Study On Multiscale Image Analysis: Theory And Applications

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***Abstract*— Wavelet has application in the field of denoising and compression but they are inefficient for computing geometrical features. To accommodate missing features multiscale methods can be used. Multiscale image analysis methods are deeply related to the field of pattern recognition, computer vision, Remote sensing. Multiscale representation of image are more desirable and ridgelet, curvelet, contourlet are such representations. Ridgelet transform is the anisotropic geometric wavelet transform which is good in representing lines. Most images has curves rather than straight lines so more efficient method called curvelet transform can be used. Contourlet transform is good in representing smooth contours and has high directional selectivity.**

***Keywords*— Character Recognition, Contourlet Transform, Curvelet Transform, Fingerprint Identification, Image Compression, Image Denoising, Image Fusion, Ridgelet Transform, Radon Transform, Wavelet Transform.**

I. INTRODUCTION

In the domain of linear transformation variety of image processing task are carried out. Such tasks include Character recognition, Image denoising, Image compression and Image fusion. Static model of natural scene images shows that representation of image should characterize multiresolution, localization and directionality. Digital image composed by edges, textures and edge associated details. While processing the image all these details must be retained. An image transform is characterized by a set of basis functions and this basis function can be redundant or not. Wavelet transform can be used in applications such as denoising, fusion and compression. Good performance of basis functions in one dimension leads to the success of wavelet, unfortunately this not in the case of two dimension. Traditional wavelet consider the point singularities only, so wavelet based compression, fusion and denoising are inefficient. Therefore new image processing methods like ridgelet, curvelet and contourlet developed. In the field of data compression it is important to preserve details of an image for reconstruction. To capture the smooth contours contourlet transform is good. In the classification of satellite images quality of fused image is important. For image fusion and denoising curvelet and ridgelet can be used. Ridgelet is a multiscale transform and is developed to overcome the disadvantages of wavelet and it can consider only the straight lines not curves. Images include not only the straight lines but also the curves and contours. To handle this curves curvelet transform developed and it is based on two concepts one is block wise approach and other is based on Fourier transform. This paper focus on different multiscale methods and its applications.

II. MULTISCALE IMAGE ANALYSIS

Representation of image is a fundamental issue. Usually matrix of pixel values are used to represent images but such representations leads to poor performance. Things are at more macroscopic levels than pixels, so multiscale representation is more desirable. Multiscale representations include ridgelet transform, curvelet transform and contourlet transform.

A. Ridgelet Transform

Fourier transform represent signal as sum of sines and cosines. It is localized in the frequency domain only, does not provide time resolution. Wavelet transform provide a solution to this problem that is it provide both local and global information. For wavelet transform a fixed mother wavelet is chosen and is translated and scaled to obtain the basis function. Problem with wavelet is that it can handle only point singularities. In 2D to account for edges more wavelet coefficients are needed. Ridgelet are introduced in higher dimensions to overcome this shortcomings. They can effectively handle the line singularities by mapping lines in 2D to points using radon transform. In radon domain wavelet are used to handle the points. Radon transform is used to map line into points, is given by

$$R_f(\theta,t) = \int_{R^2} f(x)\,\beta(x1\cos\theta + x2\sin\theta - t)\,dx$$

B. Curvelet Transform

Curvelet transform is a multiscale representation suitable for objects with curves. In images edges are curved rather than straight lines but the ridgelet transform is not effective in processing curves. To efficiently handle the curves, two forms of curvelet transform can be used first one is the block ridgelet transform and second one is the curvelet transform on the Fourier domain[18]. In block ridgelet transform images are segmented in to blocks and ridgelet is performed on that blocks, shown in figure 1. In the second form of curvelet

transform frequency partitioning is done on the frequency domain. Curvelet transform is given by

$$\emptyset_{j_{0_0}}(r,\omega) = 2_{3j/4} W(2_j r) V_{N_j}(\omega),$$
$$r \geq 0, \omega \in [0,2\pi], j \in N_0$$

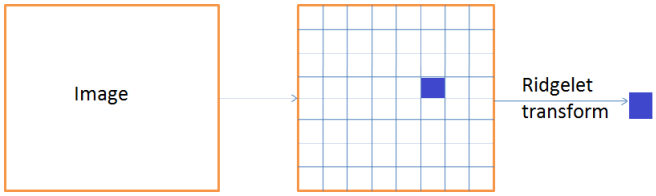

Fig-1: Curvelet Transform

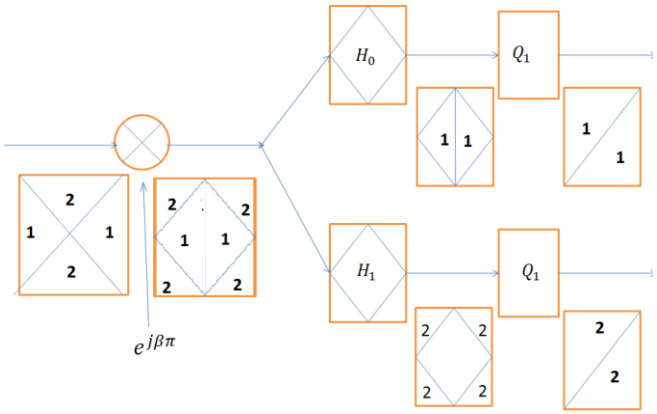

Fig-2: Contourlet Transform

C. *Contourlet Transform*

Contourlet is the modification of curvelet transform. The block based approach of curvelet is overcome by introducing Contourlet transform. It can capture smooth contours and edges at any directions. It is the combination of laplacian pyramid (LP) and directional filter bank (DFB). Multiscale decomposition is done by LP and multidirectional decomposition is done by [15][19]. LP decomposition of the image provide lowpass and bandpass version and the bandpass part is give to the DFB for directional decomposition[20]. Contourlet Transform is shown in figure 2. Directional Filter Bank consists of analysis stage and synthesis stage [16][17]. In the analysis part original image is split in to directional subbands and in the synthesis section these subbands are combined to reconstruct the original image. In the analysis stage analysis filters and downsampling matrix Q are used. The DFB used is the Quincunx Filter Bank, in the first level the banpass part of the image is filtered using low and high pass fan filters H0 and H1.

$$Q0 = \begin{matrix} 1 & -1 \\ 1 & 1 \end{matrix} \quad Q1 = \begin{matrix} 1 & 1 \\ -1 & 1 \end{matrix}$$

Then this filtered image is downsampled using Q0. The result of first level is given to the second level and same process is repeated , downsapling matrix used is Q1. Continue the same process for required levels. DFB for two levels is shown in figure 3.

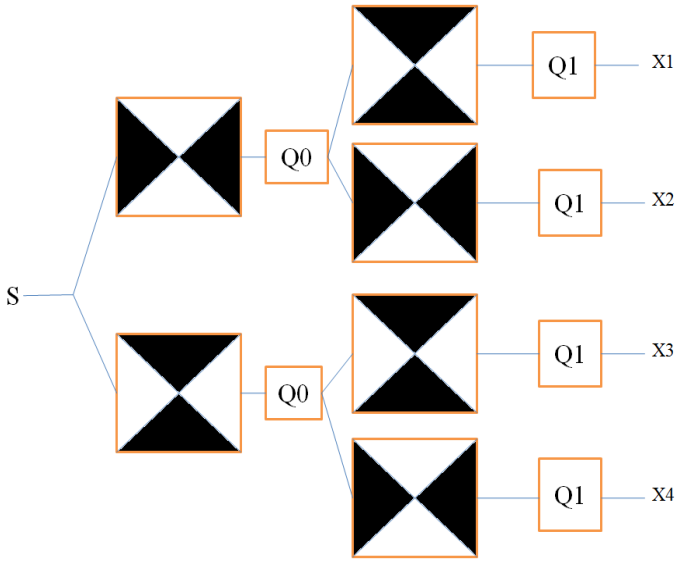

Fig-3: Two Level DFB

III. Applications

Multiscale image representations such as ridgelet, curvelet and contourlet has variety of applications in Character recognition, Image denoising, Image enhancement and Remote sensing areas. Optical character recognition is an important area in the field of pattern recognition. Because of the unstable style of writing it is very difficult to recognize the handwritten characters. In order to recognize the characters well it is necessary to extract relevant features. Ridgelet, curvelet and contourlet transform can be used to extract the relevant features. Using the extracted features characters can be classified using a classifier.

1) Hassiba Nemmour et al [1] had taken care of handwritten Arabic word recognition. Two approaches for word recognition such as analytic and holistic approaches are explained. Ridgelet transform is used for feature extraction. For different angular directions radon transform is computed and one dimensional wavelet is applied on this radon slices.

- Compute the radon transform
- To obtain the ridgelet coefficient apply the 1D wavelet on the radon slices

Advantage of using ridgelet is to highlight the line singularities in the handwritten words. SVM is used as the classifier. This work gives 84 percent efficiency.

2)G. Y. Chen et al [2] presented rotation invariant pattern recognition using Ridgelet transform. Ridgelet is defined on square not suitable for extracting rotation invariant features. In order to obtain the rotation invariant features apply ridgelet on the pattern that falls inside the circle surrounding the pattern that want to recognize. The pattern want to recognize is normalized to avoid scale and transelation variance. Discard the pixels that fall outside the circle and apply radon transform. Perform 1D wavelet in the Radon domain along the radial direction to obtain the ridgelet coefficients. Along the angular direction conduct a 1D wavelet cycle spinning and compute the FT of every wavelet subband.

3)Mamatha H R et al [3] is the recognition of Kannada numerals. Kannada is the official language of state Karnataka. It is derived from the southern Bramhi lipi. The Kannada script has a large number of structural features. Main challenge in recognizing Kannada is that some numerals have similar variation between them and leads to recognition complexity. Preprocessing of image include binarisation and thinning. To overcome the limitations of wavelet a new approach is introduced called curvelet transform. So the features are curvelet coefficients and standard deviation is the dimension reduction technique. In this work 5 levels of decomposition is used that is for 256 x 256 sized image curvelet coefficient in five different scales are obtained. Number of coefficients obtained is very high and leads to increase in feature vector size and increasing time. For extracting best features standard deviation can be used as dimension reduction technique. For the classification of characters KNN used. This paper gives accuracy of 90.5.

4)Angshul Majumdar et al [4] focus on the recognition of Bangali characters. Curvelet coefficients are taken as the feature values. Here two thinned and thickened version of the image is considered. The fundamental concept is that if the character cannot recognize with original image it will be recognized with morphologically altered variations. To compute the digital curvelet transform coefficient Ridgelet is applied on to the radon domain. For testing and training five variations of input image is taken and classified using KNN. Overall accuracy of 96.80 is obtained.

5) In Aji George et al [5] introduce offline recognition of Malayalam characters. Digital camera or scanner is used for image acquisition. To make the input image suitable for further processing noise removal, binarization, skeletonization and normalization are used as preprocessing steps. Global thresholding is used to convert the input image in to bilevel form. Erosion, dilation and thinning are the morphological operations. To obtain the skeleton thinning is used. Line segmentation, word segmentation and character segmentation used for segmenting input image in to individual characters. After all these preprocessing the character image is given to the feature extraction phase for extracting relevant features. Contourlet transform is the feature extraction method. Total 32 features are obtained by taking Four level decomposition of Contourlet, aspect ratio, ratio of horizontal and vertical grid values. The extracted features are classified by feed forward neural network. Using the 32 features yield 97.3 percent accuracy.

6)G Y Chen et al [6] suggested invariant pattern recognition. Invariant means features must be independent. Features that are invariant under translation, rotation, scaling is obtained by Fourier transform. For palm print classification original palm print image consist of fingers and background it is undesirable. Central portion of the palm is extracted and Contourlet transform is applied to extract the features and invariant feature is obtained by taking Fourier of the Contourlet coefficients. In the case of handwritten numeral recognition to eliminate the translational variance move center of the handwritten numeral in to center of the numeral image. Then Contourlet transform is applied on the normalized numeral image and invariant feature is obtained by applying FT. Classifier used is the adaptive classifier
Adaboost.

The multiscale representations can be used for image compression, image denoising, fusion and enhancement.
Medical imaging field require image compression. Lossy and lossless compression techniques are existing. The need for efficient storage of medical data and its transmission necessitated the use of compression.

7)Contourlet Transform can be applied for image compression and is explained in Ahmed Nabil Belbachir et al [7]. For data compression various lossy and lossless coding techniques have been developed. Decorrelation and quantization are the stages of lossy compression. The decorrelation in lossy compression is done by transforming from one space to another. Multiresolution transforms like Discrete Cosine Transform, Wavelet Transform can be used. Wavelet based methods is used in the field of image and video compression but the problem with wavelet is that limited orientation selectivity. So a new image representation method Contourlet can be used for compression. This paper uses the combination between Contourlet and wavelet transform. Contourlet can capture smooth contours effectively and wavelet can be used in lower resolution images for further information. Here Contourlet and wavelet is used to decompose the original image and hard thresholding is done on insignificant coefficients. The images are then reconstructed using remaining coefficients.

8) FeiYan Zhang et al [8] taken care of compression based on Contourlet Transform(CT). In CT multiscale decomposition is done by LP and multidirectional decomposition is done by Directional filter bank. In LP decomposition stage two images obtained, low pass and high pass. Directional information is computed with detailed image. By avoiding redundancy and to take advantage of directionality offered by CT Change the LP with Mallat decomposition. The wavelet based Contourlet transform remove the low frequencies before applying DFB.
Natural images brings noises while transmitting, coding and receiving. The removal of noise leads to smoothing of edges. Use of filtering techniques cannot distinguish the noise and sharp edges. So the multiscale methods are more efficient.

9)Jiang Tao et al [9] presented the use of curvelet transform in the field of image denoising. Main challenge in image processing is that noises are added in the image, it is essential to remove this noise before processing. Like Weiner filter, neighborhood average method, center value filter different filtering technique can be used for noise removal. The elimination of noise can be achieved by inverse transformations like wavelet transform. If the image outline is clear noise smooth effect is not assured and image is illegible if noise smooth effect is good, that is wavelet consider one aspect but lose another. Curvelet transform is superior to this wavelet because it has good orientation characteristics. This work proposes a combination of curvelet and wavelet for denoising and yield quite good denoising result. After the application of wavelet edge and detail information lost mostly, curvelet retain details better than wavelet. This method

achieves good denoising and it can provide good services to remote sensing areas.

10)Arthur L. da Cunha et al [10] proposes an efficient method for denoising and enhancement, Nonsubsampled Contourlet Transform. Contourlet transform is a multiscale and multidirectional transform, but due the presence of downsampling and upsampling shift invariancy is not here. The NSCT is a shift invariant, multiscale transform and is very efficient in denoising and image enhancement. In image enhancement methods when enhances the weak edges the noises are also enhanced, cannot distinguish noise and edge. The weak edge is a geometric structure but noise is not, so NACT can be used to distinguish between them.

11)Myungjin Choi et al [11] explains application of curvelet in image fusion. Fusion of multispectral and panchromatic images is an important issue in remote sensing applications. The classification of satellite image is affected by fused image quality. Methods like IHS(intensity, hue, saturation) color model, PCA, Wavelet are there for the fusion images. In remote sensing application spatial information of fused image is important. Problem with wavelet is that it has less spatial information. The multiscale method curvelet represent edges better than wavelet and it retain spatial, spectral resolution.

12) In Jean-Luc Starck et al [12] proposes the contrast enhancement using curvelet transform. Curvelet represents edges better than wavelets and is suitable for enhancement. For enhancement standard deviation of noise of input image is computed and find the curvelet transform of input image. For each curvelet band find the modified curvelet coefficients. The enhanced image can be reconstructed from the modified value.

13) Jean-Luc et al [13] presents the image denoising based on curvelet transform. This is developed to break the limitation of using wavelet in image denoising. The observations from the work are

- Curvelet transform has superior performance over wavelet and ridgelet.
- The curvelet doesn't have any disturbing artifacts.
- Curvelet transform reconstruction is efficient than wavelet transform.

Fingerprint is extensively used for personal identification. Fingerprint based authentication system have received more attention among all biometric technique. Many algorithms are exists for fingerprint identification such as structure based, frequency based and syntactic.

14) Ismail Taha Ahmed et al[14] taken care of fingerprint recognition using curvelet transform. Fingerprints are used for criminal investigation and to indicate the ownership. The advantage of fingerprints are they are unique and universal. Curvelet can be used for identification of finger prints. Stages of fingerprint recognition include,

- Conversion of color image to gray scale image.
- During the second stage enhancement is done using the median filter.
- Third and most important stage is the feature extraction, for extracting the relevant features Curvelet is used.
- Final stage is the matching stage, here compare the image stored in database with the input image. Template matching is done in this stage.

15) In N Shanmuga Priya et al [15] proposes curvelet transform for finger print identification,
steps for fingerprint recognition include

- Determine the registration point, any point that is consistently detected in a finger print image.
- Apply curvelet transform on the preprocessed fingerprint image.
- Store the extracted features in a feature library for use in authentication.

The mean and standard deviations are computed as the fingerprint features for the curvelet. Matching of fingerprint can be done by finding the Euclidean distance between the corresponding feature vectors. Figure 4 gives the overall review.

TABLE 1: OVERALL REVIEW

Paper Title	Application	Observations
Hassiba Nemmour [1]	Character Recognition	84 percent accuracy using ridgelet transform.
G. Y. Chen [2]	Character Recognition	Invarient pattern recognition is efficient using ridgelet transform
Mamatha H R [3]	Character Recognition	90.5 percent using curvelet transform.
Angshul Majumdar [4]	Character Recognition	96.8 percent accuracy using curvelet transform.
Aji George [5]	Character Recognition	97.3 percent using CT
G Y Chen [6]	Pattern Recognition	CT is used for pattern recognition

Jiang Tao [7]	Image Compression	CT has less information loss and provide more compact representation than wavelet when used for compression
Myungjin Choi [8]	Image Compression	Image compressed by wavelet based CT preserve more details than wavelet transform
Arthur L. da Cunha [9]	Image Denoising	Good denoising effect can be achieved using curvelet method. In the denoising process lose occurred in the small part of the edge feature and detail information .
Ahmed Nabil Belbachir [10]	Image Denoising	CT is coupled with hard thresholding for denoising and enhancement and good performance than wavelet
FeiYan Zhang [11]	Remote Sensing	The combination entropy, correlation coefficient and mean gradient for HIS color method, wavele and curvelet are calculated and best fusion performance is shown by curvelet.
Jean-Luc Starck [12]	Image Enhancement	When curvelet used for image enhancement it does not amplifies the noises , while reconstructing it is advantageous if block artifacts do not occur.
Jean-Luc [13]	Image Denoising	Good denoising effect can be achieved using curvelet
Ismail Taha Ahmed [14]	Fingerprint Identification	Recognition rate of 84 percent is obtained by the combination of curvelet and cosine transform for the fingerprint recognition.
N Shanmuga Priya [15]	Fingerprint Identification	97% obtained using mean and standard devation of curvelet transform

IV. Proposed work

From the observations in the Table 1 it is clear that the multiscale methods are very efficient in all applications, than the wavelet transform. The limitation of curvelet transform is that blocking artifact introduced while enhancing the image. During the removal of noise small part of edge details may fall back when using curvelet transform. To avoide this blocking artifacts, combination of curvelet and contourlet will yield a better result for image enhancement and denoising. Because the introduced blocking effects by curvelet can be removed by using the contourlet transform, which has high directional selectivity.

V. Conclusions

This paper presents a detailed study of multiscale methods and applications. From this study it can be observed that multiscale methods such as ridgelet, curvelet and contourlet can be applied in the field of character recognition, image denoising, compression and remote sensing. In medical imaging field the storage of image is an important issue so while compressing the images reconstruction must be efficient. For better reconstruction contourlet transform can be used. In remote sensing the quality of fused image must be maintained for better classification of satellite images, can be done by using curvelet transform.

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