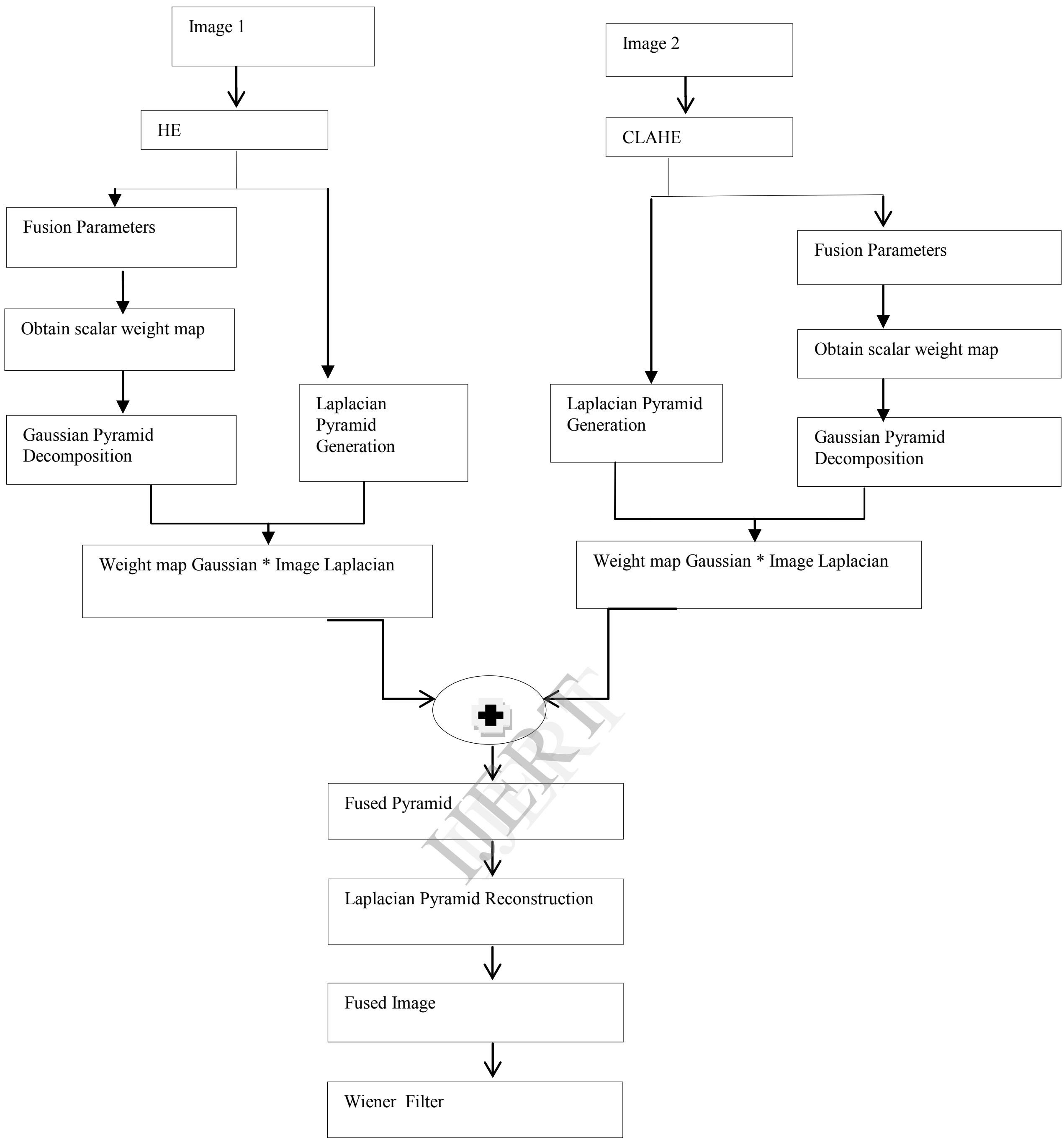

Figure 2. Block diagram of image fusion using pyramid decomposition

B. Image Fusion

The fused pyramid is constructed as a weighted average of the Laplacian decomposition for each level by weighting them with the Gaussian pyramid of the weight map. Each level of fused pyramid [1] of level l is calculated as a weighted average of equalized Laplacian pyramid with weight map Gaussian as

$$L\{F\}_{i,j}^{l} = \sum_{k=1}^{N} G\{W\}_{i,j,k}^{l} L\{f\}_{i,j,k}^{l} \qquad (5)$$

The image pyramid $L\{F\}^{l}$ is then collapsed to obtain the fused image F. Here takes two X-ray images of same person at different instants and fused them. By combining those X-ray images using pyramidal decomposition based fusion we can achieve a contrast enhanced image than source images. The goal of image fusion is to integrate complementary data from the input images. Composite pyramid is formed by taking the mean value of the multiplied Gaussian weight map and Laplacian pyramid. Image pyramid is then collapsed to restore the composite image as

$$G_k = L_k + \text{Expand}(G_{k+1}) \qquad (6)$$

Then, reconstruct image from the composite pyramid by applying Laplacian pyramid reconstruction. Expand function adds the number of columns and rows to each subsequent levels.

B. Wiener Filter

Wiener filter is a filter used to produce an estimate of a desired random process by linear time invariant filtering of an observed noisy process. Wiener filters suppress the frequency components which have been degraded by noise. The wiener filtering is optimal in terms of the mean square error. It minimizes the overall mean square error in the process of inverse filtering and noise smoothing. It is a linear estimation of the original image. So it can be used in image processing to remove noise.

V. RESULTS AND DISCUSSION

The performance of the proposed method can be evaluated using visual assessment and calculating some quantitative measures such as edge content based contrast metrics.

The EC [1] accumulates all the contrast changes giving a quantitative measure for contrast enhancement achieved by different algorithms. The purpose of detecting sharp changes in image brightness is to capture important events and changes in the edge contents. Thus, the proposed metric accumulates the contrast changes, as perceived by the human observer to get a quantitative measure of the contrast enhancement achieved by different algorithms. The values of the EC for the original and enhanced tire images are given in Table 5.1. We see that EC gives an objective measure of the detail enhancement. Highest value of EC corresponds to the Adaptive histogram equalized image. In a metric edge content (EC) is used to estimate the blur in image for the multi-focus image fusion problem. The pixel values, or contrasts, in each contrast image were compared to the threshold value measured in the contrast sensitivity test corresponding to the appropriate frequency. The images obtained by this process are called threshold images, and are added together along with the lowest frequency component to complete the simulation. The resulting image is representative of what a person with a particular threshold response would see when looking at an image. Thus applying an edge detection algorithm to an image may reduce the amount of data to be processed and may therefore filter out information that may be regarded as less relevant, while preserving the important structural properties of an image. Edge detection methods rely on the computation of image gradients and filtering out the images.

Table 5.1: Comparison of Edge Content for proposed method and existing methods

IMAGE	Edge Content
Input Image 1	.0323
Input Image 2	.0318
HE	.0432
AHE	.0691
Fused Image	.0521
Proposed Method	.0591

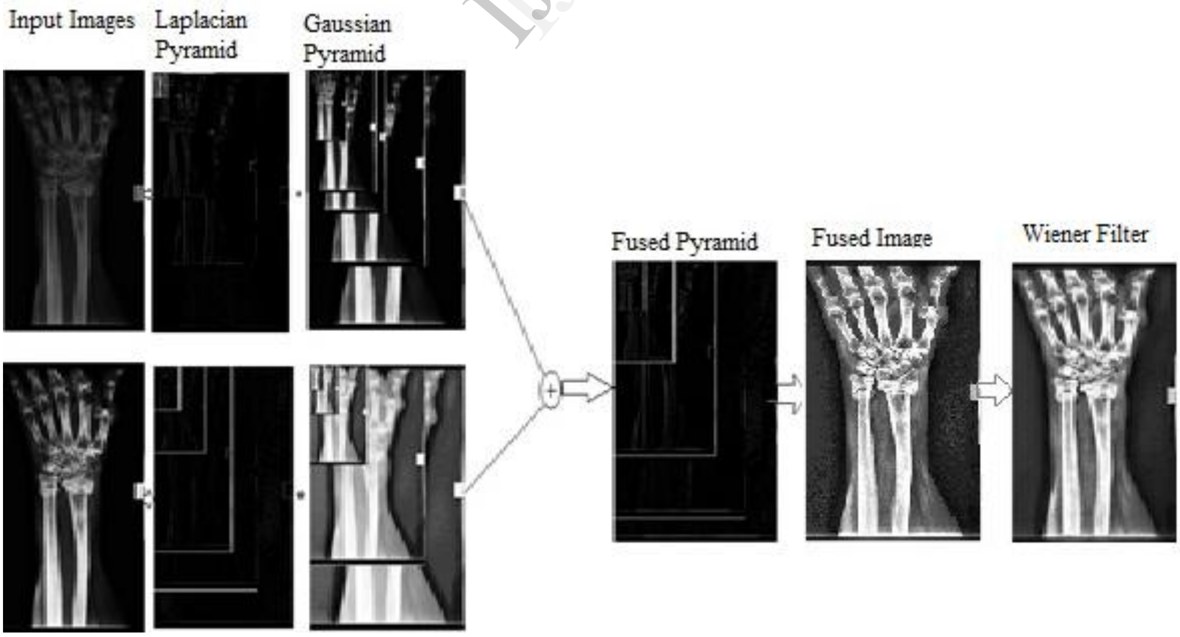

Fig. 3. Overview of Image Fusion simulation results using Pyramid Decomposition

V. CONCLUSION

Here presents a novel method for contrast enhancement of digital images using pyramid decomposition. It is a simple method and well suited for remote sensing and medical image processing applications that demand images with high quality. The proposed method fuses two X-ray images of same person taken at different time and the resultant image has better contrast enhancement. Greater contrast enhancement is achieved by passing the input images through HE and CLAHE algorithm. By passing the composite image through wiener filter, we can reduce the mean square error. The quality of the fused image can be evaluated using quantitative measures such as edge content and subjective perceptual image quality evaluation.

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