ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 2, Issue 4, April 2014

A Review on Image Processing Techniques for Synthetic Aperture Radar (SAR) Images

P.Geetha[1], B. Chitradevi[2]

M.Phil Research Scholar, Dept. of Computer Science, Thanthai Hans Roever College, Perambalur, Tamil Nadu, India[1]

Asst. Professor, Dept. of Computer Science, Thanthai Hans Roever College, Perambalur, Tamil Nadu, India[2]

ABSTRACT: Synthetic Aperture Radar (SAR) has been deeply used for sea ice monitoring in polar regions. A computer aided analysis of SAR sea ice imagery is extremely difficult due to several imaging parameters and environmental factors. Image processing and neural network techniques are used to improve the performance of detecting and classifying sea ice in SAR images. This paper gives an overview of image processing techniques of SAR images and its recent progress. The primary objective of this paper is to summarize some of the well known methods used in various stages of image processing system.

KEYWORDS: Synthetic aperture radar, Sea ice, Preprocessing, Segmentation, Feature extraction and Classification.

I. INTRODUCTION

Sea ice is frozen water characterized by a sheet of ice of varying thickness floating on the surface of the ocean. It is constantly changing due to melting, freezing, ocean currents and wind. Even though sea ice occurs in some of the most remote regions of the Earth, it has a great impact on the climate, the ecosystem, and human activities. Classification of sea ice is a difficult task in naval surface. In order to overcome such scenario an automated computer aided classification system is required. Image processing techniques are used to improve the performance of classification sea ice in synthetic aperture radar images. The following figure comprises the four basic steps in image processing system.

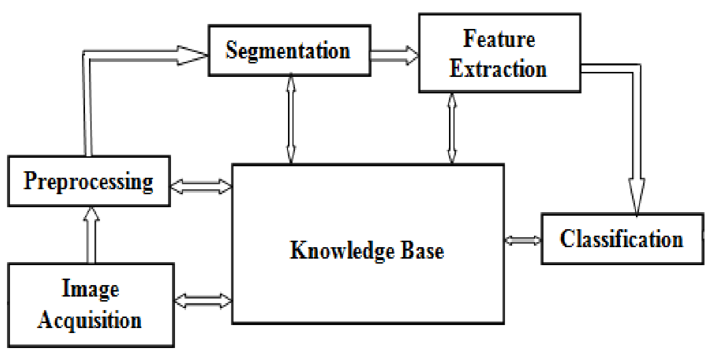

Fig.1. Fundamentals steps in digital image processing

ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 2, Issue 4, April 2014

Digital Image Processing is largely concerned with four basic operations: image preprocessing, segmentation, feature extraction and image classification. *Image preprocessing:* Image data recorded by sensors on a satellite restrain errors related to geometry and brightness values of the pixels. These errors are corrected using appropriate mathematical models which are either definite or statistical models. Image enhancement is the modification of image by changing the pixel brightness values to improve its visual impact. *Segmentation:* It refers to the process of partitioning a digital image into multiple segments. It is the process of assigning a label to every pixel in an image such that pixels with the same label share certain visual characteristics. The goal of segmentation is to simplify and change the representation of an image into something that is easier and more meaningful to analyze.

Feature extraction: The feature extraction techniques are developed to extract features in synthetic aperture radar images. This technique extracts high-level features needed in order to perform classification of targets. Features are those items which uniquely describe a target, such as size, shape, composition, location etc. *Image classification:* The objective of image classification procedures is to automatically categorize all pixels in an image into land cover classes or themes. A pixel is characterized by its spectral signature, which is determined by the relative reflectance in different wavelength bands. Multi-spectral classification is an information extraction process that analyses these spectral signatures and assigns the pixels to classes based on similar signatures.

II. SEA ICE

Sea ice plays an important role in the Earth's climate. Its high albedo causes much of the sunlight that hits its surface to be reflected back into space. The reflected solar energy helps keep the polar region cool. When sea ice begins to melt, more sunlight is absorbed. This causes the area to warm up, which leads to more melting ice. Thus, sea ice impacts the Earth's radiation budget and alters the temperature of the polar regions. Areas of open water within the sea ice can lose heat rapidly causing the ice to grow. The ice formation produces dense brine which sinks into the ocean. In the reverse process, melting ice creates an influx of fresh water at the ocean's surface. Sinking brine and low density freshwater significantly affect the ocean circulation [1].

Many human activities rely on knowledge of sea ice. Knowledge about the sea ice can improve our understanding of the climate of the Earth. Sea ice plays critical roles in not only the earth's climate system but also human activities. Navigation is one of the most important issues on human activity. The navigations concerns, marine creatures, marine operations and human's traditional way of life are likely to impact by sea ice. So detecting ice and obtaining a near-real report is very essential [1].

Table.1 illustrates the various ice types and physical properties of sea ice are introduced to make sense how they have impacts on the appearances of various ice types in SAR imagery. It is necessary to understand the properties of new ice, gray ice and first year ice since these three types of ice cover the study area.

ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 2, Issue 4, April 2014

Ice Type	Definition
New ice	A general term for recently formed ice. These types of ice are composed of ice crystals, which are only weakly frozen together (if at all) and have a definite form only while they are afloat. Here, new ice refers collectively to frazil, grease ice, nilas and pancake ice.
Frazil ice	Fine spicules or plates of ice, suspended in water
Grease ice	A later stage of freezing than frazil ice when the crystals have coagulated to form a soupy layer on the surface. Grease ice reflects little light giving the sea a matte appearance.
Nilas ice	A thin elastic crust of ice easily bending on waves and swell and under pressure, thrusting in a pattern of interlocking “fingers” (finger rafting). Has a matte surface and is up to 10 cm in thickness.
Pancake ice	Predominantly circular pieces of ice from 30 cm – 3 m in diameter, and up to about 10 cm in thickness, with raised rims due to the pieces striking against one another.
Young ice	Ice in the transition stage between nilas and First-year ice, 10-30 cm in thickness. May be subdivided into grey and grey-white ice.
Gray ice	Young ice 10-15 cm thick. Less elastic than nilas and breaks on swell. Usually rafts under pressure.
Gray white ice	Young ice 15-30 cm thick. Under pressure more likely to ridge than to raft.
First year ice	Sea ice of not more than one winter’s growth, developing from young ice; thickness 30 cm – 2 m. May be subdivided into thin First-year ice (30-70 cm thick), medium First-year ice (70-120 cm thick) and thick First-year ice (over 120 cm thick).

Table.1. Brief description of the various ice types

III. SYNTHETIC APERTURE RADAR

Synthetic-aperture radar (SAR) uses microwave radiation to illuminate the Earth’s surface. An image is formed after the SAR system receives the coherent sum of reflected radiation at the antenna that is synthesized by the large motion of the sensor system. Since SAR provides its own illumination, it overcomes some of the fundamental problems associated with conventional passive remote sensing. For example, SAR is not affected by cloud cover or variation in solar illumination, and thus can operate day or night. Under certain circumstances, radar can partially penetrate arid and hyper-arid surfaces, revealing subsurface features of the Earth. Although radar does not penetrate standing water, it can reflect the surface action of oceans, lakes, and other bodies of water and may sometimes provide information about the bottom features of the water body. Electromagnetic waves emitted by active sensors travel in phase and interact minimally on their way to the target area. Sea ice signatures are detectable by Synthetic Aperture Radar (SAR)

ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 2, Issue 4, April 2014

Satellites like RADARSAT-1, ERS1, ERS2, ENVISAT, JERS, and the newest generation of SAR systems like RADARSAT-2 and Terra SAR-X. Part of the emitted radar energy (5.6 cm wavelength) directed at the ocean is reflected back to the satellite because of the roughness of the sea surface and is imaged as a gray speckle [2]. Fig.2 shows the processing of synthetic aperture radar.

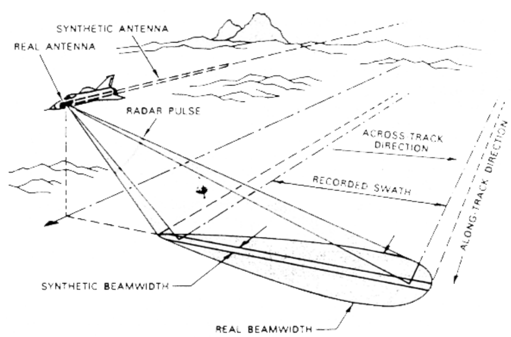

Fig.2 SAR Processing

IV. IMAGE PREPROCESSING

M. Mansourpour , M.A. Rajabi , J.A.R. Blais proposed the ***Frost Filter*** technique for image preprocessing. The Frost filter replaces the pixel of interest with a weighted sum of the values within the nxn moving kernel. The weighting factors decrease with distance from the pixel of interest. The weighting factors increase for the central pixels as variance within the kernel increases. This filter assumes multiplicative noise and stationary noise statistics [3].

A ***gradient based adaptive median filter*** is used for removal of speckle noises in SAR images. In this method fourth order gradient is introduced to reduce the oscillations at high frequencies (i.e. noise) which are much effective than second order gradients. This method is used to reduce/remove the speckle noise, preserves information, edges and spatial resolution and it was proposed by S.Manikandan, , Chhabi Nigam, J P Vardhani and A.Vengadarajan [4].

The ***Wavelet Coefficient Shrinkage (WCS) filter*** is based on the use of Symmetric Daubechies (SD) wavelets. There are two advantages in using SD wavelets (ie) symmetric extension prevents discontinuities introduced by a periodic wrapping of the data and identical vanishing of the second centered moment of the real part of the scaling function provides better approximation at sampling points [5]. The WCS filter developer by L. Gagnon and A. Jouan in 1997.

Discrete Wavelet Transform (DWT) has been employed in order to preserve the high-frequency components of the image. The resolution enhancement technique uses DWT to decompose the input image into different sub bands. Then, the high-frequency sub band images and the input low-resolution image have been interpolated, followed by combining all these images to generate a new resolution enhanced image by using inverse DWT [6]. In order to achieve a sharper image, an intermediate stage for estimating the high-frequency sub bands has been proposed by P. Karunakar, V. Praveen and O. Ravi Kumar.

V. SEGMENTATION

Image segmentation is a process of dividing an image into different regions based on certain attributes such as intensity, texture, color, etc. This process is fundamental in computer vision and many applications, such as object recognition, image compression, image retrieval, and feature extraction etc., various approaches of SAR image segmentation have been proposed and the recent work includes a variety of techniques. For example, clustering algorithm, threshold methods, morphologic methods, graph-based approaches, and statistic model-based methods.

ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 2, Issue 4, April 2014

Maximally Stable Extremal Regions (MSER) algorithm and spectral clustering (SC) method is proposed by Yang Gui, Xiaohu Zhang and Yang Shang to provide effective and robust segmentation. First, the input image is transformed from a pixel-based to a region-based model by using the MSER algorithm. The input image after MSER procedure is composed of some disjoint regions. Then the regions are treated as nodes in the image plane, and a graph structure is applied to represent them. Finally, the improved SC is used to perform globally optimal clustering, by which the result of image segmentation can be generated [7].

Modified SRG (MSRG) procedure was developed by Young Gi Byun, You Kyung Han, and Tae Byeong Chae. In the approach, the SRG algorithm is modified to make use of information in all spectral bands and edge information for better image segmentation. A seed selection method based on the local variation characteristics of a multispectral edge is also developed to obtain seeds for the Modified SRG (MSRG) procedure. Image segmentation is achieved by applying the MSRG procedure, which integrates the multispectral and gradient information to provide homogenous image regions with accurate and closed boundaries [8].

The ***Holder exponent*** is used as a tool to utilize the spatial and spectral information together to compute the degree of texture around each pixel in the high-resolution panchromatic images. The measure of dispersion is employed to compute the Holder exponent. A clustering procedure including maximum likelihood analysis is used to classify the Holder exponent image. The method adequately segment complex images containing texture regions as well as non-texture regions. This method was proposed by Debasish Chakraborty, Gautam Kumar Sen and Sugata Hazra in 2009 [9].

Ousseini Lankoande, Majeed M. Hayat, and Balu Santhanam used a novel ***Markov Random Field (MRF) based segmentation algorithm*** for SAR images based on minimizing a proposed Convex Gibbs energy function, which is derived from the statistical properties of speckle noise. The proposed algorithm can be applied to speckled imagery directly without the need for preprocessing the imagery for speckle-noise reduction. Second, the proposed algorithm has the ability to differentiate various targets within an image, which make the resulting segmentation more reliable [10].

The feature extraction is one of the key steps for SAR ATR. It can greatly reduce the amount of information processing by SAR ATR, improve the identification efficiency, reduce the time of recognition and lower resources utilization by means of the feature extraction.

VI. FEATURE EXTRACTION

The feature extraction is one of the vital steps for image processing techniques. It can greatly reduce the amount of information processing by SAR images, improve the identification efficiency, reduce the time of recognition and lower resources utilization by means of the feature extraction.

A feature extraction technique is presented that extracts ice floes from SAR Sea ice imagery. The Leen-Kiat Soh and Tsatsoulis, C investigates two types of floe: 1) independent ice floes that collide and meet, and 2) component ice floes that melt and consolidate to form an independent ice floe. To detect independent ice floes, the authors consider two kinds of edges: clear edges and blurred edges. They use a ***spatial enhancement technique combined with thresholding*** to obtain the clear edges. To detect the blurred edges, they make use of corners which are pixels where a considerable change in direction of a floe boundary occurs. To connect the corners appropriately, they incorporate both their geometric and semantic properties into heuristics that choose which pair of corners to connect. To investigate component ice floes, they have developed a technique that combines thresholding, correlation, morphological cleaning, and structural growing [11].

John F. Vesecky, Martha P. Smith and Ramin Samadani report image processing techniques for extracting the characteristics of pressure ridge features in SAR images of sea ice. Bright filamentary features are identified and broken into segments bounded by either junction between linear features or ends of features. ***Ridge statistics*** are computed using the ***filamentary segment*** properties. Estimates of the density of sea ice ridging and the distribution

ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 2, Issue 4, April 2014

of lengths and orientation are made. The information derived is useful in studying sea ice characteristics for ice science in remote sensing (ice classification) and in polar off shore operations (ship routing) [12].

Karvonen, J. and Kaarna.A have studied the feature extraction from sea ice SAR images based on non-negative factorization methods. The methods are the ***sparseness-constrained non-negative matrix factorization (SC-NMF)*** and ***Non-negative tensor factorization (NTF)***. The studies performed show that these methods can be used to extract meaningful features from SAR images and that they can be used in sea ice SAR classification [13].

The Neural Network algorithm uses both ***backscatter data and textural characteristics*** of the images. Texture depends on the spatial scale of sea ice surface and volume inhomogeneity, as well as on radar spatial resolution. Texture features describe spatial variations of image brightness within a group of neighbor pixels large enough to calculate statistically significant estimates [14].

A given texture feature can be different from one ice type to another and reflect variability in sea ice properties sensed by the SAR. Before texture can be used in classification, it is necessary to investigate which texture features are useful for differentiation between the ice types defined in this study. A set of texture features has therefore been calculated in a number of SAR images using ***gray-level co-occurrence matrix (GLCM)*** [14]. This method was proposed by Natalia Yu. Zakhvatkina, Vitaly Yu. Alexandrov, Ola M. Johannessen, Stein Sandven and Ivan Ye. Frolov.

VII. CLASSIFICATION

Image classification analyzes the numerical properties of various image features and group similar features as clusters. Classification will be executed on the base of spectral or spectrally defined features, such as density, texture etc. Classification algorithms typically employ two phases of processing: training and testing. In the initial training phase, characteristic properties of typical image features are isolated and based on these, a unique description of each classification category, i.e. training class, is created. In the subsequent testing phase, these feature-space partitions are used to classify image features.

Wang, Tan, Yang and Xuezhi proposed a multi-level SAR sea ice image classification method. First, sub images which correspond to egg codes are segmented by using the region-level MRF model. Then, other egg code regions are classified in a hierarchical way and the intensity mean of each class can be computed, hence sea ice classification in the whole SAR scene can be finished based on the ***Euclidean distance discriminant method***. The efficiency of the proposed method is demonstrated on the classification of real SAR sea ice images [15].

The ***K-Nearest Neighbor (KNN) Algorithm*** is a method for classifying objects based on the closest or most similar training samples in the feature space. It is a form of instance based learning. The nearest neighbor is determined by the use of distance function. An object is classified by a majority vote of its neighbors. It is an extension of nearest neighbor algorithm as it takes into account nearest k neighbors instead of a single nearest neighbor to vote for the majority of classification for a pixel [16]. This algorithm was proposed by Kanika Kalra, Anil Kumar Goswami and Rhythm Gupta.

Independent component analysis (ICA) is used by Karvonen, J. and Simila, M. to compute sets of basis vectors for image data, i.e. for small randomly selected image windows. From these basis vectors a smaller set is selected to be used in classifying sea ice SAR images. A SAR image window is classified based on its projection to the selected basis vectors [17].

A supervised neural network learning architecture was used by Lars Kaleschke and Stefan Kern for classification, namely Kohonen's ***Learning Vector Quantization (LVQ)***. LVQ approximates the probability density functions by a set of optimally placed vectors which are called codebook vectors (CV). The codebook is generated by learning from examples of class labeled feature vectors. Representative examples of all occurring classes have to be selected. The LVQ neural network classification was found to be very flexible by learning from examples [18].

ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 2, Issue 4, April 2014

VIII. CONCLUSION

This paper has analyzed different image processing techniques which have the feasible to support the classification of sea ice in synthetic aperture radar imagery. In synthetic aperture radar imaging applications, various components of image processing systems are examined. These components are Image preprocessing, segmentation, feature extraction, and classification. For each of these components, image processing techniques with the potential to improve the performance of sea ice in synthetic aperture radar systems were discussed, and examples of successful or instructive methods from the literature were given.

REFERENCES

1. F. Carsey, Microwave Remote Sensing of Sea Ice. American Geophysical Union, no. 68. 1, 2, 1992.
2. Fang Qiu, Judith Berglund and Pathik Thakkar "Speckle Noise Reduction in SAR Imagery Using a Local Adaptive Median Filter" GI Science and Remote Sensing, 41, No. 3, 2004.
3. M. Mansourpour , M.A. Rajabi , J.A.R. Blais" EFFECTS AND PERFORMANCE OF SPECKLE NOISE REDUCTION FILTERS ON ACTIVE RADAR AND SAR IMAGES" isprs, XXXVI/1-W41.
4. S.Manikandan, , Chhabi Nigam, J P Vardhani and A.Vengadarajan "Gradient based Adaptive Median filter for removal of Speckle noise in Airborne Synthetic Aperture Radar Images" ICEEA ,2011.
5. L. Gagnon and A. Jouan "Speckle Filtering of SAR Images - A Comparative Study between Complex-Wavelet-Based and Standard Filters" SPIE, 1997.
6. P. Karunakar, V. Praveen and O. Ravi Kumar"Discrete Wavelet Transform-Based Satellite Image Resolution Enhancement" Advance in Electronic and Electric Engineering, ISSN 2231-1297, Volume 3, Number 4, pp. 405-412, 2013.
7. Yang Gui, Xiaohu Zhang and Yang Shang "SAR image segmentation using MSER and improved spectral clustering" *EURASIP, 2012.*
8. Young Gi Byun, You Kyung Han, and Tae Byeong Chae" A Multispectral Image Segmentation Approach for Object-based Image Classification of High Resolution Satellite Imagery" KSCE,2012.
9. Debasish Chakraborty, Gautam Kumar Sen and Sugata Hazra" High-resolution satellite image segmentation using Holder exponents " J. Earth Syst. Sci. 118, No. 5, October 2009, pp. 609–617.
10. Ousseini Lankoande, Majeed M. Hayat, and Balu Santhanam "Segmentation of SAR Images Based on Markov Random Field Model".
11. Leen-Kiat Soh and Tsatsoulis" A feature extraction technique for synthetic aperture radar (SAR) sea ice imagery" IEEE, 1993.
12. John F. Vesecky, Martha P. Smith and Ramin Samadani"Extraction of Ridge Feature Characteristics from Sar Images of Sea Ice" IEEE, 1989.
13. Karvonen, J. and Kaarna, A."Sea Ice SAR Feature Extraction by Non-Negative Matrix and Tensor Factorization" IEEE, 2008.
14. Natalia Yu. Zakhvatkina, Vitaly Yu. Alexandrov, Ola M. Johannessen, Stein Sandven, and Ivan Ye. Frolov "Classification of Sea Ice Types in ENVISAT Synthetic Aperture Radar Images" IEEE, 2012.
15. Wang, Tan, Yang and Xuezhi"A multi-level SAR sea ice image classification method by incorporating egg-code-based expert knowledge" IEEE, 2012.
16. Kanika Kalra, Anil Kumar Goswami and Rhythm Gupta "A Comparative Study of Supervised Image Classification Algorithms for Satellite Images" IJEEDC, 2013.
17. Karvonen.J and Simila.M "Independent component analysis for sea ice SAR image classification" IEEE, 2001.
18. Lars Kaleschke and Stefan Kern"ERS-2 SAR Image Analysis for Sea Ice Classification in the Marginal Ice Zone" DFG.

BIOGRAPHY

Geetha.P is a M.Phil Research Scholar in the Computer Science Department, Thanthai Hans Roever College, Bharathidasan University, She received Master of Computer Application (MCA) degree in 2008. Her research interests are Image Processing, Neural Network Algorithms etc.

B. Chitradevi is a Assistant Professor in the Computer Science Department, Thanthai Hans Roever College, Bharathidasan University, She finished M.Sc.,M.Phil and B.Ed degrees. Her research interests are Image Processing, Data Mining and Neural Network Algorithms etc.