CHAPTER 1

INTRODUCTION

1.1 Need for the Study

The Synthetic Aperture Radar (SAR) which is an active microwave sensor utilized for capturing the two dimensional images. The image brightness is a contemplation of the microwave backscattering properties of the surface. The critical tool in oil spill monitoring is the SAR that is deployed on satellites and it is considered as an important tool because of its wide area coverage both day and night, in all-weather conditions. There has been a dangerous increment in the extent of incidents of marine pollution. The marine oil spills are very dangerous and it can be blown out over a widespread areas. The oil spill accidents in the past decades as a consequence of our massive oil consumption have raised global awareness. There are many approaches which includes infrared (IR), radar, radiation, lasers and night vision techniques that have been developed to monitor and detect oil spills which have been hound to be expensive and complex and require high processing power and time. Identification of oil spills from SAR images is complex task that has recently come into use and there are different approaches and techniques under study. The basic information about SAR images, SAR imaging methods, various image processing methods and the advantages and disadvantages of SAR image processing is studied

1.2 SAR imaging

Environmental monitoring, earth-resource mapping, and military systems require broad-area imaging at high resolutions. Often, this imagery must be acquired at night or during inclement weather. Synthetic Aperture Radar (SAR) provides such a capability. Synthetic Aperture Radar (SAR) systems take advantage of the long-range propagation characteristics of radar signals and the complex information processing capability of modern digital electronics to provide high resolution imagery. Synthetic Aperture Radar (SAR) complements photographic and other optical imaging capabilities because it is not limited by the time of day or atmospheric conditions and because of the unique responses of terrain and cultural targets to radar frequencies.

Synthetic Aperture Radar (SAR) technology has provided terrain structural information to geologists for mineral exploration, oil spill boundaries on water to environmentalists, sea state and ice hazard maps to navigators, and reconnaissance and targeting information to military operations. There are many other applications for this technology. Some of these, particularly civilian, have not yet been adequately explored because lower cost electronics are just beginning to make Synthetic Aperture Radar (SAR) technology economical for smaller scale uses. Synthetic Aperture Radar (SAR) produces a two-dimensional (2-D) image. One dimension in the image is called range (or cross track) and is a measure of the "line-of-sight" distance from the radar to the target. Range measurement and resolution are achieved in Synthetic Aperture Radar (SAR) in the same manner as most other radars: range is determined by measuring the time from transmission of a pulse to receiving the echo from a target and, in the simplest Synthetic Aperture Radar (SAR), range resolution is determined by the transmitted pulse width, i.e. narrow pulses yield fine range resolution. The other dimension is called azimuth (or along track) and is perpendicular to range.

Synthetic Aperture Radar’s (SAR) ability to produce relatively fine azimuth resolution differentiates it from other radars. To obtain fine azimuth resolution, a physically large antenna is needed to focus the transmitted and received energy into a sharp beam. The sharpness of the beam defines the azimuth resolution. Similarly, optical systems, such as telescopes, require large apertures (mirrors or lenses which are analogous to the radar antenna) to obtain fine imaging resolution. Since Synthetic Aperture Radar (SAR) is much lower in frequency than optical systems, even moderate Synthetic Aperture

Radar (SAR) resolutions require an antenna too large to be practically carried by an airborne platform: antenna lengths several hundred meters long are often required.

However, airborne radar can collect data while flying this distance, and then process the data as if it came from a physically long antenna. The distance the aircraft flies in synthesizing the antenna is known as the synthetic aperture. A narrow synthetic beam width results from the relatively long synthetic aperture, which yields finer resolution than is possible from a smaller physical antenna. Achieving fine azimuth resolution may also be described from a Doppler processing viewpoint. A target's position along the flight path determines the Doppler frequency of its echoes, targets ahead of the aircraft produce a positive Doppler offset, while targets behind the aircraft produce a negative offset. As the aircraft flies a distance (the synthetic aperture), echoes are resolved into a number of Doppler frequencies. The target's Doppler frequency determines its azimuth position. While this section attempts to provide an intuitive understanding; Synthetic Aperture Radars (SARs) are not as simple as described above. Transmitting short pulses to provide range resolution is generally not practical. Typically, longer pulses with wide-bandwidth modulation are transmitted, which complicate the range processing but decreases the peak power requirements on the transmitter. For even moderate azimuth resolutions, a target's range to each location on the synthetic aperture changes along the synthetic aperture.

The energy reflected from the target must be "mathematically focused" to compensate for the range dependence across the aperture prior to image formation. Additionally, for fine-resolution systems, the range and azimuth processing are coupled (dependent on each other) which also greatly increases the computational processing.

1.3 RADAR Imaging

Imaging radar is an application of radar which is used to create two-dimensional images, typically of landscapes. Imaging radar provides its light to illuminate an area on the ground and take a picture at radio wavelengths. It uses an antenna and digital computer storage to record its images. In a radar image, one can see only the energy that was reflected back towards the radar antenna. The radar moves along a flight path and the area illuminated by the radar, or footprint, is moved along the surface in a swath, building the image as it does so. Digital radar images are composed of many dots. Each pixel in the radar image represents the radar backscatter for that area on the ground: brighter areas represent high backscatter, darker areas represents low backscatter.

The traditional application of radar is to display the position and motion of typically highly reflective objects (such as aircraft or ships) by sending out a radio wave signal, and then detecting the direction and delay of the reflected signal. Imaging radar on the other hand attempts to form an image of one object (e.g. a landscape) by furthermore registering the intensity of the reflected signal to determine the amount of scattering (cf. light scattering). The registered electromagnetic scattering is then mapped onto a two-dimensional plane, with points with a higher reflectivity getting assigned usually a brighter color, thus creating an image. Several techniques have evolved to do this process.

In General they take advantage of the Doppler effect caused by the rotation or other motion of the object and by the changing view of the object brought about by the relative motion between the object and the back-scatter that is perceived by the radar of the object (typically, a plane) flying over the earth. Through recent improvements of the techniques, radar imaging is getting more accurate. Imaging radar has been used to map the Earth, other planets, asteroids, other celestial objects and to categorize targets for military systems.

1.4 SAR images

Typically, Synthetic Aperture Radar (SAR image given in Figure 1.1 produces a two-dimensional (2-D) image. One dimension in the image is called range (or cross track) and is a measure of the “line-of-sight” distance from the radar to the target. Inverse synthetic aperture radar (ISAR) is a radar technique using Radar imaging to generate a two-dimensional high resolution image of a target. It is analogous to conventional SAR, except that ISAR technology utilizes the movement of the target rather than the emitter to create the synthetic aperture. A Synthetic Aperture Radar (SAR), or SAR, is a coherent mostly airborne or space borne side looking radar system which utilizes the flight path of the platform to simulate an extremely large antenna or aperture electronically, and that generates high-resolution remote sensing imagery.

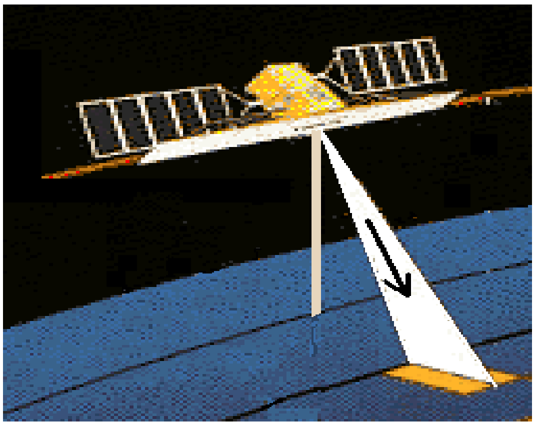

Figure 1.1 Sample SAR Image

Electromagnetic radiation in the microwave wavelength region is used in remote sensing to provide useful information about the Earth's atmosphere, land and ocean. A microwave radiometer is a passive device which records the natural microwave emission from the earth. It can be used to measure the total water content of the atmosphere within its field of view. A radar altimeter sends out pulses of microwave signals and record the signal scattered back from the earth surface. The height of the surface can be measured from the time delay of the return signals. A wind scatter meter can be used to measure wind speed and direction over the ocean surface. It sends out pulses of microwaves along several directions and records the magnitude of the signals backscattered from the ocean surface. The magnitude of the backscattered signal is related to the ocean surface roughness, which in turns is dependent on the sea surface wind condition, and hence the wind speed and direction can be derived. One platform to generate high resolution images of the earth surface using microwave energy.

1.5 Synthetic Aperture Radar (SAR)

In synthetic aperture radar (SAR) imaging, microwave pulses are transmitted by an antenna towards the earth surface. The microwave energy scattered back to the spacecraft is measured. The SAR makes use of the radar principle to form an image by utilizing the time delay of the backscattered signals as shown in Figure 1.2 (a) A radar pulse is transmitted from the antenna to the ground, and Figure 1.2 (b) The radar pulse is scattered by the ground targets back to the antenna.

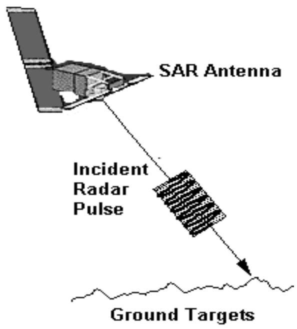

Figure 1.2 (a) A radar pulse is transmitted from the antenna to the ground.

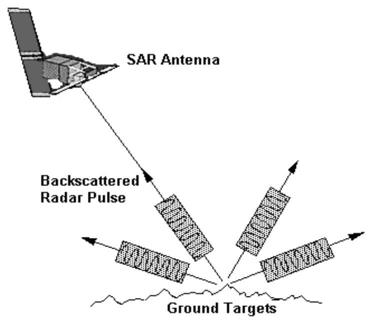

Figure 1.2 (b) The radar pulse is scattered by the ground targets back to the antenna.

In real aperture radar imaging, the ground resolution is limited by the size of the microwave beam sent out from the antenna. Finer details on the ground can be resolved by using a narrower beam. The beam width is inversely proportional to the size of the antenna, i.e. the longer the antenna, the narrower the beam. The microwave beam sent out by the antenna illuminates an area on the ground (known as the antenna's "footprint"). In radar imaging, the recorded signal strength depends on the microwave energy backscattered from the ground targets inside this footprint. Increasing the length of the antenna will decrease the width of the footprint as shown in Figure 1.3.

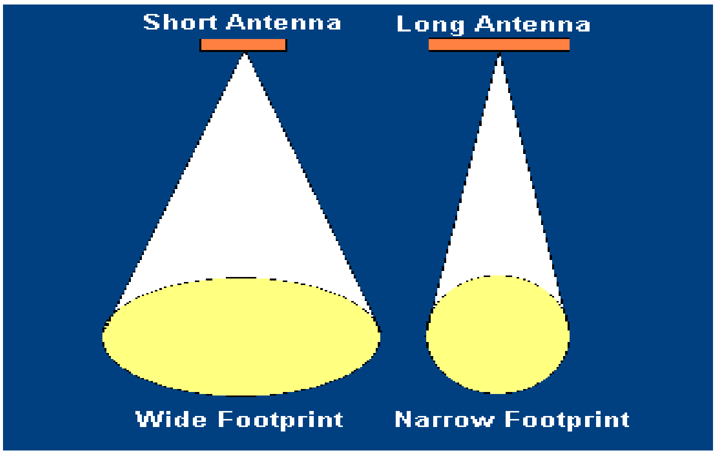

Figure 1.3 Radar Imaging

It is not feasible for a spacecraft to carry a very long antenna which is required for high resolution imaging of the earth surface. To overcome this limitation, SAR capitalizes on the motion of the space craft to emulate a large antenna (about 4 km for the ERS SAR) from the small antenna (10 m on the ERS satellite) it actually carries on board.

1.6 Interaction between Microwaves and Earth's Surface

When microwaves strike a surface, the proportion of energy scattered back to the sensor depends on many factors:

- Physical factors such as the dielectric constant of the surface materials which also depends strongly on the moisture content.
- Geometric factors such as surface roughness, slopes, orientation of the objects relative to the radar beam direction.

- The types of land cover (soil, vegetation or man-made objects).
- Microwave frequency, polarization and incident angle.

1.7 All-Weather Imaging

Due to the cloud penetrating property of microwave, SAR is able to acquire "cloud-free" images in all weather. This is especially useful in the tropical regions which are frequently under cloud covers throughout the year. Being an active remote sensing device, it is also capable of night-time operation.

The word “radar” is an acronym for Radio Detection and Ranging. Radar measures the distance, or range, to an object by transmitting an electromagnetic signal to and receiving an echo reflected from the object. Since electromagnetic waves propagate at the speed of light, one only has to measure the time it takes the radar signal to propagate to the object and back to calculate the range to the object. The total distance traveled by the signal is twice the distance between the radar and the object, since the signal travels from the radar to the object and then back from the object to the radar after reflection. Therefore, once we measured the propagation time t, we can easily calculate the range R as shown in the equation (1.1).

$$R=\frac{1}{2}ct, \qquad (1.1)$$

Where c**,** is the speed of light in vacuum and the factor $\frac{1}{2}$accounts for the fact that the radar signal actually travelled twice the distance measured, first from the radar to the object and then from the object to the radar. If the electric property of the propagation medium is different from that of vacuum, the actual propagation velocity has to be estimated for advanced radar techniques, such as Synthetic Aperture Radars (SAR) interferometry. Radars provide their own signals to detect the presence of objects. Therefore, radars are known as active, remote-sensing instruments. Because radars provide their own signal, they can operate during day or night. In addition, radar signals typically penetrate clouds and rain, which means that radar images can be acquired not only during day or night, but also under (almost) all weather conditions. For these reasons, radars are often referred to as all-weather instruments. Imaging, remote-sensing radars, such as SAR, produce high-resolution (from sub meter to a few tens of meters) images of surfaces. The geophysical information can be derived from these high-resolution images by using proper post-processing techniques. The work focuses on a specific class of implementation of synthetic aperture radar with particular emphasis on the use of polarization to infer the geophysical properties of the scene. As mentioned above, SAR is a way to achieve high-resolution images using radio waves. The next basics of radar imaging is discussed and followed by a description of the synthetic aperture principle. Finally, discussed some advanced SAR implementations, such as SAR polarimetry and polarimetric SAR interferometry.

1.8 Basic Principles of Radar Imaging

Imaging radars generate surface images that are at first glance very similar to the more familiar images produced by instruments that operate in the visible or infrared parts of the electromagnetic spectrum. However, the principle behind the image generation is fundamentally different in the two cases. Visible and infrared sensors use a lens or mirror system to project the radiation from the scene on a “two-dimensional array of detectors”, which could be an electronic array or, in earlier remote-sensing instruments, a film using chemical processes.

The two-dimensionality can also be achieved using scanning systems or by moving a single line array of detectors. This imaging approach taking photographs with a camera conserves the relative angular relationships between objects in the scene and their images in the focal plane, as shown in Figure 1.4. Because of the conservation of angular relationships, the resolution of the images depends on how far away the camera is from the scene it is imaging. The closer the camera, the higher the resolution and the smaller details can be recognized in the images. As the camera moves further away from the scene, the resolution degrades and only larger objects can be discerned in the image.

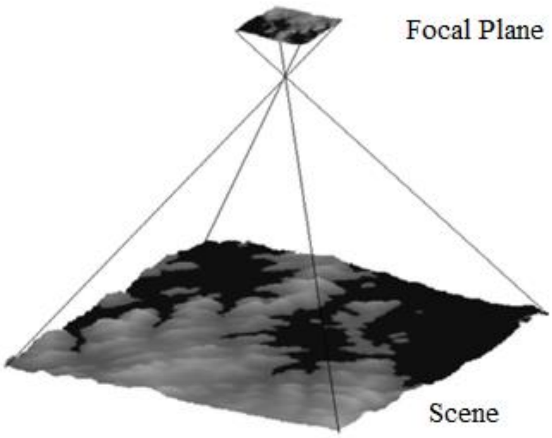

Figure 1.4 Passive imaging systems conserve the angular relationships between objects in the scene and their images in the focal plane of the instrument.

Imaging radars use a quite different mechanism to generate images, with the result that the image characteristics are also quite different from that of visible and infrared images. There are two different mechanisms by which radars can be used to produce images, the two types of radars are broadly classified as real aperture and synthetic aperture radars. The difference between these two types is discussed in more detail.

Radar images are typically acquired in strips as the satellite or aircraft carrying the radar system moves along its flight path. These strips are often referred to as swaths or tracks. To separate objects in the cross-track direction and the along-track direction within a radar image, two different methods must be implemented. The cross-track direction, also known as the range direction in radar imaging, is the direction perpendicular to the direction in which the imaging platform is moving. The direction of radar echoes and separated using the time delay between the echoes that are back-scattered from the different surface elements. This is true for both real aperture and synthetic aperture radar images. The along-track direction, also known as the azimuth direction, is the direction parallel to the movement of the imaging platform.

The angular size (in the case of the real aperture radar) or the Doppler history (in the case of the synthetic aperture radar) is used to separate surface pixels in the along-track dimension in the radar images. The azimuth imaging mechanism of real aperture radars is similar to that of regular cameras. Using the time delay and Doppler history results, SAR images have resolutions that are independent of how far away the radar is from the scene it is imaging.

The fundamental advantage enables high-resolution, space borne SAR without requiring an extremely large antenna. Another difference between images acquired by cameras operating in the visible and near infrared part of the electromagnetic spectrum and radar images is the way in which they are acquired. Cameras typically look straight down, or at least have no fundamental limitation that prevents them from taking pictures looking straight down from the spacecraft or aircraft.

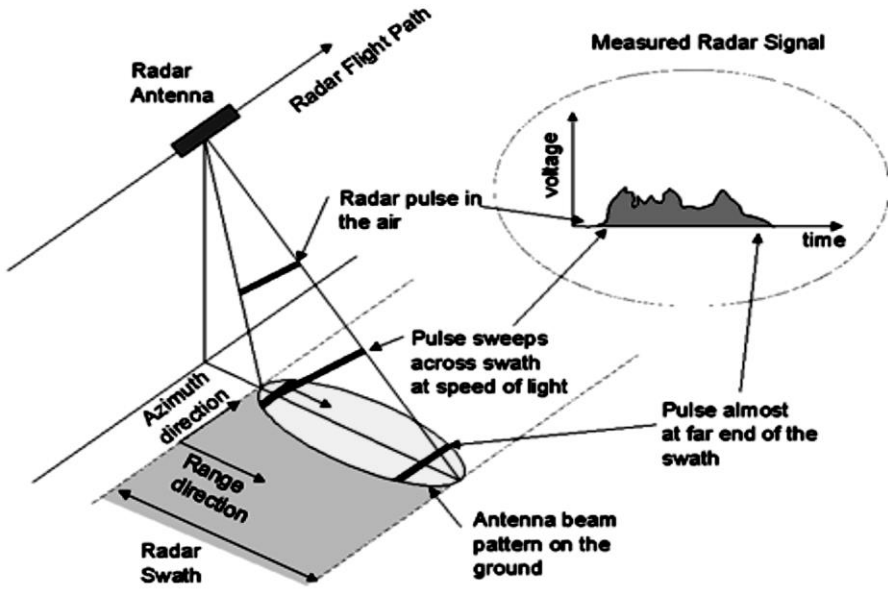

Figure 1.5 Imaging geometry for a side-looking radar system

To avoid so-called ambiguities, which we will discuss in more detail later, the imaging radar sensor has to use an antenna that illuminates the surface to one side of the flight track. Usually, the antenna has a fan beam that illuminates a highly elongated, elliptically shaped area on the surface, as shown in Figure 1.5. The illuminated area across the track generally defines the image swath.

1.9 Image processing methods

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. The primary objective of this chapter is to summarize some of the well-known methods used in various stages of image processing system. 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. Digital Image Processing is largely concerned with four basic operations such as, 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.

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.

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. M. Mansourpour, M.A. Rajabi, J.A.R. Blais (2006), 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 n x n 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. 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 Manikandan.S,Chhabi Nigam, VardhaniJ. P and Vengadarajan.A, in 1997.

The Wavelet Coefficient Shrinkage (WCS) filter is based on the use of Symmetric Daubechies (SD) wavelets. There are two advantages in using SD wavelets that is 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. 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. In order to achieve a sharper image, an intermediate stage for estimating the high-frequency sub bands has been proposed.

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. There are various approaches for SAR image segmentation that have been proposed and in the recent work include a variety of techniques, such as clustering algorithm, threshold methods, morphologic methods, graph-based approaches and statistic model-based methods.

Maximally Stable Extremely 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.

Modified SRG (MSRG) procedure was developed by Young GiByun, You Kyung Han, and Tae ByeongChae. 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. The Holder exponentis 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 DebasishChakraborty, Gautam Kumar Sen and SugataHazra in 2009. OusseiniLankoande, Majeed M. Hayat, and BaluSanthanam 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. 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, and reduce the time of recognition and lower resources utilization by means of the feature extraction.

1.10 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, and 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-KiatSoh and Tsatsoulis, C investigates two types of floe such as, 1) independent ice floes that collide and meet, and 2) component ice floes that melt and consolidate to form an independent ice floe.

The independent ice floes have to be detected, so 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. John F. Vesecky, Martha P. Smith and RaminSamadani 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 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). Karvonen.J and Kaarna.A, have studied the feature extraction from sea ice SAR images based on nonnegative 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. 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.

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 ices 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). This method was proposed by Natalia Yu. Zakhvatkina, Vitaly Yu. Alexandrov, Ola M. Johannessen, Stein Sandven and Ivan Ye.Frolov.

1.11 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 discriminate method. The efficiency of the proposed method is demonstrated on the classification of real SAR sea ice images. 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. This algorithm was proposed by KanikaKalra, 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 .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.

1.12 Need for Image processing

Image processing is often viewed as arbitrarily manipulating an image to achieve an aesthetic standard or to support a preferred reality. However, image processing is more accurately defined as a means of translation between the human visual system and digital imaging devices. The human visual system does not perceive the world in the same manner as digital detectors, with display devices imposing additional noise and bandwidth restrictions. Salient differences between the human and digital detectors will be shown, along with some basic processing steps for achieving translation. Image processing must be approached in a manner consistent with the scientific method so that others may reproduce, and validate, one's results. This includes recording and reporting processing actions, and applying similar treatments to adequate control images.

In imaging science, image processing is processing of images using mathematical operations by using any form of signal processing for which the input is an image, a series of images or a video, such as a photograph or video frame; the output of image processing may be either an image or a set of characteristics. As a subcategory or field of digital signal processing, digital image processing has many advantages over analog image processing. The technical restrictions and constraints that professional photographers work to are never considered by the amateur or the hobbyist. Constraints such as will the darker tones be distinguishable from black in a CMYK print-out, or conversely are the almost white and lighter tones bright enough, or even too bright, to distinguish against chapter white for the CMYK process. Prior to digital photography these things were controlled by the manipulation of film processing and film scanners. Tonal range and colour were controlled in the lighting and also film processing but mostly through the deft control of lighting. In digital photography considerably more latitude is possible after image capture; that is in the processing stages.

The above needs help to understand that a professional photographer will mostly shoot in digital “Raw” format. Raw images are much like a latent image in film, although unlike film, the image is readily visible. It is also important to note here that Raw format offers the highest quality possible in digital capture. Raw format is captured in RGB, representing the colours red, blue and green respectively. A number of adjustments can be made to improve a Raw image and often the difference between a Raw image and a fully processed image is substantial. And of course then there follows the almost limitless option of photo manipulation, but that is a much broader topic. So having captured the image for the client in the highest possible quality the files then need to be converted from Raw into a format useable by graphic designers and printers. To maintain the highest quality files are firstly converted from Raw to RGB 16 Bit Tiffs and generally worked on at this stage using photo editing software. Once the tonal range of the image meets the photographer’s expectations the file is then converted to CMYK format. CMYK represent the inks used by printers and the letters stand for cyan, magenta, yellow and black respectively. Here problems can occur. Because RGB contains a much broader colour gamut than CMYK, colours are often lost and need to be manipulated to resemble something close to the original RGB capture. Sometimes this is not possible and a compromise follows. Colour problems such as these often occur with dyed media, such as fabrics, paints and plastics. At this point the photographer may choose to retouch any blemishes in the subject matter, as well as any dust spots. Dust spots are tiny specks of dust, usually invisible to the naked eye. They attach themselves to the surface of the CCD, (Charge-coupled Device). They appear on the image as semi-transparent dark spots and can spoil images if not removed. The final stage of processing is the sharpening of the image. Sharpening is required on most images and the amount of sharpening can vary from image to image, depending on the number of pixels a subject has. For example a close-up of a coin using most of the CCD's capture area will have far more pixels defining the edges, texture and colour than the same coin photographed in a pile of let's say 100 coins. The amount of sharpening will then vary in these two images and that is the sum total of image processing.

1.13 Advantages of SAR Image processing

State-of-the-art high-resolution SAR sensors provide a detailed mapping of man-made objects, which could not be achieved by radar remote sensing only a few years ago. Structural image analysis approaches were up to now either tailored for extended targets or the extraction of rather coarse scene descriptions. Based on the new high-resolution data, a much finer level of detail of the object recognition seems to be possible. Polarimetry is expected to be of growing relevance for the analysis of urban areas. The geocoding accuracy should match the resolution of the SAR data and therefore the height reference data must represent the buildings. Precise geocoding is a prerequisite e.g. for the fusion of multi-aspect SAR data or the fusion of SAR data with complementing data of different kind. For many applications only a subset of the scene is of interest. In such cases, multi-scale processing and analysis are useful to speed up the analysis. SAR data with decimeter resolution contains often object details not represented in a given 3D model of the scene. Hence, the 3D model can be enhanced analyzing the SAR data.

1.14 Objectives of the Study

The objective of this research is to provide a novel method for identifying environmental pollutants on oceans using SAR Images. Oil spill in ocean is the main environmental pollutants that severely damage the marine ecosystems. The main focus is to detect oil spills from SAR images, solving oil spill monitoring and detection problems using SAR images. The oil spill location is detected and classified using different image processing techniques like Preprocessing, Segmentation, Classification that evaluate the efficiency of the oils spill detection based on accuracy, sensitivity and specificity.

1.15 Problem Statement and Proposed Solution

Problem Statement 1:

To find the location of the oil spill in the ocean. An automatic system is required to give early information where it leads to cleaned up getting more damages in the ocean.

Proposed Solution 1:

i) Designed and developed an automated approach for applying pattern recognition for oil spill detection in SAR image.

ii) Segmentation done using Watershed segmentation and features are extracted using GLCM method. The detection accuracy is increased.

Problem Statement 2:

i) To detect oil spill in the SAR image using Automatic technique.

Proposed Solution 2:

i) Automatic Computer Aided Diagnostic System is designed to know the oil spill location and its severity using SAR images.

ii) The images are segmented and the statistical features are extracted and classified using Multi-Class SVM classifier.

Problem Statement 3:

i) To automatically detect the expansive or small oil spills in RADARSAT-2 SAR satellite data sheet.

ii) To detect any type of SAR images in short processing time.

Proposed Solution:

i) MSVM approach is used to classify various kind of classes and it can be used in any types of SAR images.

ii) Dual –Threshold method is used for the detection of oil where it utilizes intensity estimation within a determined boundary.

Problem Statement 4:

i) Existing oil spill detection methods are expensive and complex and require high processing power and time.

ii) Noise removal and extracting the features of oil spill images are the issues.

Proposed Solution 4:

i) A Novel segmentation technique- Adaptive Edge and Texture Clustering is used to the detect and classify the oil spill area

ii) The images are extracted using Convoluted horizontal vertical (CHV) pattern extraction technique.

iii) Relevance vector Machine (RVM) classification technique is used to classify the oil spill portion.

1.16 Methodology of the Proposed Work

1.16.1 An Automatic Pattern Matching Approach for Oil Spill Detection in SAR Images

An Automatic Pattern Matching Approach for Oil Spill Detection in SAR Images is used to find the location of the oil spill in the ocean. The partitioned grid image is segmented using watershed segmentation and from the segmented image, set of features is extracted using GLCM method. From the extracted features like entropy and energy, the oil spill portion is detected. To enhance the quality of the image the image is preprocessed which helps to facilitate later segmentation due to non-exudates regions. Segmenting the image can be obtained by watershed segmentation within the image boundary. Partitioning and super-pixel generation based segmentation are applied to provide a uniform verification on the entire image to check for oil spill detection. For each pixel Pi, the probability $Prob_i$ is calculated in terms of a threshold value in each partition. Finally, the missing super-pixels are calculated, and then the watershed segmentation is applied over the Binarized image. In order to obtain the accurate information about the super-pixels all, the super-pixels are clustered. This clustering process detects and eliminates missed super-pixels in the image. Whenever finds the parts bigger than the highest threshold T is taken as the centers *CSP* of the confirmed oil spills. According to the size of the clustered portion and intensity distance value the negative portions are confirmed and eliminated and the other portions are extracted. The extracted result portion represents the oil spill on the SAR images.

1.16.2 An Automatic Computer Aided Diagnostic System for Oil Spill Detection and Classification in SAR Images

The second stage of the research work is to build up a completely Automatic Computer Aided Diagnostic System (ACADS) for the detection of oil spills in SAR images. In order to do this, the whole proposed ACADS is carried out in four distinct stages such as,

(i) Read and Preprocess the input image,
(ii) Binary Operation based Image Segmentation,
(iii) Feature Extraction and
(iv) Classification of the oil spill portion.

The Lee filter is used to remove the noise. It is a familiar statistical filter derived from both the additive and multiplicative noise. Here it is applied to eliminate speckle noises for preserving the edges and feature points in SAR images. Enhanced Histogram Equalization (EHE) method is used to increase the quality of the image. The binary operations are applied continuously to detect and segment the oil spills that occur in the enhanced image. The statistical features are extracted from the segmented image and it is classified using Multi-Class SVM classifier.

Then Adaptive Histogram Equalization method is used to enhance the contrast of images. Contrast level of the image can be enhanced by transforming the values in the intensity image. It operates on small data regions (tiles), rather than the entire image which is dissimilar to HISTEQ. The resultant image shows, the result of the enhancement process can deliver an enhanced image where it give exact contrast and brightness value of the image and the image is converted into binary image. Next the morphological operations are applied on the image to structure, open, segment, close and reconstruct the image. These morphological operations can do segmentations on binary images perfectly. From the segmented images the texture and statistical features are extracted using GLCM method. After extracting the features described above from the image is used for classification. In this stage, a multi class SVM classifier is used for classification. It is used to confirm the segmented object that is oil spill from the input image.

1.16.3 Dual Threshold MSVM Based Oil Spill Detection from Radarsat-2 SAR Satellite Dataset

In the third stage of the research, it is mainly focused on public concern to make healthier in terms of coastal regions and ecological systems. This stage detects and segment the oil spills on the SAR images using Dual-Threshold (DT) method classified using Multi-Class Support Vector Machine (MSVM) method. The entire flow of this stage is, read the input image is preprocessed for removing the speckle noised using speckle noise removal method. Then the preprocessed images will be segmented using low-threshold method after histogram analysis. Similarly, the preprocessed images will be segmented using high-threshold method for keeping track of the dark spots boundary. From the boundary the shape of the oil spills can be obtained for classification.

Finally, MSVM is used to classify the detected oil spill from low and high threshold method. The novelty of this paper is to reduce the false alarm in term of detection and classification accuracy by using the lowest and highest threshold values of the SAR images.

1.16.4 Segmentation and Classification of the Oil Spills from SAR Imagery

In the final stage of the research, a novel approach called as Adaptive Edge and Texture Clustering (AETC) for oil spill detection, segmentation and classification technique is utilized by comparing with the previous stages of this research work, here the edge based segmentation is applied for improving the efficiency in feature extraction. This approach use clustering technique for improving the segmentation accuracy. In the proposed approach a Convoluted Horizontal Vertical (CHV) pattern extraction technique and Relevance Vector Machine (RVM) is used for improving the classification accuracy. Hence the research improved the overall efficiency of the oils spill detection, segmentation and classification process.

1.17 Limitation of SAR Image processing

The pollution in marine environment due to oil spill into the ocean makes a harmful disaster to the species present in the environment. In order to provide protection, first the location of the oil spill in the ocean has to be detected. So, an automatic system is required to give early information where it leads to cleaned up getting more damages in the ocean. The problem is it is not able to track properly so it is taken into account, but still more research work has to be carried out in order to avoid this circumstances, for a better surveillance monitoring system using SAR images.

1.18 Organization of the Thesis

The content of the research thesis is organized in the following manner.

- **Chapter 1** gives an introduction to SAR imaging, and Image processing methods. This chapter discusses about oil spill detection system and its severity using SAR image.

- **Chapter 2** discusses about a detailed literature survey and various earlier research works focused on Image processing, SAR image processing and Oil Spill detection with its merits and demerits.
- **Chapter 3** discusses about an Automatic Pattern Matching Approach for Oil Spill Detection in SAR Images, and it is aimed to create a detection system to know the oil spill location using SAR image.
- **Chapter 4** discusses about an Automatic Computer Aided Diagnostic System for Oil Spill Detection and Classification in SAR Images. The proposed ACADS method is carried out in 4 distinct stages (i) Read and preprocess the input image (ii) Binary operation based image segmentation (iii) feature Extraction(iv) Classification of oil spill portion.
- **Chapter 5** discusses about Morphological Characters based Oil Spill Detection from Radarsat-2 SAR Satellite Dataset and GLCM method is applied for extracting the texture features for classification.
- **Chapter 6** discusses about the segmentation and classification of the oil spills from SAR Imagery. The oil spill images are preprocessed to eliminate speckle noise by Gaussian distribution function, and clustered by Linear Edge Weighted based super pixel method. After Segmentation by Adaptive edge and Texture clustering technique
- **Chapter 7** presents Performance Evaluation in terms of Detection Accuracy
- **Chapter 8** presents the conclusion of research work and the scope for future study.