Image Processing Techniques for Synthetic Aperture Radar Image Segmentation-A Survey

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Abstract – Image segmentation is the most popular research area, which identifies and segments the desired part from an image. The image segmentation is widely used in medical image processing, environmental images, agriculture etc. this paper gives a comprehensive study about the image segmentation on Synthetic Aperture Radar (SAR) images. These images are imaging radar captured from the moving zone. There are different types of image processing techniques have been used to segment such type of images such as edge based, threshold based and wavelet based techniques. The SAR image segmentation has several challenges. This survey gives an overview about SAR images and the different segmentation techniques studied in the literature.

Index Terms – Image processing, image segmentation, Synthetic Aperture Radar.

1. INTRODUCTION

The use of digital images has increased at a rapid pace over the past decade. Photographs, printed text and other hard copy media are now routinely converted into digital form, and the direct acquisition of digital images is becoming more common as sensors and associated electronics improve. Many recent imaging modalities in environmental, such as Synthetic aperture radar (SAR) [1] and sea-ice images are also generate images directly in digital form. Investigative imaging is an invaluable tool in environmental today. These imaging modalities provide an effective means for noninvasive mapping of the anatomy of a subject. These technologies have greatly increased knowledge of normal and abnormal conditions of sea analysis for environmental research and are a critical component in recognition and decision planning. With the increasing size and number of environmental sensors and satellite images, the use of computers in facilitating their processing and analysis has become necessary. Estimation of the volume of the whole sea, parts of the sea-ice and/or objects within sea or ice floes i.e. sea-ice is clinically important in the analysis of environmental image. The relative change in size, shape and the spatial relationships between image structures obtained from intensity distributions provide important information in environmental monitoring and decision making. Therefore, users are particularly interested to observe the size, shape and texture of the sea and/or parts of the sea. For this, sea images are gathered and analyzed in every part of sensors. These routine assessments are commonly subjective and quantitative, and reports typically refer to lesions as large, small, and prominent.

The recognition, labeling and the quantitative measurement of specific objects and structures are involved in the analysis of environmental images. Therefore, to provide the information about an object in terms of its size and shape, image segmentation and classification [2] are important tools needed to give the desired information. In particular, computer algorithms for the delineation of anatomical structures and other regions of interest are a key component in assisting and automating specific radiological tasks. These algorithms, called image segmentation algorithms, play a vital role in numerous medicine and environmental imaging applications. Methods for performing segmentations vary widely depending on the specific application, imaging modality, and other factors. General imaging artifacts such as noise, partial volume effects, and motion can also have significant consequences on the performance of segmentation algorithms. Furthermore, each imaging modality has its own idiosyncrasies.

There is currently no single segmentation method that yields acceptable results for every environmental image. Methods do exist that are more general and can be applied to a variety of images. However, methods that are specialized to particular applications can often achieve better performance by taking into account prior knowledge. Selection of an appropriate approach to a segmentation problem can therefore be a difficult dilemma. The techniques available for segmentation of environmental images are specific to application, imaging modality and type of body part to be studied. For example, requirements of brain segmentation are different from those of thorax. The artifacts, which affect the brain image, are different - partial volume effect is more prominent in brain while in the thorax region it is motion artifact which is more prominent. Thus while selecting a segmentation algorithm one is required to consider all these aspects such as Partial volume effect, Different artifacts: example motion artifacts, ring artifacts, etc. , Noise due to sensors and related electronic system. There is no universal algorithm for segmentation of every environmental image. Each imaging system has its own specific limitations. For example, in SAR imaging (Synthetic aperture radar) one has to take care of bias field noise. Of course, some methods are more general as compared to specialized algorithms and can be applied to a wider range of data. Like Environmental imaging, medical imaging also performed in various modalities, such as MRI, CT, ultrasound, positron emission tomography (PET), etc. This thesis primarily focuses on the segmentation of sea-ice and satellite images.

A. SAR IMAGE:

Synthetic Aperture Radar (SAR) imaging is an active microwave sensor that transmits microwave and identifies the wave that is reflected back by the objects. It facilitates in obtaining high-resolution, high-contrast observation and accurate topographical features of earth while capturing the image from an airplane or satellite. SAR takes the advantage of the long range propagation characteristics of signals and the composite data processing facility of advanced electronic imaging to give the high-resolution images. SAR images have the capacity to pass the signal unaffected by the clouds, illuminate the earth's surface with its own signals, and accurately measure distances making it useful for different applications like land cover mapping, sea ice monitoring, oil spill detection, surface deformation detection, glacier monitoring, crop production forecasting and forest cover mapping.

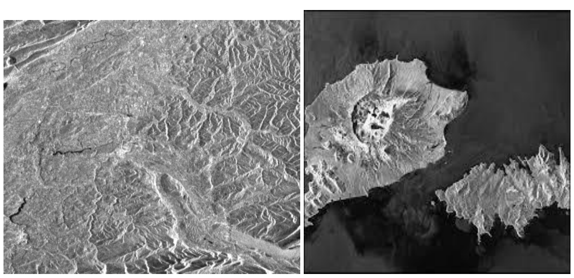

Fig 1.0 sample SAR images

The fig 1.0 shows the SAR image samples taken from satellite.

2. LITERATURE REVIEW

The objective of this literature survey is to present an overview of satellite image de-noising, enhancement and classification problems and solution methods in a concise manner. The desire is to improve the accuracy of images in order to facilitate different applications prevalent in image processing.

Mallat and Hwang (1992) reported that sparsity and multi-resolution structure properties of wavelets give a high performance in image de-noising. In the past two decades, the researchers introduced various algorithms for image de-noising in wavelet transform domain. The focus was shifted to the wavelet transform domain from the spatial and fourier domain. Satellite images are generally affected by noise.

Guo et al (1994) have mentioned that the presence of noise gives the image a speckled, grainy, textured, or snowy appearance. The most important factor is that noise can hide the visibility of certain features within the image.

Donoho (1995) developed a wavelet based thresholding approach. There was a renewed attention in wavelet based de-noising technique since it demonstrated a simple approach to a difficult problem. The different ways of computing the thresholding parameters of wavelet coefficients were also explained. The significant improvements in the quality of an image could be obtained by translating invariant methods based on thresholding of an undecimated wavelet transform which was introduced by Coifman and Donoho (1995). Later these methodologies were used to obtain the nonorthogonal wavelet coefficients to reduce artifacts.

The lifting scheme (LS) developed by Sweldenes (1996) is an alternative to wavelet transform, leading to the second generation wavelet. It is very famous because it has the capacity to adjust the wavelet transform to complex geometries and offers a simple and efficient implementation of traditional, first generation wavelet transform. The natural images are mostly assumed to be affected by an additive noise which is modeled as a Gaussian filter.

Robert (1999) hinted that the speckle noise is observed in ultrasound images whereas rician noise affects Magnetic Resonance Imaging (MRI) images. In the recent years a large amount of research has been performed on wavelet thresholding and threshold selection for de-noising. Since wavelet provides an appropriate basis for separating noisy image from the original image. Selection of threshold value is very important in wavelet thresholding.

Data adaptive thresholding method was introduced by Imola and Chandrika (2001) to achieve optimum value of threshold. Following the thresholding algorithm, Hidden Markov Model (HMM) and Gaussian scale mixture model were developed.

Guoliang Fan and Xiang Gen Xia (2001) proposed a wavelet-domain hidden markov model for image de-noising called Local Contextual HMM (LCHMM). A mixture field was introduced where wavelet coefficients were assumed to locally follow the Gaussian mixture distributions determined by their neighbourhoods. The LCHMM can exploit both the local statistics and the intrascale dependencies of wavelet coefficients at a low computational complexity.

Piella et al (2003) designed the Adaptive Lifting Scheme (ALS) that was able to adapt itself to data. The perception behind the ALS through thresholding is that this scheme perfectly allows to preserve the original characteristics of the input signal. This offers a sparse representation, which makes the thresholding rules more effective than in the case of the traditional non-adaptive LS. However, LS is just a simplified approach to perform DWT, which does nothing to increase the direction flexibility. Therefore researchers have also suggested to present lifting scheme with finer directionality, while retaining its structure and important features by using Adaptive Directional Lifting (ADL) based wavelet transform. Next, much effort has been devoted to Bayesian de-noising in wavelet domain.

Alin et al (2003) proposed a Bayesian-based algorithm within the framework of wavelet analysis, which reduces speckle noise in SAR images while preserving the structural features and textural information of the scene. The Bayesian based algorithm was compared to current state-of the-art soft thresholding techniques applied on real SAR imagery and the achieved performance improvement was quantified. Image filtering can be adopted as a technique to perform de-noising on images. Different algorithms are subjected to the target image depending on the type of the noise that the image is suffering from. It can be done locally, as in the Gaussian smoothing model explained by

Yang et al (2008) or in anisotropic filtering by Antoni et al (2005) or in the frequency domain, such as wiener filters by Suresh et al (2010). Noise is generally additive or multiplicative in nature. There are various types of noise present in the images such as Gaussian noise, salt and pepper noise, speckle noise, Brownian noise, etc., and the effect of these noise are explained by David et al (2006). Wavelet transform has become one of the most important techniques for image de-noising due to its high energy-compaction property. Wavelet-based tools and ideas are still very attractive for image processing problems because of their simplicity and efficiency. The applications of discrete wavelet transform have been extensively studied by Xu et al (2007) and have offered plenty of processing algorithms and realising structures. An important step in wavelet thresholding is the selection of threshold values. An improperly selected threshold value affects not only the denoised image, but also creates visually annoying artifacts.

Ding, Wenpeng (2007) have proposed the ADL based wavelet transform. ADL integrates the directional transform into the structure of conventional lifting scheme and incorporates local spatial direction prediction into each lifting stage. So far, ADL transform has achieved a very good success in image compression introduced by Zhang et al (2007), whereas a very little interest has been given to the probable use for image de-noising.

Zhang, Lei, et al (2010) discussed Principal Component Analysis (PCA) based image de-noising technique. PCA seeks the directions of maximum variance in the datasets and is commonly used for dimensionality reduction. In image de-noising, a compromise has to be made between noise reduction and preserving important signal features. Principal component analysis with Local Pixel Grouping (LPG) is used to reduce noise. The PCA-LPG procedure is applied second time to further improve the de-noising performance, and the noise level is adaptively adjusted in the second stage. Image restoration is used to restore the image affected by degradations to the most preferred form.

Lefkimmiatis et al (2009) focused de-noising technique on astronomy images. These images were mainly affected by atmospheric turbulence blur and additive white Gaussian noise. The researchers proposed a hybrid method to restore astronomy images. This combines three steps to restore a degraded image. The first step is based on phase preserving algorithm used for the de-noising operation. Second, a normalization operation is employed to give the image its normal grayscale intensity. Finally, Richardson Lucy deblurring algorithm is used to perform deblurring depending on the Point Spreading Function (PSF). After completing all the three steps, the expected image will be in the most desirable form. Subhojit et al (2012) expressed the combination of the adaptive median filtering technique and the non-local means filtering algorithm for image de-noising corrupted by salt and pepper noise. If the variance of the noise value is low, the existing filters like median filter and adaptive median filter can denoise salt and pepper noise. But the filters fail to remove noise effectively if the variance of the noise value increased. This method is mainly concentrated to handle salt and pepper noise even at higher variances.

Kaur et al (2012) presented a comparative analysis of various noise de-noising algorithms. The comparative analysis of various de-noising techniques shows that wavelet transform outperforms the other spatial domain filters. Although all the standard spatial filters perform very well on images, they have some assumptions when performing image de-noising.

Yazeed (2012) detailed the performance evaluation of noise reduction using neural networks. This strategy used mean and median statistical functions as the training pattern of the neural network. This also used part of the degraded image pixel to generate the system training pattern. The network is trained using Multi Layer Perceptron (MLP) and Back Propagation Network (BPN). The output of this neural network approach provided a great improvement in image de-noising performance.

Mayuri and Surbhi (2012) reported that in the recent years there has been an increase in the demand for better quality images in various applications such as medicine, astronomy and object recognition. Image resolution enhancement is widely useful for satellite image applications in Geographical Positioning System (GPS). Image resolution enhancement results in the production of better quality images that closely resemble the original image. A large number of methods for image resolution enhancement have been developed. Histogram equalization is one of the most well-known methods for enhancement of images with poor intensity distribution. In the past decade, a number of techniques have been used for increasing the quality of images in various applications. Each technique produces different artifacts and results. Spatial domain methods are commonly applied procedures that operate directly on image pixels.

However, those conventional methods often fail in producing satisfactory results for a broad range of low resolution images contaminated by noise. Wavelet analysis, as a method for image de-noising is far more efficient than linear filters when the image is dominated by transient behavior or discontinuities. The discrete wavelet transform can decompose an image into a form with a series of coefficients. Small coefficients are dominated by noise, while coefficients having a large absolute value carry more signal information than noise. Replacing noisy coefficients below a certain threshold value by zero may result in removal of noise. Early works on thresholding the DWT transform coefficients were found by Temizel and Vlachos (2005). In this method the high resolution image is generated using zero padding of high frequency sub-bands followed by inverse wavelet transform. Low resolution images were followed by wavelet domain resolution enhancement with zero padding i.e. WZP undergoes spatial shifting to generate output high resolution image.

Also, plenty of research efforts have shown that the results using multi-scale contrast enhancement are superior to those obtained using traditional approaches as discussed by Piao et al (2007). The inter sub-band correlation in wavelet domain uses correlation of sub-band with different sampling phases in DWT. Here, the sampling phase in DWT is taken into consideration for design by analyzing correlation between lower level subband and higher level sub-bands. The wavelet filters are estimated by applying wavelet transform to the low resolution image. Estimated filters are used to estimate sub-bands in higher frequency sub-band level. Finally inverse transform is performed to enhance the resolution of the input image.

Gupta and Rajiv (2007) discussed an adaptive wavelet thresholding method to remove noise and enhance the contrast of images, followed by mathematical morphology operations to get a better denoised and enhancement result. When compared with VisuShrink and BayesShrink, the experimental results showed that the proposed method can remove noise more efficiently and adjust the contrast well. Interpolation technique is a method to increase the number of pixels in a digital image.

Interpolation has been widely used in many image processing applications, such as facial reconstruction introduced by Yi-bo et al (2007), multiple description coding developed by Rener et al (2008) and image resolution enhancement. The interpolation-based image resolution enhancement has been used for applications to increase the quality of this task. The nearest neighbour, bilinear, and bicubic are the three well-known interpolation techniques. Bicubic interpolation is more sophisticated than nearest neighbour and bilinear interpolation techniques and produces smoother edges. Wavelet transforms also play an important role in many image processing applications. The decomposition of two dimensional discrete wavelet transform images is performed by applying the one dimensional discrete wavelet transform along the rows of the image first, and then the results are decomposed along the columns.

Turgay and Huseyin (2009) proved that combining the waveletbased method with mathematical morphological operations can generate better enhancement results than the results of using wavelet decomposition alone. However, the researchers mainly dealt with images without noise or with very weak noise; their enhancement methods are incapable of enhancing noisy images. Alexander et al (2010) discussed that the time multiplexed acquisition produces a set of low resolution images which undergoes single frame demosaicing algorithm. Then, the single frames are subjected to monochromatic super resolution to produce high resolution colour images.

Hasan and Gholamreza (2011) suggested the DWT technique for interpolating the images. But the comparative analysis has shown that the result obtained from inverse discrete wavelet transform technique is not sharper and yields low PSNR. Hasan and Gholamreza (2011a) used Complex Wavelet Transform (CWT) for image processing. CWT of an image produces two complexvalued low-frequency sub-band images and six complex-valued highfrequency sub-band images. This technique does not interpolate the original pixels of an image but also interpolates high frequency sub-band image resulting from DT-CWT. The final output image is high resolution of the original input image. Quality and PSNR of the super resolved image also improved in this method Synthetic aperture radar imaging research focusing on classification of an image into water body and non-water body has long attracted the attention of the remote sensing community because classification results are the basis for many environmental and socioeconomic applications. Gong and Howarth (1992), Kontoes et al (1993), Foody (1996), San Miguel-Ayanz and Biging (1997), Aplin et al (1999) and Gallego (2004) have made great efforts in developing advanced classification algorithms and techniques for improving classification accuracy. The airborne and spaceborne remote sensing data vary in spatial, radiometric, spectral and temporal resolutions. The selection of suitable remote sensing data is important while classifying the image into water body and non-water body regions. Understanding the strengths and weaknesses of different categories of sensor data is important issue for image classification.

Althausen (2002) and Lefsky and Cohen (2003) have reviewed the characteristics of major types of remote sensing data for image classification. Researchers summarized the characteristics of different remote sensing data in spectral, radiometric, spatial, and temporal resolutions, polarization and angularity.

Phinn et al (2000) and Lefsky and Cohen (2003) have discussed the selection of suitable remote sensing data as the first essential step for a successful classification for a specific purpose. It requires the following factors: a user's need, the scale and characteristics of a study area, the availability of various image data and their characteristics, cost and time constraints and the analyst's experience in using the selected image. Selection of suitable features is a significant step for successfully implementing the specific applications. The different features used in image classification are spectral information, vegetation indices, transformed images, textural or contextual information, multitemporal images, multisensor images and ancillary data.

Myint (2001), Asner and Heidebrecht (2002), Neville et al (2003), Platt and Goetz (2004) and Christina et al (2009) discussed different feature extraction techniques like principal component analysis, minimum noise fraction transform, discriminant analysis, decision boundary feature extraction, non-parametric weighted feature extraction, wavelet transform, gabor transform, spectral mixture analysis and gray level co-occurrence matrix. These techniques reduced the data redundancy inherent in remotely sensed data or enhanced extraction of specific features of the information. The mapping of classes is much more accurate in supervised classification but is heavily dependent on the given input.

Krishnan et al (2010) compared and analyzed Singular Value Decomposition (SVD) and Gray Level Co-occurrence Matrix as two methods for feature extraction. The comparison shows that GLCM gives a better result than SVD. Chen and Stow (2002) hinted that a sufficient number of training samples and their representations are vital for image classifications. The training samples are collected from fieldwork, aerial photographs and satellite images. The various collection strategies such as a single pixel, seed and polygon may be used, but they would influence classification results, especially for classifications with fine spatial resolution image data.

3. PROBLEM DEFINITION

Automatic identification of individual floe edges is a key tool for extracting information of floe size distribution from satellite images. In an actual ice covered environment, ice floes typically touch each other, and the junctions may be difficult to identify in satellite images. This issue challenges the boundary detection of individual ice floes and significantly affects ice floe size analysis. Several researchers have tried to mitigate this issue like separated closely distributed ice floes by setting a threshold higher than the ice-water segmentation threshold and separated the connected ice floes manually when the threshold did not work well. When compared derivative and morphology boundary detection algorithms in both model ice and sea-ice images will not work in proper manner. The boundaries are too weak to be detected directly, which significantly affects the ice floe statistical result. However, non-closed boundaries are often produced by traditional derivative boundary detection, while some boundary information is often lost by morphology boundary detection.

4. CONCLUSION

In this survey, we discussed various tools and techniques for Synthetic Aperture Radar Image Segmentation using image processing techniques. There are numerous researches have done segmentation process for with various images. In this paper, we described the challenges and problems associated with the SAR images. In specific, the ice floe images are taken and various issues are tracked in that.

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