CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Earth observation satellites offer comprehensive and continually updated information about our planet. This includes information about earth’s atmosphere, oceans and coasts, land surface and polar regions, among others, that can be effectively used in disaster relief, climate research, and environmental and security monitoring. Accurate and timely change detection of the earth's surface features is important in these areas in order to aid policy making and emergency action.

Aizen et al (2007) discussed in the polar regions, the melting of glaciers due to an increase of average temperature in the previous decades, and the subsequent rise in sea levels, are some of the aspects monitored by the use of remote sensing data. In marine environment, changing conditions, storm propagation and distribution of temperature and wind are analysed.

Climate related and human induced changes such as natural disasters, land and ocean changes, ecosystem interference, etc., are analyzed through remote sensing. Some of the problems like population stress, decrease in economic productivity, deepening social differences, and migration occur due to scarcity and environmental degradation. This scarcity and environmental degradation can be effectively analyzed using remote sensing data.
Satellite images play a vital role in modern computer aided applications like geographical information systems. Synthetic Aperture Radar (SAR) imaging is widely used for acquiring high-resolution images of the earth. These images are used in the fields of remote sensing, oceanography, geology, ecology and interferometry.

Satellite images are greatly affected by unwarranted noise likely to be contributed by capturing devices, transmission media, discrete sources of radiation and other environmental aspects. Moreover, noise can be introduced by transmission errors and compression.

The removal of noise from these images is a challenging problem for researchers because this introduces artifacts and causes blurring of the images. In order to remove the presence of noise in the images, many complex denoising techniques have been proposed. In spite of the complexity of the existing methods, these techniques have not yet achieved a desirable level of applicability. All show a good performance when the images are corresponding to the assumption of an algorithm but remove image fine structures. Thus, efficient denoising is the first and crucial step to be taken before the images are analyzed.

One of the important objectives of this research is to first define a mathematical and experimental methodology called hybrid directional lifting for image denoising. This technique is then compared with existing image denoising algorithms for assessing the performance of the proposed technique.

The primary aim of this research is to improve the accuracy of classifying an image into water body and non-water body regions. The improvement of classification accuracy results in better realization of edge and contour information in an image. An application requires an image that can be easily examined by a human and that can be analyzed and interpreted.
by a system. There are two distinct strategies to achieve the classification accurately. First, the image can be displayed appropriately so that the conveyed information is maximized. Hopefully, this will help a human to extract the desired information. Second, the image can be analyzed so that the useful part of the data is preserved and the remaining data is discarded. This requires the importance of the useful part, and makes the enhancement technique application specific.

Image resolution enhancement focuses on modifying the resolution of an image so that the result is similar to the original image. Images can have geometric distortions due to different satellite view angles, variable ground resolution cell sizes, environmental conditions and directional reflectance effects from surface materials. For overcoming these geometric distortions, satellite image resolution enhancement is very important in image processing applications. Here, a DWT based interpolation technique is proposed to improve the resolution of the satellite image.

The image classification technique is broadly divided into unsupervised and supervised learning techniques. Clustering algorithms used for unsupervised learning of remote sensing data vary according to the efficiency with which clustering takes place. The unsupervised clustering provides the cluster information about the water body in a relatively quick manner. This lacks complete information about the region of interest and particularly subtle variations therein. To avoid unexpected groupings, supervised classification is recommended.

The mapping of classes is much more accurate in supervised classification but is heavily dependent on the input given. The classes of interest that are the water body and non-water body areas and the learning rate are determined to optimize the classification accuracy of the images. This
research aims to further improve the accuracy of classification by considering five texture features as input.

A support vector machine is a supervised learning algorithm that analyze the inputs and recognize the water body and non-water body classes, used for classification and regression. The performance of the classification shows the requirement of denoising and resolution enhancement technique.

This chapter is organized as follows. Synthetic aperture radar imaging is discussed in section 1.2. An overview of existing methodologies is given under literature survey in section 1.3. Objectives of the thesis are outlined in section 1.4. Section 1.5 describes the organization of the thesis.

1.2 SYNTHETIC APERTURE RADAR IMAGING

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.
1.3 LITERATURE SURVEY

The objective of this literature survey is to present an overview of satellite image denoising, 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 denoising. In the past two decades, the researchers introduced various algorithms for image denoising 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 denoising 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 Colifman and Donoho (1995). Later these methodologies were used to obtain the non-orthogonal 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 denoising. 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 denoising 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 (2002) 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 denoising 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 denoising 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 Alle et al. (2004) and 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 denoising 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.

Wenpeng and Peng (2007) and Chang and Girod (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 denoising.

Murali et al (2012) discussed Principal Component Analysis (PCA) based image denoising technique. PCA seeks the directions of maximum variance in the datasets and is commonly used for dimensionality reduction. In image denoising, 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 denoising 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. Zohair et al (2012) focused denoising 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 denoising 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 denoising 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.

Jappreet et al (2012) presented a comparative analysis of various noise denoising algorithms. The comparative analysis of various denoising 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 denoising.

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 denoising 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 denoising 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 sub-band 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 wavelet-based 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 complex-valued low-frequency sub-band images and six complex-valued high-frequency 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.


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.

A suitable classification system and a sufficient number of training samples are prerequisites for a successful classification. In general, a classification system is designed based on requirement of the user, resolution of the image, image-processing and classification algorithms available and
time constraints. Landgrebe (2003) expressed such a system should be instructive, meticulous and separable.

When the study area is complex and heterogeneous, it is very difficult to select the required training samples. Then the classification of data would be difficult if medium or coarse spatial resolution data are used for classification, because an enormous volume of pixels may be present in the image. Therefore, selection of training inputs must consider the spatial resolution of data being used, availability of ground reference data, and the complexity of landscapes in the study area.

Selection of suitable training samples is a critical step for successful implementation of an image classification. So, it is very important to select the training samples that are most useful for separating water body and non-water body regions. The retrieval of these training samples is called as image feature extraction.

Texture portrays a rich source of data about the natural landscape. Rowman and George (2009) discussed the ways of extracting the texture features that have been performed through GLCM. It is a perfect and an efficient tool to perform the extraction of texture features. GLCM is a principle technique for assigning the relationship between two neighbouring pixels in one offset as the second order texture. The gray value relations in a target image are transformed into the co-occurrence matrix by a given kernel. It contains information of the position of pixels having similar gray level values.

K-means clustering is a deterministic partitional clustering method where the distance between the pixel values are calculated using Euclidean distance. In the variation of K-means clustering is introduced by Mao and Jain (1996), where the distance between the pixel value is calculated using the Mahalanobis distance. Another variation is isodata clustering developed by
Ball et al (1997). This operates splitting a large cluster, merging two close clusters and deleting a very small cluster.

Next, much concentration has been given to Fuzzy C-Means (FCM) deterministic partitional clustering discussed by Rui and Donald (2005). FCM clustering algorithm permits a data to belong to more than two clusters. Fuzzy clustering is frequently used in change detection, pattern recognition and classification.

Thanh et al (2005) suggested partitional clustering is the best technique for large image data sets. The clustering methods have been applied to different kinds of data like magnetic resonance images and remote sensing images. If the classes are not previously known, then the grouping has to be done in an unsupervised manner. Generally, clustering groups the set of variables into separate groups (clusters) based on the similarity in their values. This may be used to find the relationships between the variables. Clustering techniques are broadly classified into partitional clustering, hierarchical clustering and density-based clustering.

Another important classification technique is supervised classification. This is used to cluster the data set into classes corresponding to user-defined training samples. Luis and Karsten (2009) explained that the classification techniques could also commonly be applied to other contexts such as object recognition or other industrial processes. As a result, a variety of algorithms for supervised classification have been developed with increasing demand for the specific characteristics of a variety of scientific problems. Some of the examples include the maximum likelihood method introduced by Richards and Jia (2006), fuzzy-rule based techniques developed by Deer and Eklund (2003), Bayesian and artificial neural networks introduced by Friedman (1997), support vector machines used by Massa et al (2005) and the K-Nearest Neighbour (K-NN) technique by Franco-Lopez (2001).
Perumal and Bhaskaran (2009) proposed an expert land use image classification system using support vector machines. This method consisted of training and then testing. While performing training, the multispectral image data was subjected to filtering and nonlinear isotropic diffusion segmentation. The segmented image pixels matching the land use regions were then given as training input to the SVM. In order to have the testing in an automatic manner, the segmented regions were then mined out with the use of the active contour model. Then, the trained SVM accurately classified the regions based on the pixel values of the mined out area.

Huang et al (2009) presented support vector machine modeling framework to discuss and assess the change in land use in relation to different factors like population, distance to roads and surrounding land use. Researchers used an unbalanced SVM to improve the issues faced by normal SVM, such as having an unstable land-use data.

Evaluation of classification results is an important process in the classification procedure. There are different approaches such as qualitative evaluation based on expert knowledge and the quantitative accuracy assessment based on sampling strategies. The performance of the classification system is evaluated based on six criteria: accuracy, reproducibility, robustness, ability to fully use the information content of the data, uniform applicability and objectiveness which was proposed by Cihlar et al (1998).

In the real time image processing system, classification algorithm can neither satisfy all these requirements nor be applicable to all studies, due to different environmental settings and datasets used.

Defries and Chan (2000) suggested the use of multiple criteria to evaluate the suitability of algorithms. Some of the criteria are classification accuracy, computational resources, stability of the algorithm and robustness
to noise in the training data. The accuracy assessment in classification is, however, the most common and important criteria for the evaluation of classification performance.

The accuracy assessment of the classification technique enlightens the algorithm to classify the images into regions of interest. Before implementing a classification accuracy assessment, it is very important to know the sources of errors.

Powell et al (2004) discussed the sources of errors, such as position errors resulting from the image registration, interpretation and poor quality of training or testing samples, all affect the classification accuracy. The evaluation of accuracy assessment is commonly assumed as the difference between the classified result and the reference data. However, in order to provide a reliable result, non-image classification errors should also be examined, particularly when reference data are not obtained from the field survey.

Congalton and Plourde (2002) discussed another one approach for evaluation of accuracy assessment is error matrix. The factors for generating error matrix such as collection of reference data, classification algorithm, feature extraction technique, spatial autocorrelation and sample size should be considered. The overall accuracy, omission error, commission error and kappa coefficient from the error matrix are generated. Researchers have assessed the status of accuracy assessment of image classification, and discussed relevant issues.

The limitations of the various denoising and resolution enhancement techniques are discussed for improving classification accuracy.

- Modern image capturing devices are increasingly sensitive to noise and therefore image denoising algorithms are used to
reduce the effects of such noise artifacts in the resultant image. Recently proposed denoising algorithms use different approaches to address the problem. For denoising, many researches exploit the directional correlation in either spatial or frequency domain. However, the orientation estimation for directional correlation becomes inefficient and error prone in noised circumstances. A new hybrid directional lifting (HDL) technique is proposed for image denoising that involves pixel classification and orientation estimation, along with adding small amount of noise, in order to improve the performance efficiency of the technique.

- The existing techniques do not effectively maintain the edge and contour details of an image. In order to preserve the same, it is essential to develop a new image resolution enhancement technique for accurately classifying the image into water body and non-water body regions.

1.4 OBJECTIVES OF THE THESIS

- The primary objective of this research work is to use a novel image denoising and resolution enhancement technique for improving the accuracy of classifying satellite images.

- To propose an effective hybrid directional lifting technique for image denoising in order to retain the important details of the images and to improve the visual appearance.

- To develop discrete wavelet transform based interpolation and image gradient technique for enhancing the resolution of the denoised image to preserve the edge and contour information in satellite images.
1.5 ORGANIZATION OF THE THESIS

A brief outline of various chapters is given below:

**Chapter 2** discusses the various kinds of noises and their impact on the images. This also covers different conventional denoising techniques and describes the new technique developed for improving the quality of satellite images, thus improving the visual appearance. The hybrid directional lifting technique is proposed for removing noise from the satellite images. The proposed technique uses the pixel based classification while removing noise in the texture region. The result of the proposed technique is compared with the already existing techniques such as directional lifting and adaptive directional lifting. Then, the performance of the proposed technique is evaluated using peak signal to noise ratio.

**Chapter 3** describes various existing resolution enhancement techniques such as discrete wavelet transform, stationary wavelet transform, WZP-CS based image resolution enhancement, DT-CWT based image resolution enhancement, directional wavelet transform and image resolution enhancement using SWT and DWT. The proposed DWT based interpolation technique to improve the resolution of satellite images is detailed. The proposed technique is computationally efficient as shown by PSNR.

**Chapter 4** explains commonly used features to classify the images such as spatial features, transform features, edge and boundary features, colour features, shape features and texture features. The feature extraction technique, gray level co-occurrence matrix used to extract the different texture features is described.

**Chapter 5** describes supervised and unsupervised classification techniques for classifying the image into different classes. The support vector
machine classifier is used to classify the image into water body and non-water body, which is superior to other classifiers. Different applications like change detection in the coastal area and glacier classification have also been discussed.

In **Chapter 6**, a review of work is reported, major conclusions reached and contributions made are presented. Scope for future research is also outlined.