Estimation of ship velocity by fusion of radon transformation with wavelet filters using SAR images

Dr.P.Subashini

Associate Professor
Department of Computer Science
Avinashilingam University for Women,Coimbatore,India

Ms.M. Krishnaveni

Research Assistant -NRB
Department of Computer Science
Avinashilingam University for Women,Coimbatore,India

***Abstract* - Since monitoring of ship traffic is a routine exercise, it is thus desirable to develop computer-based algorithms to perform this task. It is well known that certain ships and wakes can be observed in the SAR .This paper broadens an appropriate logic for detection of the object causing the wake from the data collected to develop an appropriate algorithm for estimation of ship velocity. This works investigate the possibility in detecting ships and their wakes in the ERS Synthetic Aperture Radar (SAR) imagery. SAR processor usually assumes target to be stationary and by taking this advantage two existing techniques of wavelet filters with some innovation by radon transform is used to detect the ship wake and thus estimated the range velocity element. A method is erected to implement an effective structure to automatically segment the image after denoising with wavelet filters and accordingly use a manipulation process to calculate the velocity of the vessel. The output would be a systematic process of segmentation and an interactive method to detect the objects in an effective manner.**

Keywords- *Ship velocity, ship detection, radon transformation, wavelet, connected components, evaluation metrics*

I. INTRODUCTION

Ship detection from remote sensed imagery is an invaluable tool for maritime traffic monitoring in area of particular interest (for fishery, tourism, etc.), and for identification of polluter in non-accidental oil spills[1]. Radar are well suited to detect metal non-flat targets, like ships, which result very bright in a radar map, due to their high back-scattering power for radar signal. Synthetic Aperture Radars from space are able to detect ships as well; moreover they are generally able to show ship wakes, as lines darker (or sometimes brighter) than the surrounding sea. The combined detection of a ship and its wake allows to drastically reduce the problem of false detections[1]. The radars performance in ship and wake detection is limited by the sea state: a too high sea state can give a too noisy image in which ships and wakes are no more recognizable. This paper investigates number of procedures and concludes that detection of high-backscattering targets (i.e. bright objects which are ship candidates) , within given grey-value and extension ranges is possible. However acquisition of SAR images faces certain problems[3]. SAR images contain speckle noise which is based on multiplicative noise or rayleigh noise. Speckle noise is the result of two phenomenon, first phenomenon is the coherent summation of the backscattered signals and other is the random interference of electromagnetic signals. Speckle noise degrades the appearance and quality of SAR images [4]. Ultimately it reduces the performances of important techniques of image processing such as detection, segmentation, enhancement and classification. There are three main objectives of any speckle filtering technique. First is to remove noise in uniform regions. Second is to preserve and enhance edges and image features and third is to provide a good visual appearance. Therefore, tradeoff wavelet has being made used among these requirements. Wakes are then automatically searched for each ship candidate, within a given angular range from the ship direction. The detection program is simulated which processes the entire image in some finite time depending on the number of found targets. The outputs are showing all the detected ships and files containing the corresponding information (coordinates, size, mean grey value, direction and presence of wake).The paper is organized as follows: Section 2 deals with denoising with wavelet filters (SAR images). Section 3 deals with target detection using segmentation techniques. Section 4 comprises the methodology for determining velocity Section 5 converses the experimental results of the proposed logic. This paper also concludes with remarks on achievable prospects in this area.

II. DENOISING SAR IMAGE USING WAVELET FILTERS

The two main limitations in image accuracy are categorized as blur and noise. Blur is intrinsic to image acquisition systems, as digital images have a finite number of samples and must respect the sampling conditions. The second main image perturbation is noise. Image denoising is used to remove the additive noise while retaining as much as possible the important signal features. Currently a reasonable amount of research is done on wavelet thresholding and threshold selection for signal de-noising, because wavelet provides an appropriate basis for separating noisy signal from the image signal[7].Two shrinkage methods are used over here to calculate new pixel values in a local neighborhood. Shrinkage is a well known and appealing denoising technique. The use of shrinkage is known to be optimal for Gaussian white noise, provided that the sparsity on the signal's representation is enforced using a unitary transform[6]. Here a new approach to image denoising, based on the image-domain minimization of an estimate of the mean squared error-Stein's unbiased risk estimate (SURE) is proposed and equation (1) specifies the same. The Surelet method directly parameterizes the denoising process as a sum of elementary nonlinear processes with unknown weights. Unlike most existing denoising algorithms, SURE makes it needless to hypothesize a statistical model for the noiseless image. A key of it is, although the (nonlinear) processing is performed in a transformed domain-typically, an undecimated discrete wavelet transform[8], but it also address nonorthonormal transforms-this minimization is performed in the image domain.

$$sure(t;x) = d - 2.\#\{i : |x_i| \le t\} + \sum_{i=1}^{d} (|x_i| \Lambda t)^2 \quad \text{--(1)}$$

where d is the number of elements in the noisy data vector and xi are the wavelet coefficients[11]. This procedure is smoothness-adaptive, meaning that it is suitable for denoising a wide range of functions from those that have many jumps to those that are essentially smooth.

It have high characteristics as it out performs Neigh shrink method. Comparison is done over these two methods to prove the elevated need of Surelet shrinkage for the denoising the SAR images. The experimental results are projected in graph format which shows that the Surelet shrinkage minimizes the objective function the fastest, while being as cheap as neighshrink method. Measuring the amount of noise equation (2) is done by its standard deviation , $\sigma(n)$, one can define the signal to noise ratio (SNR) as

$$SNR = \frac{\sigma(\mu)}{\sigma(n)}, \quad \text{-- (2)}$$

where $\sigma(\mu)$ in equation (3) denotes the empirical standard deviation of $\mu(i)$,

$$\sigma(\mu) = \left(\frac{1}{|I|} \sum_{i} (u(i) - \overline{\mu})^2 \right)^{1/2} \quad \text{--(3)}$$

And $\bar{\mu} = \frac{1}{|I|} \sum_{i \varepsilon I} \mu(i)$ is the average grey level value. The standard deviation of the noise can also be obtained as an empirical measurement or formally computed when the noise model and parameters are known. This parameter measures the degree of filtering applied to the image. It also demonstrates that the PSNR rises faster using the proposed method than the former and its results are stated in experimental section[2]. Figure 1 gives the subjective evaluation results for wavelet filters

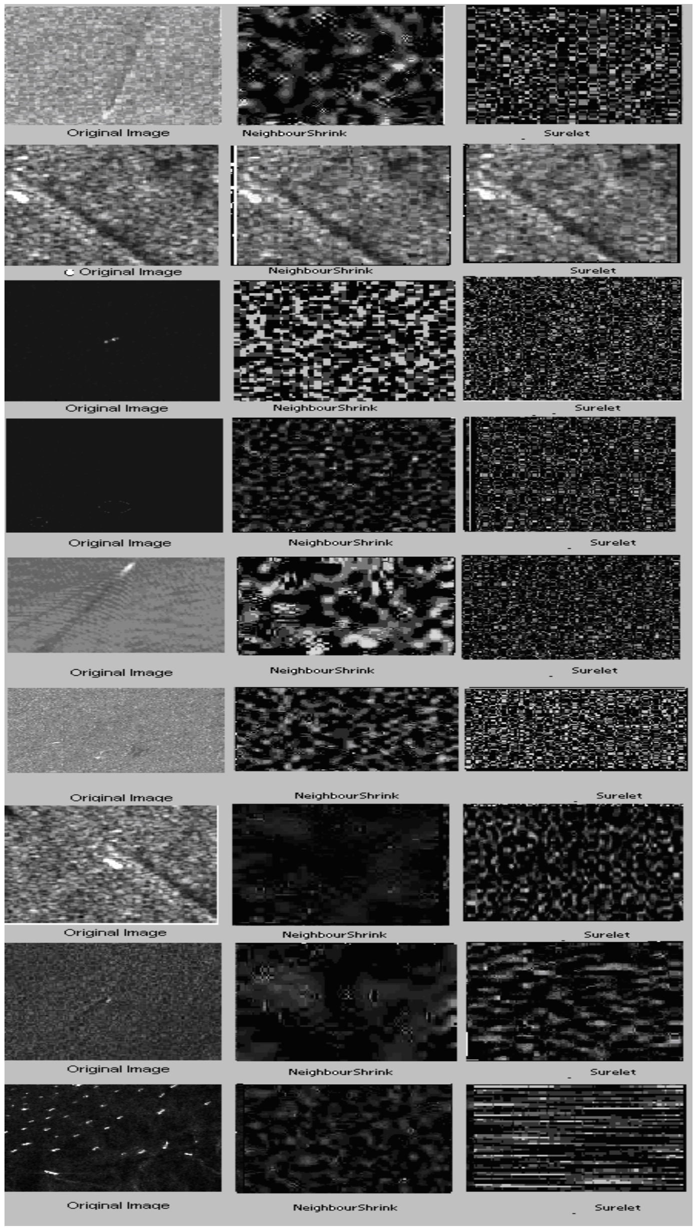


Figure 1 : Subjective evaluation of wavelet denoising filter (SAR image)

III. DETECTION OF TARGET USING CONNECTED COMPONENT

The detection of ships relies on three individual modules that are run independently, and whose results are combined in a subsequent fusion step [12]. Initial ship detection is based on wavelet-analysis, which is combined and analyzed in section 4. The main purpose of segmentation algorithm is to precisely segment the image without under or over segmentation[5]. And this is achieved by comparing threshold based, region finding, object attribute, boundary based and component analysis method. The connected component technique gives better evaluation on SAR images. Every SAR image taken has been implemented with morphological reconstruction, extended maxima transformation using thresholding . The extended maxima transformation is the regional maxima computation of the corresponding *h*-maxima transformation[10]. As a result, it produces a binary image.

This morphological operation suppresses all points whose value with respect to their neighbors is smaller than a threshold level h. It is computed using:

$$HMAX_h(f) = R_f(f - h) \quad \text{-----(4)}$$

where $R_f(f - h)$ is the morphological reconstruction by dilation of image f with respect to f − h. The transform is then followed by an extended maxima operation to identify all regional maxima:

$$EMAX_h(f) = RMAX\left[HMAX_h(f)\right] \quad .....(5)$$

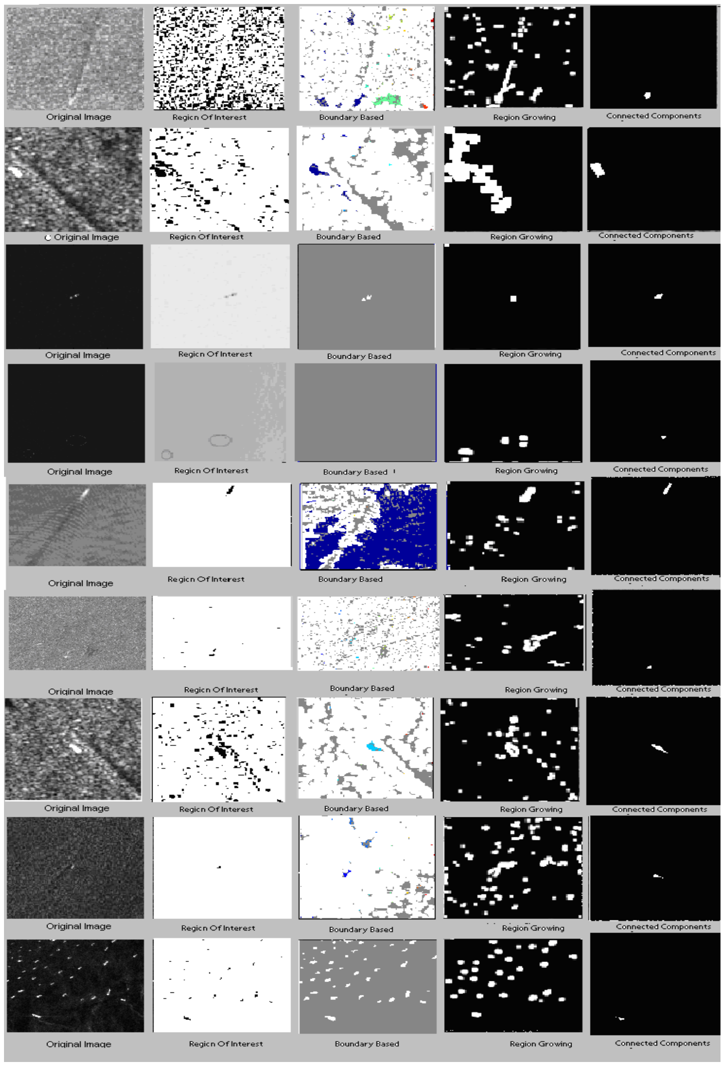


Figure 2: Subjective evaluation of detection algorithm

Morphological filters like the h-maxima transform belong to the class of connected operators. They preserve contour information and produce regions with approximately the same grey values (flat zones concept). A connected-component labeling operation is performed, in order to evaluate the characteristics and the location of every object. As a second object reduction step, objects not located within a region of another object, are also discarded, since target objects are not typically clustered. The region of interest (ie) the target is got by connected component segmentation in which the relevant pixels of the object will be grouped and extorted. The extended-maxima transform computes the regional maxima of the H-maxima transform. Here H refers to nonnegative scalar. Regional maxima are connected components of pixels with a constant intensity value, and whose external boundary pixels will have a lower value

IV. DETERMINING SHIP ORIENTATION AND VELOCITY USING WAKE REPRESENTATION

After detecting the individual target ship pixel is grouped in which target centre and orientation is found using its properties[13]. Region properties measure a set of properties for each labeled region called features [6]. Centre and Orientation of the target is been retrieved from this method of function. Centroid is obtained in 1 by n dimension (L) vector in which center of the target region will be detected. The first element of Centroid is the horizontal coordinate (or x-coordinate) of the center of mass, and the second element is the vertical coordinate (or y-coordinate). The next property of the ship is the orientation the scalar value. It is the measure of angle in degrees between the x-axis and the major axis of the ellipse that has the same second moments.

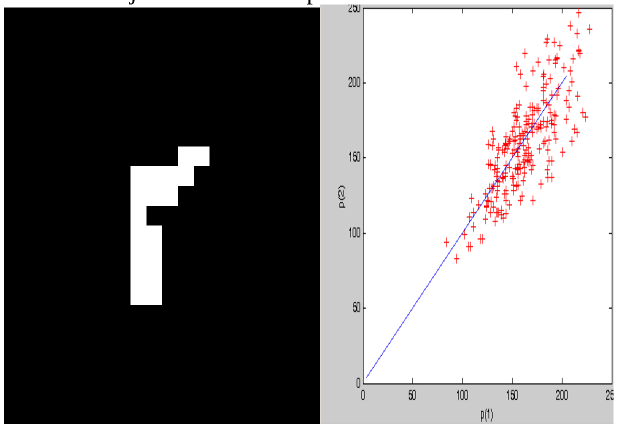


Figure 3: Ship pixels are plotted as scatter plot and the best fit straight line is drawn.

For determining the velocity wake detection is done using radon transformation. Here the proposed method takes advantage of two wavelet filtering techniques and inserts some advance by using the Radon Transform to detect the ship wake and estimate the range velocity component. The proposed technique was applied to synthetic raw data, which contains a moving vessel and its respective wake. The Radon transform calculates the angle that a straight line perpendicular to the track makes with the x-axis in the center of the image. Knowing this, simply add 90º to the value obtained to find the angle of the wake arm. If an image is considered as *I*, with dimensions MxM. The Radon transform $\hat{I}$ is given in equation (7)

$$\hat{I}(\chi_\theta,\theta) = \sum_{y\theta=-M/2}^{M/2} I(x_\theta \cos\theta - y_\theta \sin\theta, x_\theta \sin\theta + y_\theta \cos\theta) \text{-(6)}$$

where ($(x_\theta, y_\theta) \in Z$ and $\theta \in [0;\pi]$ …..(7)

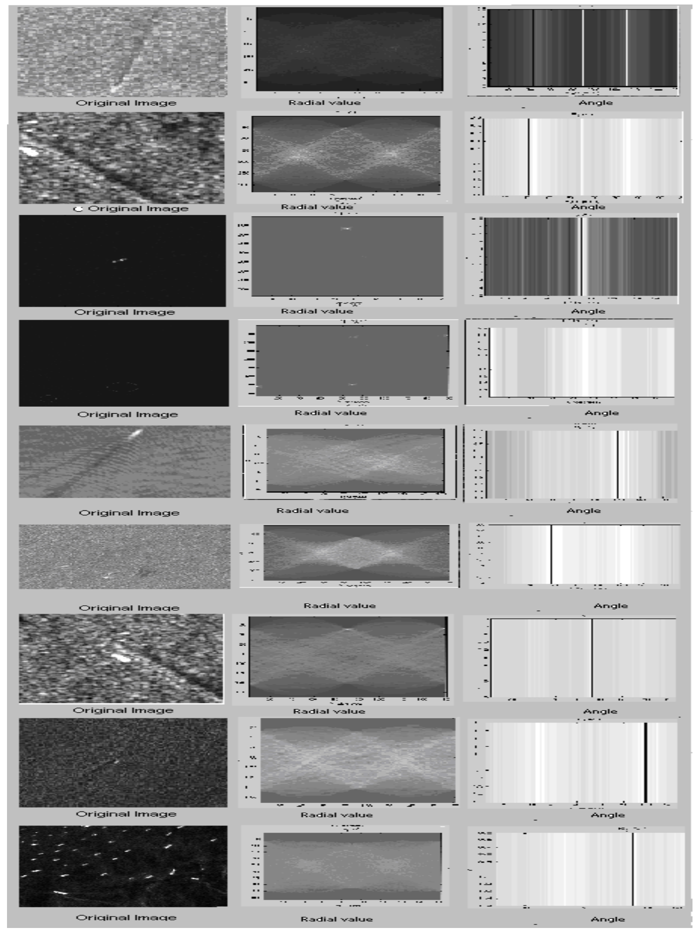


Figure 4: Radon Transfomation (a) Angle and (b) Radial values

Several definitions of the radon transform exist, and expresses lines in the form of rho=x*cos(theta)+y*sin(theta), where theta is the angle and rho the smallest distance to the origin of the coordinate system[12]. The Radon transform for a set of parameters (rho,theta) is the line integral through the image g(x,y), where the line is positioned corresponding to the value of (rho,theta). The delta() is the Dirac delta function which is infinite for argument 0 and zero for all other arguments. Figure 4 gives the subjective results after using radon transformation. This radon function is implied with the original image, and denoised image of two methods. The detection of line segment in the SAR images is more appropriate with surelet denoising and radon transformation then with the former and the conventional method. Experiments are carried over with the proposed method to verify and validate the results. With the angle of both arms of the wake calculated, the equation of the line that passes by each of them can be estimated.

V. PERFORMANCE EVALUATION

To prove the proposed effort the results are also verified with the objective evaluation parameters. The 120 x 120 pixel region SAR images are used for applying the proposed techniques. The images taken are corrupted with noise levels, sigma of 10 20 30 50 75 100. Here surelet method compared with Neighshrink can determine optimal results by using finest threshold instead of using the suboptimal universal threshold in all bands. Figure 5 gives the PSNR values for the denoised images for two methods with noise sigma 30.

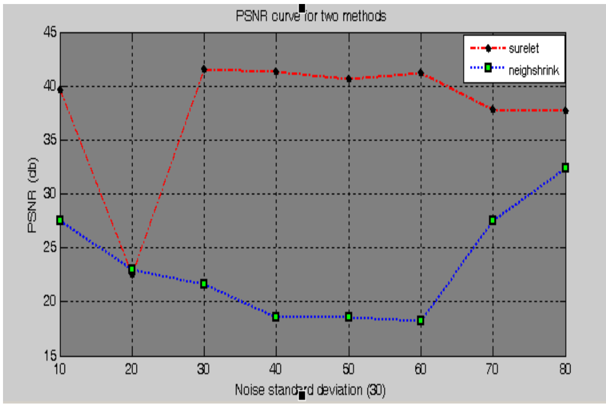


Figure 5: Comparison of PSNR values for two methods (NeighShrink and surelet) for Ten images (with Noise SB 30)

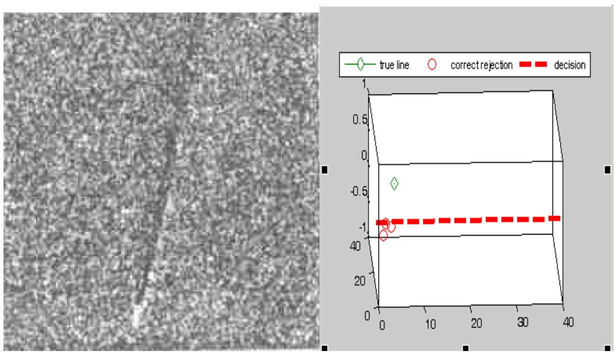


Figure 6 : Decisions in feature space

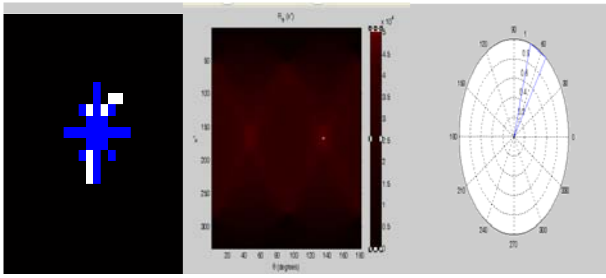
Figure 6 gives the correct rejection rate of non targets is the SAR image. With the extension of the segment work, detection of angle is also compared based on the radial coordinates (rho). The DWT was used with Daubechies, least asymmetric compactly-supported wavelet with eight vanishing moments with four scales[9].

Table 1: Comparison of two methods with change of noise values

SAR images	**Noise values**	**Original values**		**Denosied image (first method with RT**		**Denosied image (first method with RT**	
		Radial	Angle	Radial	Angle	Radial	Angle
Image1	10-100	79	90	79	90	80	90
Image2	10-100	165	42	86	38	83	41
Image3	10-100	135	95	82	135	79	95
Image4	10-100	115	90	81	90	82	90
Image5	10-100	180	120	81	90	79	90
Image6	10-100	105	59	79	60	79	90
Image7	10-100	84	89	80	90	80	89
Image8	10-100	85	140	79	140	79	140
Image9	10-100	259	89	79	89	250	89

A Sample SAR image is taken for estimating the velocity.

The pixel size for ERS SAR PRI image is 12.5m ×12. 5m , and the satellite altitude is h = 780km , and incidence angleθ = 23. 5°, and satellite velocity is 7500m/ s. Real velocity of ship is 7. 162m/ s.



Centroid:[13.11118.1667]   Orientation: 70.1615

The ship velocity is calculated by $\upsilon = \frac{-1}{44}(\frac{\rho}{|\cos\phi|\sin\alpha})$..(8)

Estimated velocity = 7.408163 m/s

The angle f is calculated as $\phi = \tan^{-1}(m)$, and a = f +90° . This is achieved by performing radon transformation. However, in the case of wake detection, it is necessary to have denosied images and that is attained by using best fitted method, surelet and this research work has proven better results in getting angle and rho values effectively. Similarly, it is not necessary to use the full range of r since ship can only travel at some maximum speed. After the transformation, the maximum and minimum of all the g(a ,r) are calculated. The maximum will correspond to a bright turbulent wake while the minimum will be associated with a dark turbulent wake and the wake position in terms of (a ,r) can be identified.

Table 2 gives the experimental results for the velocity estimation.

S.No	Real Velocity m/s	Estimated Velocity m/s
1.	**12.5**	**12.31**
2.	**7.16**	**7.40**
3.	**-2.7**	**-2.69**
4.	**4.1**	**-19.7**

The table 2 depicts that the estimated velocity is almost equivalent to the real velocity by using the proposed methodology.

VIII. CONCLUSION

In the proposed work the methodology is framed based on denoising and its best output is got through transformation techniques. Thresholding and morphological operations steps are also very important for binarization and localization of the detection results. The experiments show that selection of the threshold for each image pair gives more promising results than a global threshold selection. The simulations also show that the other segmentation operation improves results in object detection, although they are very simple. Wake detection is handled with all the conventional transform method and the radon transform gives better solution for finding the velocity of the ship. The results of this detection scheme are reliable and satisfactory while the computation time is quite high compared to background elimination method. However, the segmentation process is very critical in this approach and it may require manual interaction for optimization. Therefore, more consistent unification approaches, which include temporal analysis, is required and is left as a future work.

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AUTHORS PROFILE

Dr. Subashini is the Associate professor in Department of Computer Science, Avinashilingam Deemed University for Women, Coimbatore. She has 16 years of teaching experience. Her areas of interest include Object oriented technology, Data mining, Image processing, Pattern recognition. She has 55 publications at national and International level**.**

Ms.M.Krishnaveni has 4 Years of Research Experience Working as Research staff in DRDO and pursuing her Ph.D in Avinashilingam University for Women, Coimbatore. Her research interest are Image Processing, Pattern Recognition and Neural Networks. She has 24 publications at national and international level.