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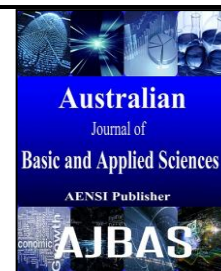
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Image Segmentation Using the Features Derived from Wavelets and Curve lets in Forecasting the Weather Patterns

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ABSTRACT

The Doppler weather radar imagery with the advent of smart sensors and sophisticated acquisition methods to get multi temporal, multi spectral and multi spatial high resolution images which finds efficient tools used to forecast the rainfall, rain fall mapping, flood alert warnings, identification and tracing the paths of storms and cyclones. The analysis of the radar image plays a vital role in the success of the X band radars. An attempt is made to perform image segmentation using the features derived from wavelets, ridge lets and curve lets. These classifications of the spatial objects for object recognition and extraction of information for the evaluation has been discussed. The supremacy of this methodology is the sparse representation of the wavelet, ridge let and the curve let with good directionality and anisotropy for the analysis of the radar imagery

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INTRODUCTION

Multi scale methods are popular with the development of wavelets, and with the sparse representation of the image vectors. The ridgelet and curve lets are new extensions of the wavelets and their orientation selectivity in multi scale higher dimensional domains have found varied use in many new applications. The use for the analysis of the radar imagery and its related works carried with the radar images., the trend of Doppler weather radars, investigations with the mathematics of the wavelet, ridgelet and curvelets and relative techniques of handling the radar images with a proposed methodology for object segmentation and extraction of information from the images based upon it some results have been arrived and it is utilized to predict the more accuracy in this area of research.

Some features from satellite Imagery:

Synthetic aperture radar (SAR) images are inherently affected by multiplicative speckle noise, which is due to the coherent nature of scattering phenomena, to preserve the sharp features and details of the SAR image effectively when despeckling, a new method of speckle reduction in wavelet domain has been presented (Mansoor Roomi, 1997). Extraction of information and

Speckle Noise Reduction in SAR Images Using the Wavelet Transform is presented (Marc Simard, 2008). It is investigates for the utility of applying to the radar detection problem several nonlinear filtering structures that have been shown to be useful in image processing (Yingdan, 1991). Two innovative algorithms for motion tracking and monitoring of rainy clouds from radar images are proposed. The methods are generalizations of classical optical flow techniques, including a production term (modeling formation, growth or depletion of clouds) in the model to be fit to the data. (Luca Mesin, 2009). Multiple images are processed and different smoothness constraints are introduced. With the multitude of remote sensing instruments and the number of channels and data types increasing, it is necessary to develop a principled and generally applicable technique. In this paper, an efficient, sequential, morphological technique called the watershed transform is adapted and extended so that it can be used for identifying storms. (Valliappa Lakshmanan, 2009) To identify different regions over radar images, it is required to perform image classification. The present work performs image classification for extracting regions over radar images. The work is a hybrid approach that will use the concept of moment analysis along with histogram analysis to perform the image classification (Ruchi, 2013). An

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evaluation of system analysis techniques for obtaining short-term quantitative precipitation forecasting, based on radar images, is presented (Laura Montanari, 2006). Stochastic models of the autoregressive type, as well as neural networks, are applied for modeling the Lagrangian storm dynamics. The sensitivity of the forecasting performances with respect to prediction lead time and spatial resolution of the radar images is investigated (Dimitrios Charalampidis, 2010). A methodical evaluation of the performance of a new, two traditional approaches to automatic target recognition (ATR) based on silhouette representation of objects. Performance is evaluated under the simulated conditions of imperfect localization by a region of interest (ROI) algorithm (resulting in clipping and scale changes) as well as occlusions by other silhouettes, noise and out-of-plane rotations (Conrad Sanderson, 2007). A method for producing maps of precipitation return levels and uncertainty measures and apply it to a region in Colorado. Spatial methods were improved by working in a space with climatological coordinates. Inference is provided by a Markov chain Monte Carlo algorithm and spatial interpolation method, which provide a natural method for estimating uncertainty. (Daniel Cooley, 2012) A new approach using the Bayesian framework for the reconstruction of sparse Synthetic Aperture Radar (SAR) images made computationally efficient by utilizing the fast Fourier transform (FFT) and conjugate gradient (CG) method to carry out its computations. (Duc, 2013). Template and pattern recognition-based filters are firstly used to remove the ground clutter and keep the precipitation echoes unchanged. Bi-dimensional FFT is then applied to the filtered images, showing that the Fourier spectra characterizing convective clouds differ significantly from those of stratified ones. (Ouafra Raaf, 2012) New wavelet based approaches for efficient data compression of complex SAR images with high reconstruction quality are presented. (Wavelet). Algorithms and techniques for automated detection and tracking of mesoscale features from satellite imagery employing wavelet analysis are presented (Christian Melsheimer, 2001).

Polarimetric Doppler Weather Radars:

Weather radars are available as X band (10 GHz, $\lambda=3$ cm), L band (5 GHz, $\lambda=10$ cm), S band (3 GHz, $\lambda=10$ cm). In India the indigenously designed X band (9375 = ± 20 MHz) was installed in Indian Meteorological Department in 1970. A large number of S and X bands have been installed for storm and cyclone predictions. The introduction of X band radars provide an opportunity to do precision rainfall mapping and flash flood warning system. These radars are deployed to operate as metropolitan area radar system. Small cheaper X band radars are

under research and development and the economics of weather radars have changed. The efficiency of a radar system depends on its ability to identify the echoes in the presence of noise and unwanted clutter. The important parameters are average power of transmission and the antenna aperture size. Signal detect ability is an important measure of radar performance. Doppler weather radars in India are installed under the initiative of ISRO and these weather radars are used extensively to know the weather alerts. The IMD Radar network of IMD has 14 S band radars and 25 X band radar including 5 Doppler weather radars. Out of the 25X9 band radars are at Kolkata, Chennai, Guwahati, Ranchi, Delhi, Lucknow, Mumbai, Nagpur and Agartala airports are used for storm detection and 17 for wind finding and facility for weather observation. Doppler radar gives information on the radial velocity and spectral width in addition to reflectivity. Software algorithms of Doppler weather radars are useful for forecasters in estimating storm's center and its intensity, fixing its position and predicting its future path. Two indigenously designed Doppler weather radars manufactured by BEL will be installed at Mumbai and Kochi. One Doppler weather radar is commissioned at Palm airport, Delhi on 22nd April 2010. The existing Doppler weather radars have been networked through VPN to a server at IMD, Delhi. The received data at this server is processed by SIGMET IRIS and provides a composite image. The software also converts format of the raw data to Net CDF, HDF5, UF and BUFR Oper for assimilating into NWP model and for ingesting in SYNERGY system supplied by MFI.

Mathematics of MRA:

A. Wavelets the digital images are two dimensional and the JPEG 2000 format is followed for the wavelets in image processing [16]. The image is split into tiles instead of blocks. The MRA of image processing has the input signal represented as an element of $V^{(0)}$, by having the components of the signal as coefficients for the translates of the scaling function

$$x(t) = \sum_n y_n^{(0)} \phi(t-n)$$

$W^{(m)}$ is defined by the span of $\{\psi_n^{(m)}(t)\}_n$.

1. $V^{(m)}$ and $W^{(m)}$ are orthogonal subspaces.
2. $V^{(m)} = V^{(m+1)} \ominus W^{(m+1)}$
3. The coefficients in such a decomposition can be obtained by filtering with h_0 and h_1 respectively.

The wavelet coefficients are obtained by iterative applications of the filters h_0 and h_1 .

To have separable two dimensional transform, we calculate by applying the corresponding one dimensional transform to columns first and then to the rows. When filtering we have four possibilities.

1. low pass filter to rows, followed by low pass filter to columns (LL coefficients)

2. low pass filter to rows, followed by high pass filter to columns (HL coefficients)

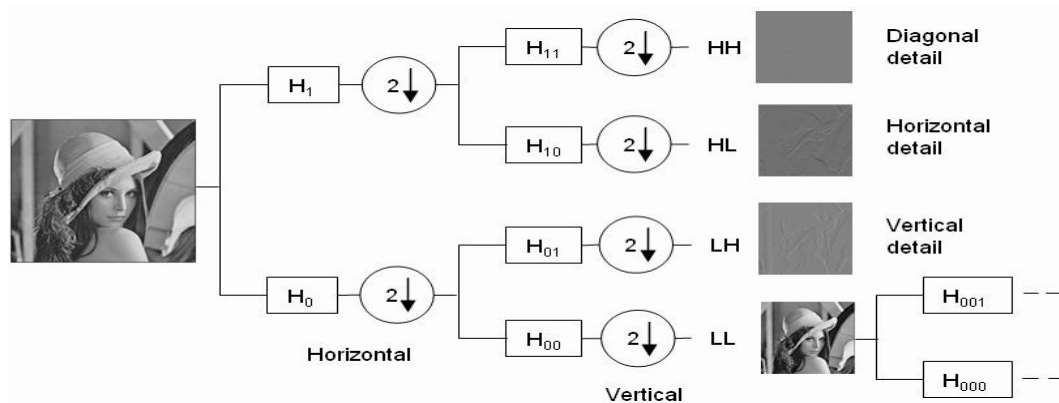


Fig. 4.1: 2D Discrete wavelet Transform.

3. high pass filter to rows, followed by low pass filter to columns (LH coefficients)

4. high pass filter to rows, followed by high pass filter to columns (HH coefficients)

When a separable transform is applied, only the LL coefficients may need further decomposition. When this decomposition is done at many levels, we get the subband decomposition. The wavelet subspace decomposition in two dimensions has the form

$$V^{(m)} = V^{(m+1)} \Phi_{W_{0,1}}^{(m+1)} \Phi_{W_{1,0}}^{(m+1)} \Phi_{W_{1,1}}^{(m+1)}$$

And the mother wavelet basis functions are expressed in terms of the synthesis filters by

$$\Psi_{0,1}(s_1, s_2) = 2 \sum g_0[n_1] g_1[n_2] \phi(2s_1 - n_1, 2s_2 - n_2),$$

$$\Psi_{1,0}(s_1, s_2) = 2 \sum g_1[n_1] g_0[n_2] \phi(2s_1 - n_1, 2s_2 - n_2),$$

$$\Psi_{1,1}(s_1, s_2) = 2 \sum g_1[n_1] g_1[n_2] \phi(2s_1 - n_1, 2s_2 - n_2),$$

Not all sub band transforms and ortho normal transforms gives rise to wavelets. For a filter bank to generate a wavelet, it must have a zero at and the number of zeroes affects the smoothness of the scaling function. The wavelets transform extracts the directional details that capture the horizontal vertical and the diagonal activity. The wavelets are suitable for dealing with the objects with point singularities. They can capture limited directional information due to its poor orientation selectivity.

B. Ridgelets:

In 1998, Donoho (Stark, 2007) introduced the ridge let transform. The continuous ridge let transform can be defined from a 1D wavelet function oriented as constant lines and radial directions. Wavelets do not isolate the smoothness along the edges of an image and are not appropriate to distinguish the lines in images. The ridge let

transform overcomes the functionality of the wavelet at higher dimensional, singularities and is a effective tool to perform sparse directional analysis. Ridge lets are able to represent objects with line singularities.

The finite ridgelet transform is computed by calculating a discrete radon transform and then applying wavelet transform to it. The finite radon transform is obtained by calculating the 2D FFT for the image and then applying the 1D inverse FFT on each of the 32 radial directions of the radon projection. 1D DWT is applied restricted to radial directions going through the origin for the three levels of decomposition. The radon transform for a real function on the finite grid Z_p^2 is define as

$$r_k[] = \frac{1}{\sqrt{2\pi}} \sum_{(x,y) \in Z_p^2} f(x,y) e^{-i k \cdot (x,y)}$$

To compute the Kth radon projection all the pixels in the original image need to be passed once and all the P histogram med values are divided by K to get the average values. Once the wavelet transform and the radon transforms are implemented, each output of the radon transform projection is passed through the wavelet transform before it reaches the output multiplier. The FRAT maps a line singularity into point singularity and the wavelet transform effectively detects and segments the point singularity in the radon domain.

In continuous wavelet transform the point parameters (x,y) in the cartesian grid which are the image pixels are replaced by the line parameters (β, θ) where β is the intercept and θ is the angle. The straight lines are evaluate the image in the frequency domain. Ridgelets can be used to detect lines in images but was not suitable to detect further singularities along the curves and edges in the image.

C. Curvelets:

The curvelet transform was introduced in 2000, by Candes and Donoho which was obtained

by applying the ridgelet analysis to the radon transform of an image. The performance was very slow. The improved new method proposed by Candess et al for the curvelet transform is known as the Fast Discrete curvelet transform. The FDCT is constructed from unequally spaced FFT or performing a wrapping function. It is simpler, faster and redundant than the original curvelet transform. The implementations differ mainly by the choice of the spatial grid that used to translate curvelets at each scale and angle. Both digital transformation return a table of digital curvelet coefficients indexed by a scale parameter, an orientation parameter and a spatial location parameter.

The Curvelets provide optimally sparse representation of objects which display smoothness along the curved edges. Curvelets have micro local features which makes them well suited to certain reconstruction problem using missing data. If we combine the frequency responses of curvelets at different scales and orientations, we get a rectangular frequency tiling that covers the whole image in the spectral domain (Fig.4.2). Thus, the curvelet spectra completely cover the frequency plane and there is no loss of spectral information like the Gabor filters. To achieve higher level of efficiency, curvelet transform is usually implemented in the frequency domain. That is, both the curvelet and the image are transformed and are then multiplied in the Fourier frequency domain. The product is then inverse Fourier transformed to obtain the curvelet coefficients. The process can be described as Curvelet transform = IFFT [FFT(Curvelet) $\times$ FFT(Image)] and the product from the multiplication is a wedge.

The trapezoidal wedge in the spectral domain is not suitable for use with the inverse Fourier transform which is the next step in collecting the curvelet coefficients using IFFT. The wedge data cannot be accommodated directly into a rectangle of size $2^j \times 2^{j/2}$. To overcome this problem, Candès et al. have formulated a wedge wrapping procedure [18] where a parallelogram with sides 2^j and $2^{j/2}$ is chosen as a support to the wedge data. The wrapping is done by periodic tiling of the spectrum inside the wedge and then collecting the rectangular coefficient area in the center. The center rectangle of size $2^j \times 2^{j/2}$ successfully collects all the information in that parallelogram good as the curvelet transform captures multidirectional features in wedges. The multidirectional features extract the important features which are then segmented accurately.

The computational complexity of the wrapping based analysis and the reconstruction algorithm is $O(\log)$ and the computation time is 6 to 10 2D FFT

FFTs. This is a faster algorithm compared to the first method of generation of the curvelet. This,

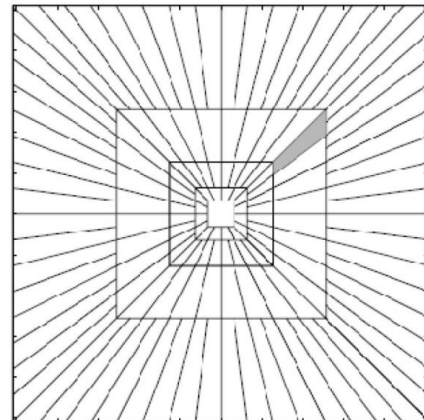
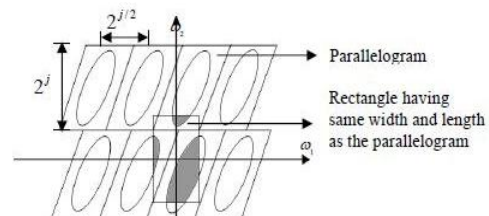


Fig 4.2: Rectangular frequency tiling of an image with 5 level curvelets



ig wedge around the origin by periodic tiling of the wedge data.

The angle θ is in the range $(\pi/4, 3\pi/4)$.

Fig 4.3: Wedge of curvelet.

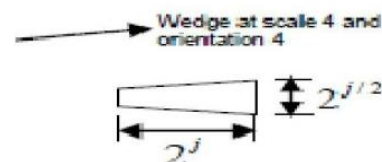


Fig. 4.4: Wrapping transform.

Handling a radar image:

Doppler radar emits beams (pulses) of microwave energy from a transmitter into the atmosphere (see the figure below for a diagram of the electromagnetic spectrum). When these beams collide with objects in the atmosphere such as raindrops, hail stones, snowflakes, cloud droplets, birds, insects, dust particles, trees, and even the ground, some of the energy bounces back towards the radar. A receiver on the radar then collects the reflected energy and displays it in different ways.

A radar image is a digital image comprised of a two dimensional array of individual picture elements called pixels arranged in columns and rows. Each pixel represents an area on the Earth's surface. A pixel has an intensity value and a

location address in the two dimensional image. The intensity value represents the measured physical quantity such as the solar radiance in a given wavelength band reflected from the ground, emitted infrared radiation or backscattered radar intensity. This value is normally the average value for the whole ground area covered by the pixel. The intensity of a pixel is digitised and recorded as a digital number. Due to the finite storage capacity, a digital number is stored with a finite number of bits (binary digits). The number of bits determine the radiometric resolution of the image. For example, an 8-bit digital number ranges from 0 to 255 (i.e. $2^8 - 1$), while a 11-bit digital number ranges from 0 to 2047. The detected intensity value needs to be scaled and quantized to fit within this range of value. In a Radio metrically Calibrated image, the actual intensity value can be derived from the pixel digital number. The address of a pixel is denoted by its row and column coordinates in the two-dimensional image. There is a one- to-one correspondence between the column-row address of a pixel and the geographical coordinates (e.g. Longitude, latitude) of the imaged location. In order to be useful, the exact geographical location of each pixel on the ground must be derivable from its row and column indices, given the imaging geometry and the satellite orbit parameters.

The raw digital data when viewed on the display is difficult to identify the fine features. The image has to undergo certain image processing operations (Malay.k.pakhira 2002).

Image restoration compensates for data errors, noise and geometric distortions introduced during scanning and recording.

Image enhancement alters the visual impact of the image .It can be contrast enhancement, density slicing and edge enhancement.

Information extract on utilises the decision making capability of the computer to recognize and classify the pixels.

Methodology:

The analysis of radar image involves three important steps, pre processing, processing and evaluation steps.

2.1 Pre processing:

The doppler weather radar images are acquired from the government agencies. Select the type of images taken for the study. The raw mosaic images may be converted to GTIFF image.A spatial subset is created. The image enhancement may be done using contrast enhancements. The spatial can also be used if requirement arises..The speckle noise with the image due to back scattering may be suppressed. It is necessary to apply atmospheric corrections and geometric corrections. to obtain the image.

2.2 Processing:

Image segmentation divides the image into meaningful regions. There are basically three types of discontinuities in a digital image - points, lines and edges. The image is divided into discrete number of segments of grouping neighbouring pixels of similar spectral characteristics. Each region can be quantitatively measured for their relative size, shape, texture, contexture and topology, based on the specific characteristic taken for the consideration. Information objects are formed by spatial aggregation of neighboring pixels with similar spatial or spectral characteristics. A sample of the radar images can be tested with the wavelet, ridgelet and the curvelet to bring forth the directionality and anisotropy of each of them. A comparative study on their ability in identifying the singularities in higher dimensions and extracting the features in a desired image should be done. The object oriented classifier operates on object or group of pixels. During classification every object is treated as an unit of analysis. K means clustering can be used to extract the information. If the number of clusters are unknown ISODATA algorithm can be used to automatically determine the number of clusters along with the cluster configuration depending on the user supplied data. Optimization if necessary can be done using genetic algorithm or evolutionary programming techniques.

Conclusion:

This paper presents an overview on the application of wavelets, ridgelets, curvelets to the X band radar images to perform image segmentation to get the region of interest. The wavelet transform is used extensively for many applications..The ridgelet and the curvelet transforms are new extensions of wavelet transforms. A comparative study on the effectiveness of the three transforms has been discussed. This X band radar has the feasibility of dominating the current scenario of monitoring the daily climate changes in our locality.

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