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Improved Curvelet Transform Fusion Using Sobel Edge Analysis

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***Abstract*—** The Image fusion is a data fusion technology which keeps images as main research contents. It refers to the techniques that integrate multi-images of the same scene from multiple image sensor data or integrate multi images of the same scene at different times from one image sensor. In this project we put forward an image fusion algorithm based on an innovative way to combine edge detection and linking using curvelet transform. Both the outputs are fused to obtain the final fused image. Finally, the proposed method was compared with the output of curvelet transform and edge detected output. The experiments show that this method could extract useful information from source images to fused images. Experiments show that the fusion image effectively improves the accuracy of edge detection and gets a quite ideal edge detection effect.

***Keywords*—** Fused image, Fusion rule, Curvelet transform, Edge detection, Sobel operator.

I. Introduction

With the advancement in the field of sensing technology, we obtain images in more possible ways, and the image fusion types are developed, such as the Image fusion of same sensor, the multi-spectral image fusion of single-sensor, the image fusion of the sensors with different types, and the fusion of image and non-image. They find application in various fields such as remote sensing, medical imaging and military appliances. Depending upon the type of fusion it is classified as pixel-level fusion, feature-level fusion and decision level fusion. They use different fusion algorithms and find application in various fields. Wavelet-based image fusion method provides high spectral quality of the fused images but they lack spatial information as it is an important factor as much as the spectral information. In particular, this improves the efficiency of the image fusion application. Hence, it is necessary to develop advanced image fusion method so that the fused images have the same spectral resolution and the same spatial resolution with minimum artefacts. One of the most important properties of wavelets transform can only reflect "through" edge characteristics, but cannot express "along" edge characteristics. At the same time, the wavelet transforms cannot precisely show the edge direction since it adopts isotropy. In order to overcome the limitations of wavelet transform, the concept of Curvelet transform was used, which uses edges as basic elements, and can adapt well to the image characteristics. Moreover, Curvelet Transform has the advantages of good anisotropy and has better direction, can provide more information to image processing. Curvelet transform can represent appropriately the edge of image and smoothness area in the same precision of inverse transform. Edge detection plays an important role in computer vision and image analysis, and is an important processing in the image analysis and pattern recognition. Edges are the abrupt change points in the image which are the basic features of the image. These abrupt change points give the locations of the image contour that shows the important feature [1]. The edge representation of an image reduces the amount of data to be processed, and it retains important information about the shapes of objects in the scene.

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II. Related Works

The paper in [1], two medical images are fused based on the Wavelet Transform (WT) and Curvelet transform using different fusion techniques. The objective of the fusion of an MR image and CT image of the same organ is to obtain a single image containing as much information as possible about that organ for diagnosis .In this paper, the input CT and MR images are registered and wavelet and curvelet transforms are applied on it.

In this paper [2], they present a PET and MR brain image fusion method based on wavelet transform for low- and high-activity brain image regions, respectively. This method can generate very good fusion result by adjusting the anatomical structural information in the gray matter (GM) area, and then patching the spectral information in the white matter (WM) area after the wavelet decomposition and gray-level fusion. They used normal axial, normal coronal, and Alzheimer's disease brain images as the three datasets for testing and comparison.

The paper in [3] proposes the task of enhancing the perception of a scene by combining information captured by different sensors is usually known as image fusion. The pyramid decomposition and the Dual-Tree Wavelet Transform have been thoroughly applied in image fusion as analysis and synthesis tools. Using a number of pixel-based and region-based fusion rules, one can combine the important features of the input images in the transform domain to compose an enhanced image. In this paper, the authors test the efficiency of a transform constructed using Independent Component Analysis (ICA) and Topographic Independent Component Analysis bases in image fusion. The bases are obtained by offline training with images of similar context to the observed scene. The images are fused in the transform domain using novel pixel-based or region-based rules. The proposed schemes feature improved performance compared to

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traditional wavelet approaches with slightly increased computational complexity.

This paper [4] presents the Laplacian Pyramid method is proposed. The combination of a Laplacian Pyramid and a Directional Filter Bank is a double filter bank structure. In Curvelet Transform, the multi-scale decomposition is done firstly. One way to obtain a multi-scale decomposition is to use the Laplacian Pyramid. The LP decomposition at each level generates a down sampled low pass version of the original and the difference between the original and the prediction could be calculated. The difference is the prediction error. The process can be iterated on the coarse (down sampled lowpass) signal

III. Proposed Model

In this paper, we propose a new method for the detection of all edge pixels in an image by fusion of multimodal images. To achieve the objective, we have introduced fusion of images obtained from the results of curvelet transform and edge mapping using sobel operator.

A. *CURVELET TRANSFORM*

The curvelet transform, with the character of anisotropy, was developed from the wavelet transform to overcome the limitation of wavelet transform to remove unwanted noise from the image while preserving information along the edges.

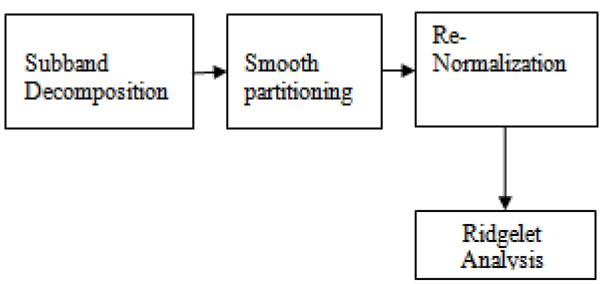

Figure 1: Steps in Curvelet Transform

The Curvelet transform involves the steps shown in Figure 1, as it is used to enhance the images. The inverse curvelet transform is also applied using these steps to obtain the reconstructed image. There is also procedural definition of the reconstruction algorithm. Basicly, inverse the procedure of curvelet transform with some mathematical revising:

$$g_Q = \sum_\lambda d_{(Q\lambda)} \cdot \rho_\lambda$$

B. Curvelet Transform Image Fusion Flow Diagram

The flow diagram in Figure 2 involves all the steps involved in fusing two medical images. First two input images of different modalities and size is applied to double conversion since it involves matrix manipulation. Then curvelet transform is applied and it is decomposed into three levels.

C. Image Fusion Using Sobel Edge Detection

The Sobel operator is a discrete differentiation operator, computing an approximation of the gradient of the image intensity function. The operator calculates the gradient of the image intensity at each point, giving the direction of the largest. The result therefore shows how "abruptly" or

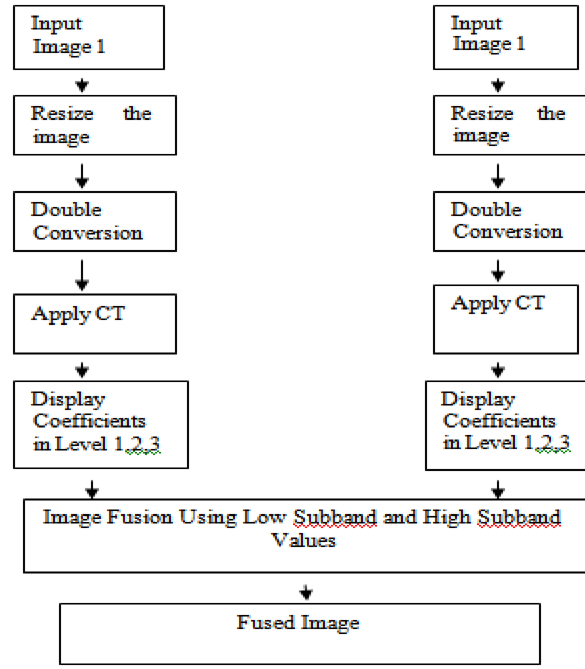

Figure 2: Flow Diagram of curvelet fusion

"smoothly" the image changes at that point and therefore how likely it is that part of the image represents an edge, as well as how that the edge is likely to be oriented. The steps involved in this fusion is as follows

- Read the input images.
- Apply sobel edge operator and set threshold value.
- With this coefficients find out the edge values using edge detector.
- Based on that classify the pixel values into 0 and 1.
- Apply fusion rules for the edge detected images and fused image is obtained.

IV. Proposed Algorithm And Fusion Rule

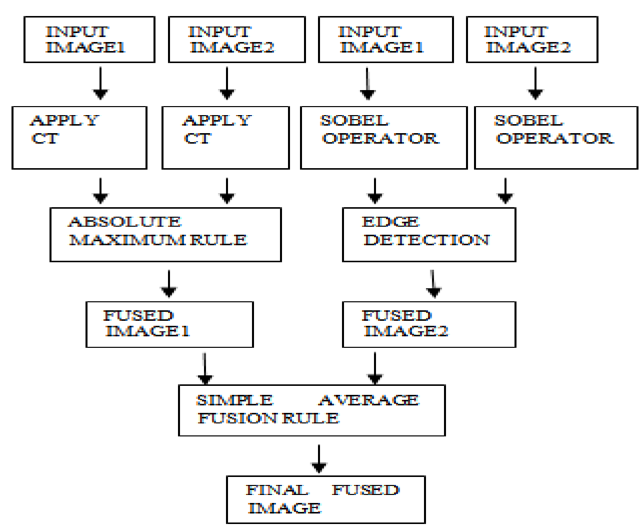

Figure.3: Proposed Flow Diagram

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The above flow diagram shows the steps involved in proposed method. First image fusion using the curvelet transform is applied separately and the output is found, then edge detection is applied to the same set of input images and fused image is obtained. Now both the fused output images are fused again using the simple average rule. The parameters are analysed for each output separately.

A) Image Fusion Rule

In general various fusion rules are proposed for a wide variety of applications. "Decision Mapping Rule" is the proposed fusion rule in the curvelet image fusion. In Decision mapping rule low pass sub band and high pass sub band are used to extract the coefficients.

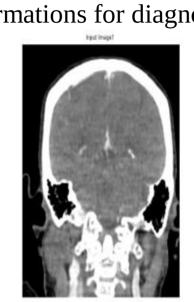
DecisionMapping = (abs(Ahigh)>=abs(Bhigh));
Fused{l}{d}=DecisionMapping*Ahigh+
(~DecisionMapping)*Bhigh

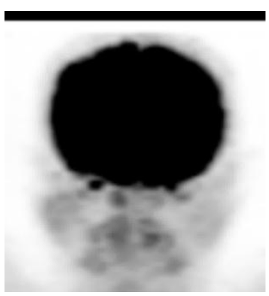
Another fusion rule used is simple average which is nothing but the average of the pixels present in both the images. It is given by

Simpleaverage=(x(i,j)+y(i,j))/2

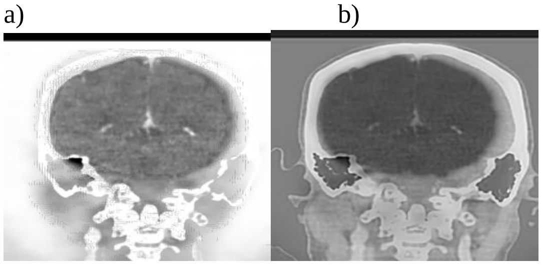
V. RESULTS & DISCUSSIONS

Image fusion using Curvelet Transform and sobel edge detection is applied to many images and the results are shown in the following figures. The proposed method is compared with the curvelet transform output and edge detected output and the results shows that the proposed method is very efficient in combining the edge information and other informations for diagnosis.





.
a) b)



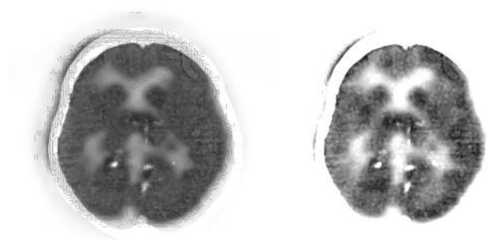
b) Edge output c) curvelet transform

Figure.5: Set 1 input images and fused image

b)

a)

c)



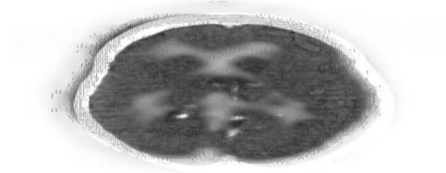
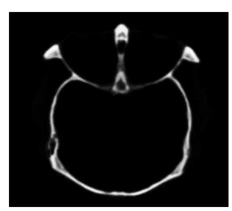
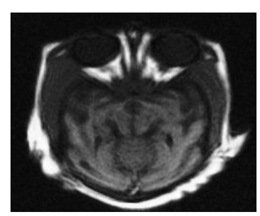


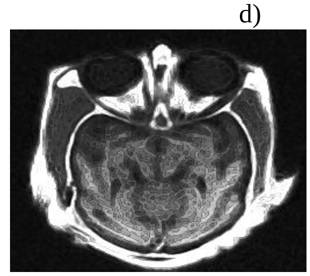
Figure 7: Set 3 input images and fused image





a) b)

c) d)



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A. Evaluation Parameters

1) MSE

The mean squared error (MSE) of an estimator measures the average of the squares of the "errors", that is, the difference between the estimator and what is estimated.

MSE=MSE/ (m*n);

Where m → Number of rows

n →Number of columns

2) PSNR

PSNR is the ratio between the maximum possible power of a signal and the power of corrupting noise that affects the fidelity of its representation. PSNR is an approximation to human perception of reconstruction quality. Although a higher PSNR generally indicates that the reconstruction is of higher quality, in some cases it may not. PSNR is most easily defined via the mean squared error (MSE).

Psnr = xx*log10((255^2)/MSE) where xx → Scaling Factor

3) Mutual information

Mutual information measures the information that *X* and *Y* share: it measures how much knowing one of these variables reduces uncertainty about the other.

4) Normalized cross correlation

The processed image is first normalised from external factors such as variation in brightness by subtracting the mean and diving by the standard deviation and then finding the cross correlation between the two images. Normalised cross correlation is given by:

$$\frac{1}{n}\sum_{x,y}\frac{(f(x,y)-\bar{f})(f(x,y)-\bar{t})}{\sigma_f\sigma_t}$$

5) Structural similarity index

The structural similarity (SSIM) index is a method for measuring the similarity between two images. The SSIM index is a full reference metric; in other words, the measuring of image quality based on an initial uncompressed or distortion-free image as reference. The SSIM metric is calculated on various windows of an image. The measure between two windows x and y of common size *N*×*N* is:

$$\text{SSIM}(x,y)=\frac{(2\mu_x\mu_y+c_1)(2\sigma_{xy}+c_2)}{(\mu_x^2+\mu_y^2+c_1)(\sigma_x^2+\sigma_y^2+c_2)}$$

6) Figure of merit

	PSNR (dB)	MSE	Mutual Info	NCC	SSIM	FOM
Set 1	42.683 2	1.3759	6.32	0.8755	0.0129	0.6447
Set 2	34.082 3	2.2572	10.8623	1.0330	0.0013	0.7816
Set 3	63.902 1	0.4056	4.9254	0.7530	-.0094	0.6928

Table 1: Performance Comparison of Fused Images

	PSNR (dB)	MSE	Mutual Info	NCC	SSIM	FOM
Set 1	18.6635	5.4832	9.3428	1.0871	0.3736	0.9787
Set 2	10.0143	9.0213	5.9037	1.0395	0.3518	0.9904
Set 3	40.0473	1.6012	8.7972	0.9828	0.0968	0.9363

	PSNR (dB)	MSE	Mutual Info	NCC	SSIM	FOM
Set 1	78.7005	0.3344	4.7410	0.5839	0.8483	0.9093
Set 2	72.6804	0.4032	3.0603	0.5385	0.6103	0.9358
Set 3	91.8401	0.0344	5.9720	0.6950	0.6552	0.8527

The result of the fusion process provides high level description of the object by a composite image with all the edge features. Then, both sub-images edges are fused according to fusion rules. Experiment results show the proposed method can detect image edges not only remove the noise effectively but also enhance the edges and locate edges accurately

From the Table 1, it is clear that again the proposed algorithm produce quality fusion image than the existing algorithms. This is evident from the high PSNR values obtained. According to the results, the proposed algorithm is best suited for medical images as it produces a high PSNR of 44.8203dB.

VI. CONCLUSION

The purpose of image fusion is to reduce uncertainty and minimize redundancy in the output while maximizing relevant information particular to an application. So in this project, a method is proposed for medical image fusion using curvelet transform and edge mapping. Aiming for the problem of discarding some important details of high-frequency sub-images when detecting the edge based on wavelet transform, and the effect of edge extracting is poor because of the noise. This paper proposed a new edge fusion detection algorithm based on wavelet transform and canny operator, its advantages are to reduce the noise simply and keep the fine image edges. Experiment results show that using this method to detect the image edges can not only get rid of the noise effectively but also enhance the image edge's details and locate the edge accurately.

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