A CONTRAST ADJUSTED WAVELET AND CURVELET TRANSFORM BASED FUSION OF BREAST IMAGES

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ABSTRACT: Restoration is one of the image processing techniques to restore the distorted image. The distorted image can be any type like blurred image, noise added either while storing or capturing of the images. the traditional restoration techniques are geometric correction, different types of filters to remove the noises. Generally, the restoration is applied to the single image to retrives its information. In this, the restoration process is applied in the application of image fusion of medical images. the reason to chose the image fusion process is to improve its entropy. The medical images used in this paper is the mammogram and MRI-breast image. In this, the image fusion is performed with the help of wavelet and curvelet transform. The curvelet transform is applied to the restored mammogram image with the help of contrast adjusted top-hat filter process. The wavelet transform is applied to the MRI image because it has more volume of data to acquire important details. The fused image is evaluated with the help of entropy, mean standard deviation and variance. The fused image has efficient value as compared to its original image but it is higher than the DTCWT-fused image. To verify the quality of the proposed method, the psnr is evaluated to determine the noise present in the image. From the evaluation, the noise is less and entropy is higher in the proposed method. Hence, the contrast adjusted wavelet curvelet fusion is the best restoration and fusion process in the breast images.

Keywords: restoration, x-ray, mri, breast image, wavelet, curvelet, top hat filtering, evaluation metrics.

Introduction:
In recent days, the analysis of images are performed with the help of machines prior to the human observation. To support such an observation, the imaging system should be highly processed one to capture the image noise and blur free. But, it is not that much possible due to the motion of the human especially in the medical imaging systems.

In such a medical imaging method, the noise is obtained from the human interventions or the initial error in the machine manufacturing. To overcome this problem the image has to be enhanced which is performed by different process namely filtering, enhancement of the contours and contrast, and fusion process. All these process are to improve the low resolution images into high resolution images [12]. The two dimensional images such as x-ray the image restoration is performed with the help of filters like mean, median and weiner filters. [16]. The three dimensional images like MRI the image enhancement is performed with the help of multi level resolution and adaptive smoothing [17].
The contours are enhanced with the help of transformations like contourlet, curvelet and active contour transform to detect the edges. The contrast is enhanced with the help of the histogram equalization process. The histogram is the count of the pixel values. By adjusting the histogram bins the contrast is enhanced. The portable devices using converters and filters [20]. The other approach for the contrast enhancement is the multiscale resolution and transformation with the help of transforms like wavelet, cosine and KL transforms. The image fusion is done by combining the two or multiple images into a single image. the single output image has more details than the input images. the fusion is done either directly on the images or the transformed images. the fusion process can be performed in the window based or pixel based manner. Mostly, the pixel based fusion is preferred due to its easily applicable and increase the entropy of the fused image. The major pixel level fusion methods are multi scale decomposition, sparse representation, different transforms and non- transforms method. The restoration process is evaluated with the help of statistical parameters like entropy, mean and so on. The visual quality of the image is evaluated using peak signal to noise ratio, mean square error and structural similarity index. This paper proposed a new restoration approach to enhance the image along with the higher details of the abnormalities of the breast cancer in the image with the help of fusion. The paper is organised by explaining the related works of the paper in section 2, the detailed explanation of the proposed method in the section 3, the implementation and evaluation is explained in the section 4 and it is concluded in the section 5.

Literature survey:

[2] paper described about the two types of image restoration techniques namely model based optimization and discriminative based restoration. Both the methods are able to restore the image but it requires larger time for operation in model based optimization and designed for specific range of applications in the discriminative based method. to overcome this, they introduced a CNN based method to design the denoiser prior to the model based optimization approach to remove the noises and restore the images. This method able to remove the noise faster but it require large set of data for the prior noise information. [3] surveyed about the pixel level image fusion and its advantages in various applications like medical imaging, surveillance, remote sensing etc., the main advantage of this type of fusion is it able to combine multiple images into a single image. The fused image will have more information as compared to the individual input images. this information is helpful for the interpretation or machine. The major pixel level fusion methods are multi scale decomposition, sparse representation, different transforms and non- transforms method. [4] explained about the necessity of the registration and fusion process in the medical images. both the process can be used individually or in the combined form in the medical images. these process helps the practioner to diagnose the disease and analyze the images easily in various domain. In registration, the image in one domain is registered to another target image to improve the visibility of the image. In fusion, the multiple images are combined to improve the information of the image.

[5] defined an approach of image fusion using cross bilateral filter. In this , the one image is used for the kernel finding and the other is for the filtering process. The fused image is formed with the help of weighted averaging method. Its advantage is to improve the smoothness and edge enhancement. But, it suffered when there is no gray scale differences.

[6] implemented the deep learning network to improve the pixel level image fusion process. The deep learning methods such as convolution neural networks, auto encoders and so on. The deep learning helps to increase the number of images and multi scale and multi focus transformation. [7] explained about the pixel level image fusion methods and its evaluation metrics. [8] implemented a new approach called plug and play which perform fusion using the denoising. In this, the denoising is applied in the form of black box method. the fusion of images in one of the following methods by sharpening or blurred noisy images. its drawback the fused image quality little bit lower as compared to other techniques due to the noisy fusion.

[9] explained about the image restoration of MRI brain images using the histogram based weiner filter. The coefficients of weiner filter is designed with the help of the histogram bins of the image. It is mainly designed to remove the impulsive noise in the image.

[10] explained about the image restoration techniques on natural images, satellite images and medical images. the filters considered for the analysis are the mean, median, weiner and gaussian mixture model with wavelet. Each filter able to noiseless image by filtering the noises like salt and pepper, poisson and gaussian noise. For the speckle , weiner is best. Salt and pepper and gaussian noise is removed with the help of mean and median filter in medical images.
explained about the image enhancement using optimized wavelet masking. The optimization used in this process is the enhanced cuckoo search with the help of genetic algorithm. The image is enhanced by combining the wavelet coefficients and enhanced cuckoo search algorithm coefficients.

**Proposed methodology:**
In this, the restoration of the image is performed in the fusion application. The fusion process to improve the information in the fused image. To perform the restoration, the images are processed with the two types of filters namely top-hat filtering and MSE- filtering. Then, the fusion process is performed to produce the new fused X-MRI image. The detailed explanation of fusion process is shown in the block diagram.

![Block diagram of the proposed method](image)

**Input image:**
The input images are the x-ray and magnetic resonance image of breast part. The x-ray of the breast image is called mammogram which is used for earlier testing method to detect the early signs of breast cancer. The Magnetic resonance image of the breast is to support the mammography and to detect the level of abnormalities in the breast. In this, both the images are fused to improve the analysis of breast cancer and help the physician.

**Pre-processing:**
Pre-processing is the basic step in all the image processing applications to improve the quality of the image. In this, the pre-processing steps are resizing the size of the images into m*n pixels of size m and n equal to 256. The resized images pixel values are converted between 0 and 1 using gray scale conversion. The converted images are processed separately with two separate filtering process namely top-hat filtering and MSE-filtering.
Where R, G and B are the corresponding pixel values in the image of (m*n).

**Top-hat filtering:**
In this, the contrast of the image is adjusted with the help of morphological operations called opening and the subtraction of opening of the image from the image. The opening process is done with the help of structuring elements called diamond of width 10. It main purpose to brighten the foreground brighter pixels as compared to the background pixels. Due to this reason, the tophat filtering is applied to the x-ray image to brighter its pixels.

\[ THF_{image} = Gray_{image} - imopen(Gray_{image}) \]

**MSE filter:**
In this, the mean square error of the original image and noiseless image is reduced in the process of inverse filtering. It preserves the texture properties of the image. Hence, the MRI breast image is subjected to this filtering to preserve its depth of the abnormalities in the image. The noiseless image is obtained by the linear estimation and its orthogonality principle is given below:

\[ M(I_1, I_2) = \frac{H^*(I_1, I_2)S_{xx}(I_1, I_2)}{|H(I_1, I_2)|^2S_{xx}(I_1, I_2) + S_{yy}(I_1, I_2)} \]

Where S indicates the power spectra of the original and noise. H denotes the value of the blurring filter.

**Wavelet transform:**
Wavelet transform is the shorter form of waves like fourier transform which starts and ends rapidly. Due to this shorter period, it able to differentiate in the time and location. The shifting factor of the wavelet helps to make the waves as finite which helps to capture the inner details of the image. The scaling factor helps to stretch or decrease the waves frequencies. The scaling of different types of wavelet transform is shown in the below figure.

![Fig.2. Scaling of wavelet transform](image)

The wavelet transform exhibits a property called isotropic which helps to analyze in the directions like vertical, horizontal or diagonal in a given level. But it is not able to capture the edges of the image. based on the frequency of the wavelet, the classification of wavelets is shown in the below figure.
These wavelets are able to capture the finer details that is the depth of the pixels in the image. Due to this, the MRI and X-ray is subjected to wavelet transform. In the above wavelet families, the daubechies wavelet produced the best result due to its scaling and translation property which helps to increase the entropy as compared to the other wavelet families. By wavelet domain theory, the larger magnitude wavelet coefficients are important image data and smaller magnitude coefficients are considered to be insignificant image data. Also, small image details are more observable at finer scales. The fine details may be preserved in an image by exploiting the dependencies between two adjacent scales called inter-scale dependency and the correlation among the wavelet coefficients in the same scale is called intra-scale dependency. If the sub-bands at various scales are of the same size it is possible to find inter-scale dependencies also.

A suitable DWT (Discrete Wavelet Transform) is used to decompose the noisy image into the required number of levels. Each level consists of one approximation level LL and the other three details of the image LH, HL, and HH. Always the number of coefficients in all the levels is equal.

**Curvelet transform:**
Curvelet transform is the extension of the wavelet transform to represent the edges in the images which is not able to describe by the wavelet transform. The first level of the curvelet transform is not able to observe the edges as effectively. To overcome this the second level of the curvelet transform is introduced. [18]
The special property of the curvelet is able to differentiate the directions in each partitioning which helps to exhibit the anisotropic nature. This property is absent in the wavelet transform. The another special property of this transform is the width of the curve is directly proportional to the square of the length of the curve. Due to this property, the two dimensional X-ray image is subjected to curvelet transform to capture the abnormalities in the image. Whereas the Magnetic resonance breast image is not subjected because its volume and its nature of exhibiting the level of abnormalities in the wavelet transform itself.

**Fusion process:**
The fusion of the transformed X-ray and MRI images are performed in the pixel level domain. The method used for the pixel level is the mean value of the two images. The mean value is chosen to improve the information that is the level of abnormalities of the breast image. this method improves the entropy of the image.

![Image](image.jpg)

**Fig.5. Second generation curvelet.**

**Experimental Results and discussion:**
The proposed method is tested on the openly available x-ray and mri breast images of the same person in the google. The proposed methodology is implemented with the help of Matrix laboratory software using version R 2018a. It is run in the windows 10 environment. The following figures are the output of the processing of x-ray images.
Fig. 7. 2 X-ray image

Fig 8. Gray scale and top-hat filtered image
The above figures are the output of the restoration of x-ray images for the fusion. The following figures are the restoration of MRI breast images.
In MRI, the wavelet transform is only applied to the image to preserve the level of abnormalities in the breast which is helpful in the fusion to hold more information of the breast. The below figure is the mean based pixel fusion of the transformed x-ray and MRI images.

The fused image is evaluated with the help of some statistical calculations based on the pixel values as follows:

- **Entropy**
  The entropy is used to define the information present in the image using the pixel values of the histogram bins. For a good image, the entropy value should be higher.
  \[ E = - \sum p \log_2 p \]
  
  The \( p \) indicates the normalized histogram bin values.

- **Mean**
  The mean of the image is to define the quality of the image based on the mean difference between the pixels. The mean value will be low for the good quality image.
  \[ M = \frac{1}{n} \sum_{i=1}^{n} (x_i - y_i)^2 \]
Where $x_i$ is the original image and $y_i$ is the denoised image. $n$ is the number of pixels.

- **Standard deviation and Variance**
  The standard deviation and variance is used to differentiate the pixels of different class. For the image fusion application, these values should be low.

  $$s = \sqrt{\frac{1}{n-1} \sum_{i=1}^{n} y_i - M}$$

  Where $y_i$ is the denoised image and $M$ is the mean of the image.

  The variance is the square of the standard deviation.

  $$v = s^2$$

  These four values are tabulated in the table for the proposed method and it is compared with the existing method and original images to evaluate the proposed method. The mean of the proposed method is high because the fusion is based on the mean value of the pixels of the images.

| Entropy | Mean    | STANDARD DEVIATION | VARIANCE (*10^3) |
|---------|---------|--------------------|-------------------|
| X-RAY   | 6.8925  | 63.3174            | 67.4471           | 4.5491         |
| MRI     | 7.2348  | 71.4178            | 68.1574           | 4.6454         |
| RES-DTCWTFUSED IMAGE | 7.5127 | 39.9991            | 40.3455           | 1.6278         |
| Contrast-adjusted WTCT | 7.6843 | 69.5942            | 56.3199           | 3.1719         |

Even though, the mean and standard deviation is high the noise present in the image is less as compared to the traditional method. The mean value is higher because the fusion is based on the mean value of both the images. Due to this, the mean value is high which helps to improve the entropy. The reason for high entropy and less noise is due to the top-hat filtered curvelet transform. The daubechies wavelet family transform produces the best result with the average entropy of 7.5. The proposed method is better than the existing method is proved by the evaluation of the noise in the image. To evaluate the noise, the peak signal to noise ratio is used and it is calculated as follows:

- **Peak signal to noise ratio:**

  The PSNR value is to estimate the quality of the image after the removal of noise. For a noiseless image, the psnr value should be high.

  $$PSNR = 10 \log_{10} \frac{M^2}{mean \ square \ error}$$

  The $M$ indicates the maximum intensity of the image and the mean square error is calculated from the mean of the image.

| Method                | psnr   |
|-----------------------|--------|
| RES-DTCWTFUSED IMAGE  | 14.19  |
| Contrast-adjusted WTCT| 16.2651|

From both the tables, the proposed method achieved the best result irrespective of its higher mean in both the fusion and image restoration. For the fusion process, the proposed method produced the higher entropy and in the restoration the psnr value is improved. Hence, the proposed Contrast-adjusted WTCT is suitable for the image restoration and fusion process.

**Conclusion**

The image restoration is an important process in the field of image processing. This process is to improve the quality of the image which helps the analyst to analyse the image effectively and efficiently. The paper described
about the various restoration process earlier implemented in the medical field. Based on the analysis, a new restoration approach is proposed using filtering and transformation techniques. The filtering process helps to remove the noise in the image. The transformation helps to extracts the level of abnormalities in the breast. The mean-based pixel fusion helps to improve the entropy of the image. The proposed method is having the higher mean value but the level of the noise is reduced as compared to the existing method. Hence, the proposed Contrast-adjusted WTCT is suitable for the restoration and fusion process in the breast imaging. In future, the restoration is improved with the help of unsupervised learning network for the online fusion of images.

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