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A New Approach for Medical Image Fusion Based on Laplacian Pyramid and GA

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Abstract: Medical image fusion is a process which is used to minimize the redundancy while increasing the required information from input images acquired from different medical imaging sensors. Thus, the primary factor of fusion is to acquire a single enhanced and more informative image which can be employed for efficient analysis. This paper presented a hybridization approach used for medical image fusion. Initially, Laplacian Pyramid technique is utilized to extract the relevant features from set of images followed by resize operation. Afterward, Genetic Algorithm based upon swarm intelligence approach has applied over the extracted feature image for fusion. So as to ensure the efficiency of the proposed work, quantitative analysis of fused image is carried out under different performance metrics such as Entropy, Standard Deviation, Peak Signal to Noise Ratio, Structured Similarity and Measure of enhancement using MATLAB software. The experimental study concludes that proposed LP-GA approach outperforms the traditional techniques in terms of high quality and less noise.

Keywords: Medical Image Fusion, Laplacian Pyramid, Genetic Algorithm, DWT techniques, Fusion Metrics.

I. INTRODUCTION

Bringing together two or more than two images into a single and developing a more enhanced image is a technique of Image fusion. This is done for the purpose of obtaining more enhanced or meaningful image so that effective decision making can be done with the help of the fused image. In layman, the image fusion can be defined as a process which combines the two incomplete images in order to form a complete one. Sometimes, we have more than two images and all of them are lacking somewhere, thus storing all of such images will consume large memory space and almost all of the images does not consist relevant information exclusively, in such cases the need of image fusion arises [6], thus the concept comes to the existence. The process of image fusion commences by introducing two images as input and then these input images are extracted to a single image by implementing suitable fusion technique which consists of all of the meaningful content of the image that was original. The problems of memory area consumption in excess and incomplete meaningless images are solved by the image fusion [7].

The principle of image fusion is to maintain the enrich section of the image. The meaningful information of the image can be preserved by associating multiple images. On domain of the input images, there are no constraints or limitations. The input image can be related to multi focus, multi sensor or other domains [8]. The image below defines the example of image fusion. As there are two images which is not clearly visible in the figure 1, one is blurred from right angle and other is blurred from left angle.

(a) Right Focused Image *(b) Left Focused Image* *(c) Fused Image*

Figure 1. Image Fusion Process

By fusing both images, the final fused and more enhanced image is acquired. Moreover both of the images are incomplete also, as they contain some sort of irrelevant or noisy data in the form of obscure regions. The visual notion of above images is not clear. Hence the need of image fusion arises in this case. After combining the relevant segment of both of the images, the following fused image is obtained with striking or visible notion and worthwhile information [9].

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II. PROBLEM FORMULATION

Image fusion is the process that combines information from multiple images of the same scene. These images may be captured from different sensors, acquired at different times, or having different spatial and spectral characteristics. There are various type of methods for image fusion, earlier the image was fused directly by combing the pixels of the image but that result in blurring of the fused image. In direct pixel combining method, the source image and the neighbor images are combined with the corresponding pixels of both the images. The defined weights of the images are merged into an image. The pixels of the new image are generated on the basis of the average weight of pixels of that image. HSI is another method used for image fusion but the limitation of this method is the involvement of only three bands. Then DWT method came into existence that is also known as Discrete Wavelet Transform. The DWT gave improved results than the conventional methods like it had good spectral preservation but it also had certain drawbacks which limited its use in image fusion. The spatial improvement after applying DWT was poor and it had high shift invariance that reduced the efficiency of the system. In Several situations image processing requires high spatial and high spectral resolution in a single image. Wavelet fusion technique also induces small distortion. But all these method were not efficient.

An efficient technique needs to be implemented for image fusion that is more efficient than the conventional techniques and a high spatial and high spectral resolution image should be obtained after fusion.

III. PROPOSED WORK

The major problem in image fusion is the selection of technique that will perform image fusion, as there are various methods available so there is a need to find the best method that will fuse the image without any loss of edges or data. The images obtained after fusion should be highly spatial and should have high resolution. The techniques when applied at single level did not produced image of the required quality. Some drawbacks were overcome but then arose some other problems so it was thought of implementing two or more techniques together. Implementing a hybrid technique for fusion produced better and efficient results than the techniques when implemented at a single level. In this fusion methods, two techniques of wavelet fusion and LP i.e. Laplacian Pyramid are combined and a new hybrid approach is proposed for image fusion. The images are first applied the technique of swarm intelligence and then the fused images with these techniques undergo fusion using LP technique. The problem of high shift invariance is resolved using this hybrid approach. The images obtained are of high spatial and high spectral resolution.

This hybrid technique of mage fusion is considered to be better than the previously used techniques. The results obtained are better, efficient than the conventional techniques.

The methodology of proposed work has been divided into two figures. In the first figure, the proposed methodology has been explained and fusion process used in the figure 4 explained in the figure 5.

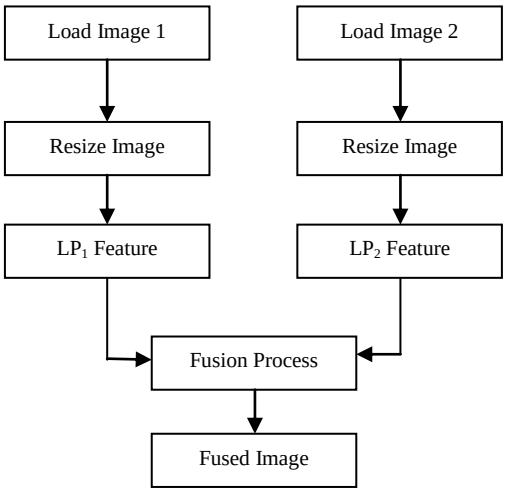

Figure 2 Proposed Methodology

In this methodology, the following steps are taken to perform fusion.

1. Initially, two different images are loaded taken from different perspective and requires improvement.
2. Then images are resized for the purpose of normalization.
3. After resize, the LP features are extracted from individual image.

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4. Lastly, fusion is performed using LP extracted features of two different images to form a single enhanced image. In the proposed work, Genetic Algorithm has been used for the process of fusion.
5. Finally the fused image is acquired.
6.

3.1 Fusion Process

For the purpose of image fusion, Genetic algorithm is used. Genetic Algorithm helps in finding the reasonable solution for a complex problem while searching through a large as well as complex search space. The methodology follows to find the solution for a fusion is as follows:

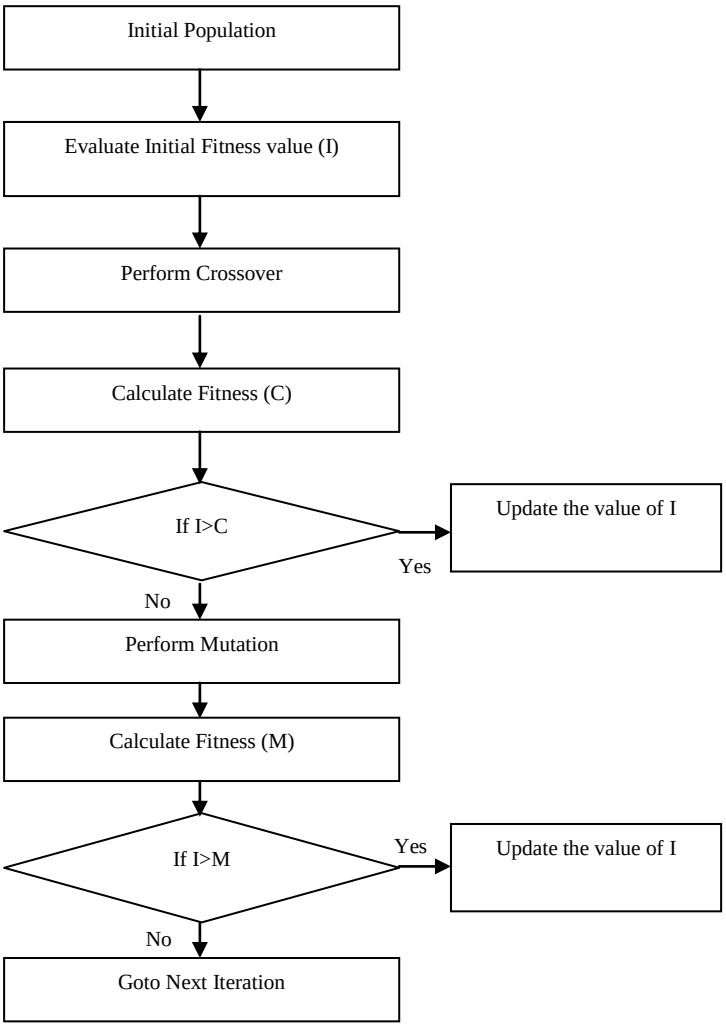

Figure 3 Methodology of Fusion Process.

1. Calculate the initial population i.e. Weight value. The initial population pointing to the initial solution taken to proceed for further evaluation.
2. Then calculate the initial fitness value and update it frequently until appropriate fitness value is not acquired.
3. Perform Crossover operation. Crossover is considered as a genetic operator which is used to produce new population for random solution. Thus, crossover has performed to acquire new fitness value.
4. Then compare acquired fitness value C with initial fitness I. If initial fitness value is greater than C then update initial fitness in else case Perform mutation to further update the fitness value.
5. Perform Mutation process in view of acquiring the new solution. It is also considered as a genetic operator to produce a new solution of appropriate size.
6. Again compare fitness value acquired from mutation process with the initial fitness value I. If initial fitness value I is greater than fitness value acquired from mutation M then update initial fitness value otherwise continued the process from crossover until a best solution is not find out.
7. Go to step 3 and repeat until best solution is not acquired.

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IV. EXPERIMENTAL ANALYSIS

The simulation analysis has been performed using proposed and traditional wavelet approaches. For the comparison purpose different versions of discrete wavelet techniques has been taken. The performance parameters such as Entropy, STD, PSNR, SSIM and EME are taken into consideration for evaluation of both techniques. These parameters assist the user to estimate the performance of individual approach. The acquired results are shown in the below section with the brief introduction of different performance parameters.

4.1 Fusion Metrics

The fusion metrics explained the performance of fusion techniques. In order to evaluate the objective of fused image below metrics are used:

1. Entropy (E):

The entropy parameter is used to describe the information content in an image. The equation used for the evaluation is as:

$$E = \sum_{L=0}^{L-1} P_l log_2 P_l \text{.....(1)}$$

2. Standard Deviation (STD):

Another parameter considered for the evaluation is SD. The higher standard deviation value signifies better contrast in the gray levels of the image. The equation used for the evaluation is as follows:

$$STD = \left(\frac{1}{m*n}\sum_{l}^{m}\sum_{l}^{n}(f(n,m)-\mu)^2\right)^{1/2} \text{.....(2)}$$

3. Peak Signal to Noise Ratio (PSNR):

This parameter is used to approximate the reconstruction quality. Thus, the value of this metrics should be high which indicates that reconstruction is of higher quality. Consequently, PSNR value must be high in order to acquire better fused image. The equation used for the formulation is as follows:

$$PSNR\ (dB) = 10log_{10}\frac{(2^{r-1})^2}{MSE} \text{.....(3)}$$

4. Structured Similarity (SSIM):

The Structural similarity index is a parameter used to identify the similarity between two different images. It is a method of predicting perceived quality of digital images as well as videos. The higher SSIM value identifies the preservation of luminance and structural content. The equation is as follows:

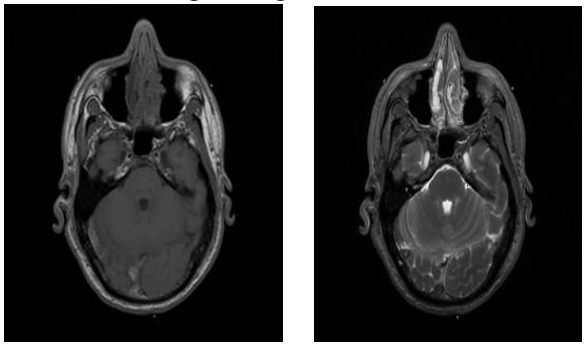
$$SSIM = \left(\frac{\sigma_{xy}}{\sigma_x\sigma_y}\right)\left(\frac{\overline{2xy}}{(\bar{x})^2+(\bar{y})^2+K_1}\right)\left(\frac{2\sigma_x\sigma_y}{(\sigma_x)^2(\sigma_y)^2+K_2}\right) \text{.....(4)}$$

5. Measure of Enhancement (EME):

This parameter is used to assess the degree of contrast improvement in the fused image. The formulation of EME is done as:

$$EME = \frac{1}{K_1K_2}\sum_{m=1}^{K_1}\sum_{l=1}^{K_2} 20\ln\left(\frac{I_{max}^{l,m}}{I_{min}^{l,m}}\right) \text{.....(5)}$$

The simulation results acquired from the proposed technique including comparison with the traditional techniques has been shown below. In order to perform Image fusion, two blur images are taken to form a single enhanced image. The simulation analyses are performed on medical images using MATLAB.



(a)First Image (b) Second Image

Figure 4 Input Images

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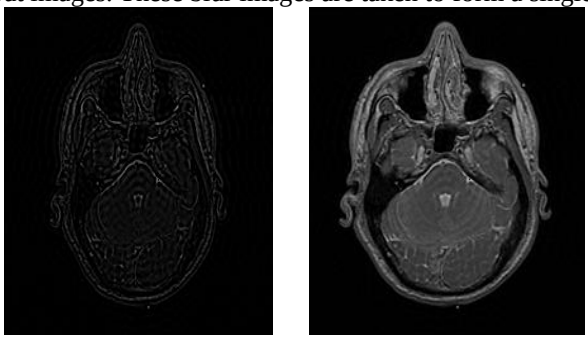
The figure 4 depicts two blur input images. These blur images are taken to form a single enhanced image.



(a)Initial Fused Image (b) Final Fused Image

Figure 5 Fused Images

The figure 5 shows the fused images. In the figure two different fused images are shown. The first image depicts the fusion at initial stage and then after process ends final fused image is acquired shown in the figure 7 (b).

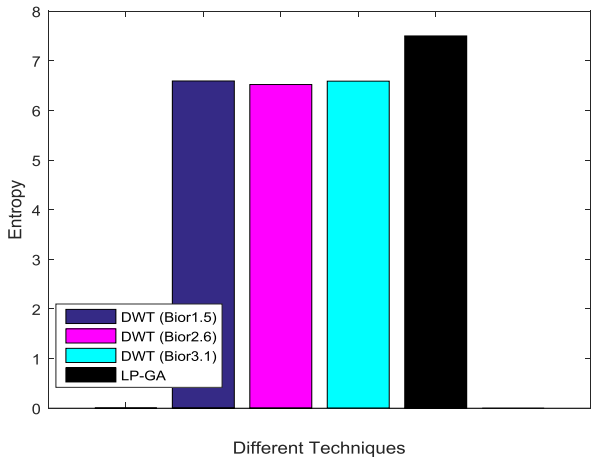


Figure 6 Comparison of traditional and proposed technique in terms of Entropy

The figure 6 exemplifies different techniques i.e. proposed and traditional technique in terms of Entropy performance parameter. This parameter's value should be high in order to acquire better fused image. Considering this fact, three traditional wavelet techniques such as DWT (Bi-orthogonal 1.5), DWT (Bi-orthogonal 2.6) and DWT (Bi-orthogonal 3.1) with respect to proposed LP-GA has been performed. In comparison with traditional techniques, proposed technique outperformed.

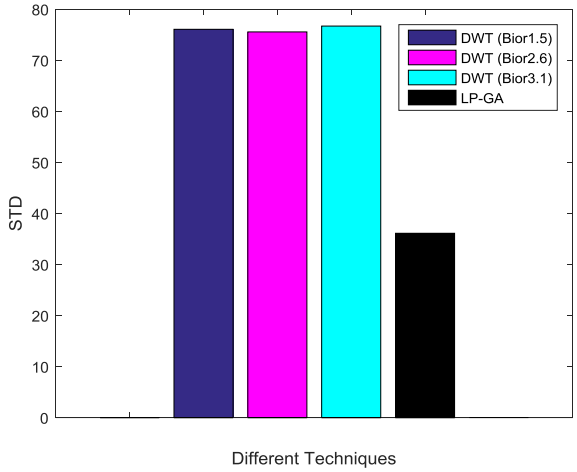


Figure 7 Comparison of traditional and proposed technique in terms of STD

The figure 7 depicts the performance of traditional and proposed technique. From the comparison, it has been concluded that proposed technique performs efficiently in terms of different traditional techniques. Standard deviation

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value should be minimum and likewise proposed technique produces thrice minimum value from traditional wavelet approaches.

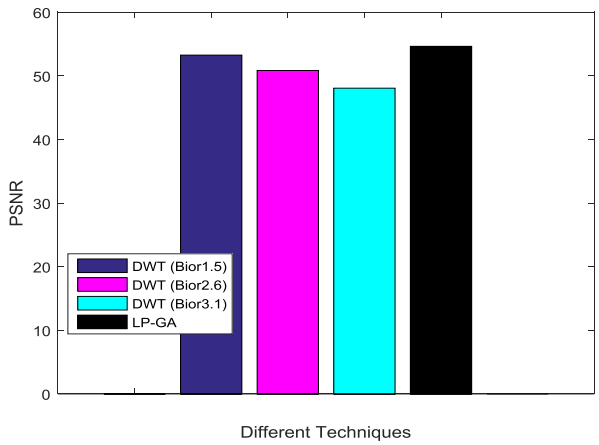

Figure 8 Comparison of traditional and proposed technique in terms of PSNR

The PSNR parameter has been exemplified in the figure 8. From the results acquired, it has been concluded that proposed technique produces efficient results and produces high PSNR value. Moreover, the maximum value of PSNR confirmed less noise in the fused image.

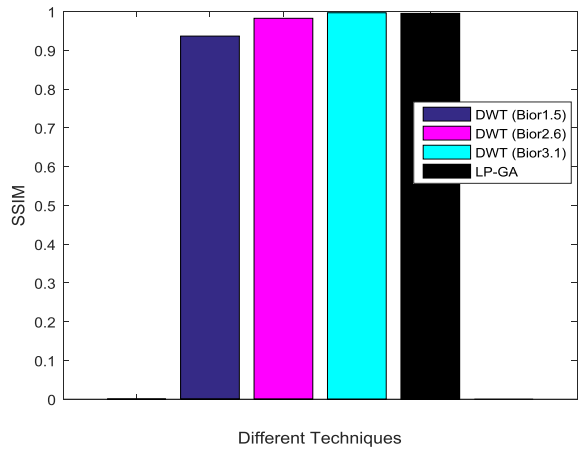

Figure 9 Comparison of traditional and proposed technique in terms of SSIM

The figure 9 depicts the performance of different wavelet traditional techniques and proposed LP-GA approach. Among different wavelet approaches, DWT bior 3.1 shows significant increase and produced highly similar image. Even though proposed technique shows high level of structured similarity and resides at 0.9997 values.

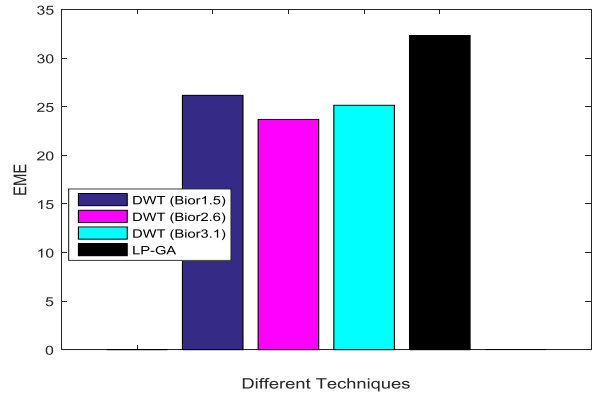

Figure 10 Comparison of traditional and proposed technique in terms of EME

EME shows the contrast improvement in the fused image. The amount of EME depicts the high or low performance of the projected technique. Among different techniques, proposed technique performs significantly efficient and enhanced the contrast of the fused image. The comparison table 1 concludes that proposed technique outperformed the

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traditional technique in terms of entropy, STD, PSNR, SSIM and EME. The entropy value of proposed technique i.e. 7.50 is maximum in comparison with traditional techniques such as 6.5931, 6.5211 and 6.5895 respectively for DWT Bior 1.5, Bior 2.6 and Bior 3.1. Correspondingly, other parameters are evaluated such as STD of proposed technique is minimum which actually should be, PSNR, SSIM and EME is high respectively. Thus, proposed technique is superior than other traditional techniques which produce high quality fused images.

Table 1 Comparative analysis of different image fusion techniques in terms of performance metrics

Parameters	DWT (Bior 1.5)	DWT (Bior 2.6)	DWT (Bior 3.1)	Proposed LP-GA
Entropy	6.5931	6.5211	6.5895	7.50
STD	76.0538	75.5451	76.6891	36.0980
PSNR	53.2776	50.8648	48.0801	54.6589
SSIM	0.9367	0.9826	0.9968	0.9997
EME	26.1722	23.6925	25.1475	32.3243

V. CONCLUSION AND FUTURE SCOPE

Image fusion is considered as a process that combines two blur images to form a single enhanced image. There are several wavelet based techniques have been developed. However, these techniques have been suffering from several issues such as low quality image and high noise in the acquired image. Considering a novel approach has been proposed in this work. Initially Laplacian Pyramid approach is used to extract the features from set of images and then Genetic Algorithm is applied to acquire optimum solution for the process of fusion. The performance of proposed approach is computed under MATLAB software. From the simulation analysis, it has concluded that proposed technique outperformed the traditional technique in terms of different performance parameters such as Entropy, Standard Deviation, Peak Signal to Noise Ratio, Structured Similarity index and Measure of Enhancement. The proposed technique in every aspect performs significantly in comparison with traditional approach. Furthermore, the acquired fused image from proposed technique is of high quality with less noise. Additionally, the fused image generated through the proposed technique is highly similar to the original image that shows the optimality of the LP-GA technique.

The proposed technique has been exemplified on CT scan and MRI images. In future, the proposed technique can be extended to PET medical images to understand its performance. Moreover, a single optimization technique has applied over the proposed work for better output. More than one optimization algorithm can be used for advanced results in future work.

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