IMPROVED IMAGE CHANGE DETECTION USING FRACTIONAL FOURIER TRANSFORM

Dissertation submitted in the fulfilment of requirement for the award of the

Degree of

MASTER OF ENGINEERING

In

ELECTRONICS AND COMMUNICATION ENGINEERING

Submitted by:

Satbir Singh

Roll. No. 801161027

Under guidance of:

Dr. Kulbir Singh

Associate Professor

Electronics and Communication Engineering Department

THAPAR UNIVERSITY

(Deemed University)

PATIALA-147004, INDIA

JULY-2013

DECLARATION

I, Satbir Singh, hereby certify that the work that is being presented in the dissertation entitled as "Improved Image Change Detection Using Fractional Fourier Transform" in the fulfilment of the requirement of the award of degree of Master of Engineering in Electronics and Communication Engineering from Thapar University (Deemed University), Patiala, is an authentic record of my own work carried out under the supervision of Dr. Kulbir Singh.

The matter being presented in the dissertation has not been submitted in any other University/ Institute for the award of any degree.

Date: July 15, 2013

Satbir Singh

Roll No.801161027

It is certified that the above statement made by the student is correct to the best of my knowledge and belief.

Date: July 15, 2013

Dr. Kulbir Singh

Associate Professor, ECED

Countersigned by:

Head ECED

Thapar University, Patiala

Date:

Dean of Academic Affairs

Thapar University, Patiala

Date:

ACKNOWLEDGEMENT

All praises to almighty, who gave me strength and abilities to complete this dissertation work successfully.

This Dissertation would not have been possible without the unconditional support of my teacher and supervisor **Dr. Kulbir Singh**, Associate Professor, Electronics and Communication Engineering Department, Thapar University, Patiala. I am grateful for his for his wisdom and inspiration that forced me to push forward when the going got tough. I sincerely appreciate his liveliness, honesty and dedication. I am very lucky to have the opportunity to work with him. He has provided me help in technical writing and presentation style and I found this guidance to be extremely valuable.

At the same time, I am grateful to Head of Department, **Dr. Rajesh Khanna** for providing the facility for completion of dissertation.

A special thanks to **Mr. Ankush Kansal**, Assistant Professor, ECED, for his continuous guidance and support.

I am grateful to my beloved friends for their love and continuous support during the dissertation work at Thapar University till the completion of work.

Also, I would like to thank all the members of the Electronics and Communication Department for their lively assistance.

Finally, I take this opportunity to express the profound gratitude from my deep heart to my mother, my younger brother and sister and all family members for their love and continuous support in all respects.

Satbir Singh
Roll No. 801161027

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ABSTRACT

Image change detection is increasingly becoming one of the major areas of research in Image processing. The reason for this is the proliferation of images all over the globe. New technologies are largely dependent on visual data, so it has become very important to find out sharp and faster image processing techniques which also have precision. Images are significant to us because they can be an extraordinarily effective medium for the storage and communication of information. A photograph/image allows us to avoid the need for a lengthy, tedious and, ambiguous verbal narration regarding what is there in an image. The field of image change detection attempts to replicate what our brains do, for instance, the comparative analysis of two visual landscapes, in the external world to enhance our ability of visual data processing.

Change Detection techniques play a very significant role in modern infrastructure. Although there are a number of methods, their applicability is restrained by limitation of the information they are evaluated upon, the type of image acquisition available, need of information to be retrieved after change detection etc.

The present dissertation undertakes a study of image change detection using Fractional Fourier transforms.

DFrFT technique has been used for ordinary image change detection, primarily because the advantages this technique has over other techniques. The use of DFrFT gives us an additional parameter 'a' which is a fractional parameter. The parameter allows more flexibility in obtaining the output. In the end, gradient co-relation has been used for classifying the changes obtained from two images depending upon the value of correlation coefficient.

Two more techniques have been used to obtain image change detection. The results from these are then compared with the outputs given to us by the DFrFT technique. Parameters like recall and precision are used to judge the level of change detection. While using an image set, we obtained values of 0.43 and 0.67 with JIH, 0.56 and 0.67 with DCT and with DFrFT at parameter 'a' value=0.9 we obtained 0.62 and 0.87. Overall it was observed that results improved by about 30-80%.

Furthermore, the research work applies DFrFT to analyse changes in the images taken via satellites. The satellite images have been analysed because of the vital role these play in the management of natural resources and maintaining the human-nature balance. Here the results are judged using precision, recall and F score parameter values. While taking example of an image set (3), the results have revealed that approach of Fractional Fourier transform is better than the approach followed in [35] because it provided F score value of 0.92 for fractional parameter ‘a’ = 0.98 as compared to value of 0.90 with approach followed in [35].

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LIST OF ABBREVATIONS

DIP	Digital Image Processing
ANN	Artificial Neural Networks
FAX	Fixational Auto Xerox
MRI	Magnetic Resonance Imaging
JIH	Joint intensity Histogram
DCT	Discrete Cosine Transform
SAR	Synthetic Aperture Radar
PRT	Personal Rapid Transit
ATS	Advanced Transport Systems
SVM	State Vector Machine
LPT	Log Polar Transform
APT	Adaptive Polar Transform
FFT	Fast Fourier Transform
SIFT	Scale- Invariant Feature Transform
RANSAC	Random Sample Consensus
MGRF	Markov-Gibbs Random Field
LGDM	Local Gradual Descent Matrix
PCA	Principal Component Analysis
UAV	Unmanned Aerial Vehicle

DSP	Digital Signal Processor
FT	Fourier Transform
FrFT	Fractional Fourier Transform
DFrFT	Discrete Fractional Fourier Transform
DDA	Dalaian Development Area

1. INTRODUCTION

1.1 PREAMBLE

The field of Change detection analysis is a well-known area of research analysis. It still remains an active research topic in which new techniques are being developed to solve the problems and increase the efficiency of previously used methods and techniques. A new change detection technique could only be helpful if it is easy to understand and implement. Another aspect that needs to understood, whenever a new technique is introduced, is to see the accuracy with which this new technique detects changes in the image and gives appropriate results related to the changes and trajectories of change in an image. Throughout the history of change detection, variety of change detection techniques have been developed and new techniques continue to develop as the need for accuracy and precision is increasingly felt in modern-day technologically oriented world. However, it is still very difficult to find a suitable method of change detection for a specific research purpose or study area. The need to choose the appropriate method of change detection demands a meticulous analysis and careful study of major impact factors. Making an appropriate choice of change detection method has immense significance in producing a high-quality change detection product with reference to a given research purpose.

Change detection is a procedure used to determine any transformation/change between two images captured at different time instants. These changes may arise due to various factors. Important applications which require change detection include video surveillance, remote sensing, medical diagnosis and treatment [1], civil infrastructure, underwater sensing [2] and driver assistance systems [3]. Despite the diversity of applications, change detection researchers employ many common processing steps and core algorithms [4]. The major premise of change detection is can be stated as: “a difference exists in the spectral response of a pixel on two dates if the biophysical materials within the instant field of view have altered between dates”. In other sense we can say that change detection is basically an act of comparing two or more satellite images acquired at different times (multi temporal) for the purpose of detecting spectral reflectance differences between the images.

Also, satellite communication is becoming ventral to everyday life. As a result, there are hundreds and thousands of satellite images which travel across the world at a breakneck pace. In this scenario it has becoming very significant to use change detection techniques to perceive the changes that take place within two timespans when an image is clicked. Satellite imagery is now commonly used in various fields of research. Change detection is one of the prime uses of remotely sensed images from Earth-orbiting satellites, due to their repetitive coverage at short intervals and reliable image quality. Remote sensing satellites which monitor forest change in a repetitive manner provide the ideal opportunity for estimating forest structure changes. However, in satellite image change detection, it is generally difficult to discriminate significant intensity changes, such as produced by the appearance/disappearance of building structures, from intensity changes of the background.

Change detection is an important field of study which is increasingly being researched and analyzed to find new change detection method with more precision and accuracy. The present research work uses the method of fractional transform to study image change detection with reference to normal and satellite images. By using the fractional fourier transform, we have an advantage of varying the fractional parameter to obtain a numerous options for an output that can be as equivalent of having a number of thresholds to obtain image change detection.

1.2 DIGITAL IMAGE

In the broadest possible sense, images are *pictures:* a way of recording and presenting information visually. Pictures are important to us because they can be an extraordinarily effective medium for the storage and communication of information. We rely on our eyes for most of the information we receive concerning our surroundings, and our brains are particularly adept at visual data processing. There is thus a scientific basis for the well-known saying that *'a picture is worth a thousand words'*.

A digital image a [m, n] described in a 2D discrete space is derived from an analog image a(x, y) in a 2D continuous space through a sampling process that is frequently referred to as digitization. Representation of an image in to an M×N numerical array may be as follows:

$$f(x,y)=\begin{bmatrix} f(0,0) & f(0,1) & \dots & f(0,N-1) \\ f(1,0) & f(1,1) & \dots & f(1,N-1) \\ \dots & \dots & \dots & \dots \\ f(M-1,0) & f(M-1,1) & \dots & f(M-1,N-1) \end{bmatrix}$$

2D array of numbers represents the sampled version of an image. The image defined over a grid, each grid location being called a pixel. Represented by a finite grid and each intensity data is represented a finite number of bits. A digital image is composed of pixels, which can be thought of as small dots on the screen and it becomes more complex when the pixels are colored.

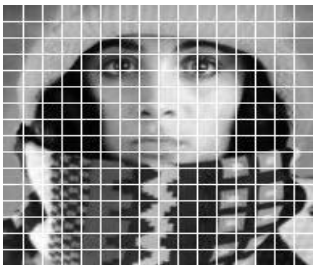

Figure 1.1 A 16x16 Digital Image

For example, the image shown in Figure has been divided into N = 16 rows and M = 16 columns. The value assigned to every pixel is the average brightness in the pixel rounded to the nearest integer value. The process of representing the amplitude of the 2D signal at a given coordinate as an integer value with L different gray levels is usually referred to as amplitude quantization or simply quantization.

1.3 DIGITAL IMAGE PROCESSING

Image processing is a subclass of signal processing concerned specifically with pictures whose basic aim is to improve image quality for human perception and/or computer interpretation.

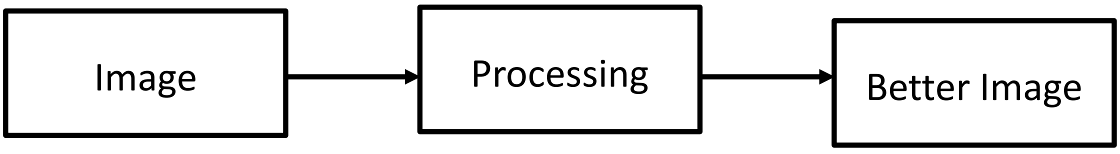

Figure 1.2 Image Processing

Since the image used now days is a digital one, the term image processing approaches to digital image processing (DIP) in the current scenario. Digital data is easy to acquire, maintain as well results in more accurate outcomes. Commonly, the Digital Image processing deals with the process such as Image Acquisition, Preprocessing, and Segmentation and so on. These elements of image processing are dealt in order to be in pace with the new developments in image-processing hardware and software.

Firstly, in the processing flow the Image Acquisition plays a significant role. After absorbing the image, it is Preprocessed i.e. the image is Enhanced, Restored and then Compressed. During image enhancement, several techniques are adopted such as gray- scale mappings for image negatives, contrast stretching, gray-level slicing and so on. After enhancing the required image, it is restored whose main aim is to improve an image or to reconstruct an image that has been degraded by using some priori knowledge of the degradation phenomenon. After it, one moves forward to Compression in which the amount of data required to represent a digital image is compressed. Image compression plays a vital role in many important and diverse applications, including telex video conferencing, remote sensing, FAX etc. In the next practice, which is the Segmentation process, the image is divided into several parts or segments. When segmentation is over, Representation and Description comes into picture. Choosing a representation scheme, however, is only part of the task of making the data useful to the computer. The next job is to describe the region based on chosen representation. Further Recognition and interpretation are employed, in which the acquired image is recognized and also interpreted to get a final image of high resolution and clear picture clarity. In practical, DIP is a useful technology for the following:

1. Enhancement and restoration
   - Remove artifacts and scratches from an old photo/movie
   - Improve contrast and correct blurred images
2. Composition (for magazines and movies), Display, Printing
3. Transmission and storage
   - images from oversea via Internet, or from a remote planet
4. Information analysis and automated recognition
   - Providing “human vision” to machines

5. Medical imaging for diagnosis and exploration
6. Security, forensics and rights protection which include
   - Encryption, hashing, digital watermarking, digital fingerprinting

1.4 IMAGE CHANGE DETECTION

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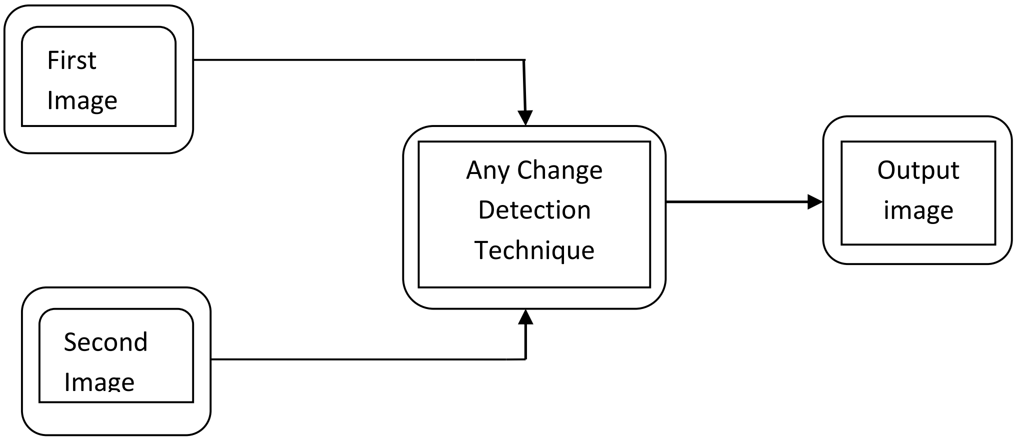


Figure: 1.3 General Scheme of Image Change Detection

Change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times [5]. The goal of a change detection algorithm is to detect "significant" changes while rejecting "unimportant" ones. Sophisticated methods for making this distinction require detailed modeling of all the expected types of changes for a given application and integration of these models into an effective algorithm [4]. Generally, several change detection techniques are employed to implement change detection whose results are then subsequently juxtaposed to identify the best product through quantitative accurate assessment. Selecting an appropriate change detection technique also requires the analysis of what kind of changes the researcher wants to detect together with the geographical area under observation in a given experiment. Varied techniques, for example, image differencing can only provide change/non-change information and post- classification comparison can provide a complete matrix of change directions, give varied types of information regarding the changes in the image. A new change detection technique could only be helpful if it is easy to understand and implement. Another aspect that needs to understood, whenever a new technique is introduced, is to see the accuracy with which this new technique detects changes in the image and gives appropriate results related to the changes and trajectories of change in an image. One can say that while implementing a change detection assignment, three major steps are involved: First include image preprocessing comprising geometrical rectification and image registration, radiometric and atmospheric correction, and topographic correction if the study area is in mountainous regions, The next step involves selection of suitable technique to implement change detection analyses, the significance of which is explained above. The last crucial step is the accuracy assessment from which we have an idea of the effectiveness of our algorithm.

Detecting regions of change in multiple images of the same scene taken at different times is of widespread interest due to a large number of applications in diverse disciplines, including remote sensing, surveillance, medical diagnosis and treatment, civil infrastructure, and underwater sensing [4]. The following section illustrates the significant applicability of Image change detection.

1.5 NEED OF IMAGE CHANGE DETECTION

Following few stanzas highlight the requirement of image change detection:

Timely and accurate change detection of Earth's surface features is extremely important for understanding relationships and interactions between human and natural phenomena in order to promote better decision making. With advancements in remote sensing technologies, change detection based on high resolution satellite images provides an efficient tool for monitoring infrastructural development within vast premises.

Automatically identifying objects and people left in the interior of vehicles is highly desirable because human monitoring has high running costs and low efficiency associated with it.

In medical analysis, detection of missing part of organs and comparative analysis of scans become easy with image change detection. For example, significance of change detection in MRI scans is highlighted in [6].

Detection/ appearance of objects in video frames along with security systems of surveillance cameras incorporate change detection for fast and efficient working. [7]

Image change detection along with classification algorithms is essential for obtaining out the statistics and hence planning the policies for the development of any geographical area.

To detect the motion in a video stream environment which is an idea to ensure that the monitoring systems not only actively participate in stopping the crime, but do so while the crime is taking place.

Monitoring Changes of environment is a problem faced by many different institutions. Especially Government agencies have the duty to detect and record these changes which may take place in urban, forest, agricultural, desert areas, and so forth [8]. Hence for gathering information for these at acceptable cost and suitable ease, we require analysis of image change detection.

Research in Environmental Remote Sensing Global and Regional Environmental Applications of Remote Sensing Data Land cover change detection using remote sensing satellite imagery is a powerful tool for monitoring urbanization and the resulting loss of forest and agricultural land.

1.6 REMOTE SENSING AND SATELLITE IMAGE CHANGE DETECTION

Satellites provide a great deal of the remote sensing imagery commonly used today. Satellites have a number of unique characteristics which make them particularly useful for remote sensing of the Earth's surface. The path trailed by a satellite is referred to as its orbit. Many remote sensing satellite are designed to follow an orbit (basically north-south) which, in conjunction with the Earth's rotation (west-east), allows them to cover maximum of the Earth's surface over a certain period of time. In Satellite images (acquired at different times/dates), change detection is an important practice that can lead to valuable information about deforestation, water level - imminent floods, tree mortality due to droughts or forest fires, urban infrastructure change - new roads, buildings [9-11]. The availability of high-resolution satellite images increases the remote sensing applications to such a level that may cause traditional methods and aerial photogrammetry to be replaced by the new technology of satellite imagery.

Satellite data is particularly beneficial for detecting changes in urban planning, land-cover and land-use because of periodically (repeated) coverage, low cost and extra details. The modern satellites like Quickbird and Ikonos provide digital panchromatic imagery of the Earth's surface which has a much improved spatial resolution than multispectral imagery and imagery from other satellites. For example, Quickbird satellite produces panchromatic imagery having a pixel equivalent to an area 0.66m × 0.66m, while the multispectral pixels represent an area of 2.4m × 2.4m. Thanks to this improvement in resolution, it has become possible for analysts to identify individual vehicles in satellite imagery. Moreover, satellite imagery provides a rapid, high-quality data source to produce images with more details. Satellite imagery has become increasingly available in recent years.

The change detection technology brings together a significant relief in terms of the volume of data to be handled for automated analysis tasks as generally the change regions constitute the objects of interest only. Many satellites around the globe collect petabytes of imagery daily. This mass volume of data is analyzed continually for various environmental, humanitarian, educational, disaster relief/response and military uses. For most of these tasks, manual analysis of this amount of data is simply impossible other than for small regions. Automated tools to identify various objects of interest such as new buildings under construction, vehicles in motion, growth in vegetation, changes in glaciers are badly needed. The change detection technology introduces a significant relief in terms of the volume of data to be processed for automated analysis tasks as mostly the change regions constitute the objects of interest.

Many satellite platforms and sensors currently in use capturing earth imaging data are building a global library of earth surface data, particularly relevant in environmental "hot spots" such as the Amazon Basin, Africa and Madagascar, Southeast Asia, China and the American Pacific Northwest. In these areas, remote sensing data makes a promising perspective free of the constraints of political borders and topographic obstacles. Some of the most recent research and applications include projects ranging from global scale monitoring to intensive research in high-risk regions.

1.7 METHODOLOGY OF RESEARCH WORK

The research project involving image change detection with the use of fractional transforms constitute of following work action flow:

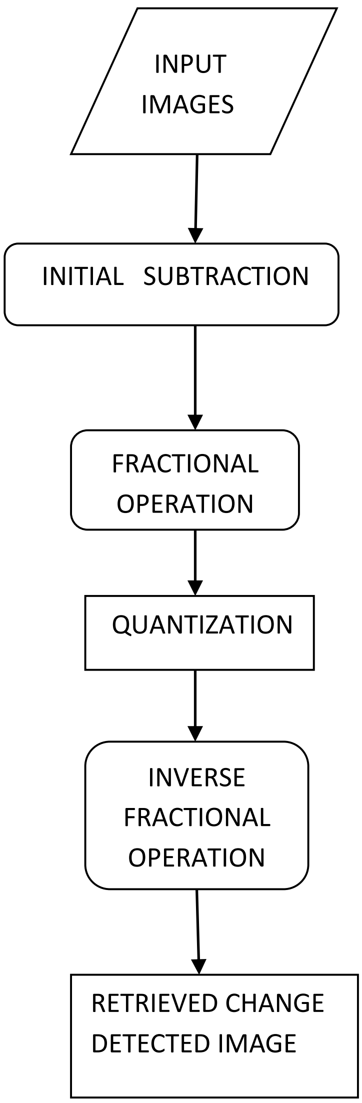


Figure 1.4: Image change detection using fractional transforms

Starting from an initial differencing step, the main blocks incorporating fractional functions are the applications of fractional and inverse fractional block with a varying value of fractional parameter. The quantizer selects only appropriate coefficients and round off the other to zero. The details of image change detection using fractional transforms will be explained in the later chapters of the dissertation.

1.8 OBJECTIVES

Dissertation has following objectives:

1) Image Change Detection using Joint Intensity Histogram (JIH).
2) Image Change Detection Using DCT.
3) Introducing the use of fractional transforms for obtaining Image Change Detection and obtaining the same using DFrFT.
4) Identifying the main change objects by leaving out shadow and other artifacts in the change image.
5) Comparison of the above three techniques.
6) Change detection in satellite imagery using DFrFT.

1.9 ORGANIZATION OF DISSERTATION

The following stanza outlines the dissertation work flow:

In the first chapter an attempt shall be made to present the contemporary relevance of the research project. Furthermore, the chapter will introduce important terminologies regarding dissertation, objectives, methodology used in the research work and organization of the dissertation. Next chapter studies the available literature related to the research project. It traces the literature regarding the simple image detection, satellite image detection and fractal transform. The chapter ends with providing an overview of the gaps in study. Third chapter introduces the field of image change detection, its techniques, methods used, applications and problems associated with it. It is a detailed study of the various techniques used in image change detection, and their advantages and disadvantages. Fractional transforms are discussed in the fourth chapter. This chapter introduces the various types of fractional transform and gives a comprehensive analysis of various types of fractional transform and their properties. Each type has been introduced and has been then mathematically defined in detail along with providing various properties. The technique of fractional transforms for image change detection including a rigorous analysis of selected images is presented in chapter five. This technique which has never been used in image change detection has been then compared to other image change detection techniques. Application of fractional fourier transform in the change detection of satellite images is introduced in the sixth chapter that makes an in-depth examination of satellite image change detection using DFrFT. In chapter seven, conclusion will attempt to make a comprehensive attempt to trace the significance of techniques of fractional transform in image change detection along with the future scope of the proposed research methodology.

2. LITERATURE REVIEW

2.1 IMAGE CHANGE DETECTION

A super-pixel-based change detection algorithm has been described by A.Bose *et al.* [12] that is mainly a reform of the image differencing method. The process has been seen to detect even a minute transient change in intensity at a frame rate of as high as fifty frames per second using cots hardware.

An unsupervised distribution-free change detection approach for synthetic aperture radar (SAR) images based on an image fusion strategy and a novel fuzzy clustering algorithm was proposed by M.Gong *et al.* [13]. The image synthesis technique is introduced to generate a difference image by using complementary data from a mean-ratio image and a log-ratio image. Wavelet fusion rules based on an average operator and minimum local area energy are selected to fuse the wavelet coefficients for a low-frequency band and a high-frequency band, respectively. A reformulated fuzzy local-information C- means clustering algorithm is projected for classifying changed and unchanged regions in the fused difference image. Experiments on real SAR images demonstrate that the image fusion plan integrates the advantages of the log-ratio operator and the mean-ratio operator and gains a better performance. The change detection results obtained by the improved fuzzy clustering algorithm revealed lower error than its previous methods.

A novel Personal Rapid Transit (PRT) system was presently being designed by Advanced Transport Systems Ltd (ATS) features. Image change detection for a personal rapid transit application by A.Peters *et al.* [14] described two methodologies that use changes in the visual image of the interior to predict the likelihood of left objects and remaining people. The first method was based on identifying structural differences. The second used a shading model method. A variation of the shading model with information from the color channels is also described. The outcomes show that the modified shading model approach gives the best performance.

A vital application for tracking the fast change of fish-pond for attaining the information that how environment is impacted by human activities. For this purpose K.Liu *et al.* [15] suggested a change detection process in order to delineate fast change fish-pond using high resolution, short term time series of SAR imagery. In this study, object-oriented method was deployed to extract and analyze the texture characteristics of fish-pond in the high spatial resolution of SAR data. Objects were created with suitable scale parameters by means of multi-temporal segmentation approach rendering to the image features. Six change types of fish-pond were realized. The results show that high resolution SAR data can offer healthier information for fish-pond change detection in the study area, and the procedure proposed in this study can efficiently acquire the fast change objects with high accuracy between three short term time series SAR images, which are beneficial for the further classification.

S.Liu *et al.* [16] gave a complete procedure for land cover change detection by fusing change information found from multiple difference images. Measurement and decision level fusion techniques are used to pool multiple difference images, and support vector machine (SVM) is chosen to detect the changes. Multi-temporal CBERS images acquired in 2002 and 2008 are used to detect land cover changes and urban expansion in Shanghai, and experimental results confirm the usefulness of the proposed approach. Using additional change information, both the omission error and commission error could be made less.

A scheme for target discrimination and classification is proposed by C.Debis *et al.* [17] which is applied to through-the-wall microwave images acquired by using a wideband radar employing frequency-domain back-projection. The proposed scheme applies image segmentation, trailed by feature extraction. Real data collected using an indoor radar imaging scanner used for justification of performance.

J.L.A.Samatelo *et al.* [18] presented a new change detection algorithm for visual surveillance system that describes the implementation of a background subtraction approach for indoor surveillance applications and proposes a novel change detection algorithm. This algorithm uses a color similarity metric that considers the information of magnitude and phase of the difference between the background model and each video frame, both represented in the RGB color space. The method was tested using the PETS2004 database obtaining acceptable results.

A novel method was proposed for jointly unsupervised change detection and image registration over multi-temporal optical remote sensing images by W.Luo *et al.* [19]. An iterative energy minimization scheme is engaged to extract the pixel opacity. The seed nodes will be updated according to the analysis of the changed and unchanged regions. Experimental results show that the proposed method can perform change detection as well as the state of the art methods. In particular, it can perform change detection rapidly and automatically over unregistered optical remote sensing images.

A Motion Detection System was employed by A.Ansari *et al.* [20] to detect the motion in a video stream environment and this is an idea to make sure that the monitoring systems not only actively play a part in stopping the crime, but do so while the crime is taking place. Hence, a system is used to detect any motion in a live streaming video and when motion has been detected in the live stream, the software will activate a warning system and capture the live streaming video.

N.Morales *et al.* [21] described a new method for the automated video surveillance of wide areas with the images obtained from a set of cameras installed on an autonomous vehicle; a video surveillance tool has been developed, based on the comparison between images that have been taken in the same place but at varying times. The vehicle drives around the watched area, looking for intruders. The method described in this paper is the image comparison system used for this task, and it is based on image registration and change detection methods. The validation process indicates the good performance of the methods selected to develop the application. It is also capable to be executed in real time with good detection rates.

A new scene change detection method using multiple histograms was proposed by S.J.Kang *et al.* [22]. The proposed method produced multiple histograms of split blocks for successive frames. Then, it calculated the optimal threshold value using automatic thresholding based on the Otsu method and decided whether the scene change occurs or not using the difference between threshold values in consecutive frames. In the experiments for the subjective evaluation, the proposed method correctly identified the scene change, thereby preventing interpolated frames with poor image quality due to block artifacts. In the objective estimation using the F1 score, the proposed method improved the accuracy of the scene change detection by up to 0.461 compared with the benchmark methods.

In the observation of a given study area, the key problem is that the ground truth collection does not usually follow the image acquisitions at the different dates. However, it is easier to have at least one image for which the ground truth is available. G.Moser *et al.* [23] projected a partially supervised change detection scheme that is based on the exploitation of the ground truth availability for at least one temporal image. A clustering algorithm is applied to both acquired images and a thresholding based unsupervised change detection algorithm is applied inside each cluster of the second date image in order not only to detect the presence of changes but also to distinguish between different typologies of changes.

R.J.Radke *et al.* [4] presented a systematic survey of the common processing steps and core decision rules in modern change detection algorithms, including significance and hypothesis testing, predictive models, the shading model, and background modeling. Also discussing important preprocessing methods, approaches to enforcing the consistency of the change mask, and principles for assessing and comparing the performance of change detection algorithms.

Y.Kita [24] proposed a method to estimate background intensity changes by examining the joint intensity histogram of compared images. Considering the point that background intensity changes tend to make clusters with ridges on the joint histogram, dominant ridges are identified using Hough transformation. Then, the joint histogram is categorized into clusters according to the dominant ridges. Clusters of background intensity changes are distinguished based on covariance of each cluster. Pixels illustrating intensity change other than the background intensity changes are extracted as candidates of significant change. The prospect of this method is examined through experiments using real satellite images.

Inspired by LPT (Log Polar Transform), a new registration algorithm that discourses the problems of the conventional LPT, while maintaining the robustness to scale and rotation, was presented by R.Matungka *et al.* [25] that familiarized a novel adaptive polar transform (APT) technique that evenly and effectively sampled the image in the Cartesian coordinates. Translation among the registered images is recovered with the new search scheme using Gabor feature extraction to accelerate the localization procedure. Moreover an image comparison scheme is planned for locating the area where the image pairs differ.

G.Xue *et al.* [26] presented a novel background modeling method by trusting on statistical models which use pixel phase instead of intensities. They first removed the phase feature of the pixel using Gabor filters. Then, each phase feature is modeled independently by a mixture of Gaussian models and updated with a novel scheme. Since foreground pixels are scattered in the preliminary detection result, distance transform is employed on the binary image which transforms the image into a distance map. Segmenting the distance image with a threshold develops the final result.

A robust method for geometric co registration, and an accurate change detection technique based on statistical method for multi-temporal high-resolution satellite imagery was given by M.Abdelrehman *et al.* [27] in which scale-invariant feature transform (SIFT) is used to attain a set of correspondence points in a pair, or multiple pairs, of images that are taken at different times and under different circumstances, then Random Sample Consensus (RANSAC) is used to eliminate the outlier set. The subsequent inliers matched points is an accurate correspondences which is used to register the given images. Changes in registered images are recognized using statistical analysis of image differences. Finally, Markov-Gibbs Random Field (MGRF) is used to model the spatial-contextual information enclosed in the resulting change mask. Experiments with generated synthetic multiband images, and LANDSAT5 Images, approved the correctness of the proposed algorithm.

The work presented by D.Crispell *et al.* [28] generalized previous probabilistic 3-D models in such a way that multiple orders of magnitude savings in storage were possible, making high-resolution change detection of large-scale scenes from high-resolution aerial and satellite imagery possible. Precisely, the inherent dependence on a discrete array of uniformly sized voxels is removed through the derivation of a probabilistic model which represents uncertain geometry as a density field, allowing implementations to efficiently sample the volume in a non-uniform fashion.

Based on fair analysis of precision and direction selection characteristic of image frequency feature using wavelet transform, combined with important influence factors of sub-space estimation during independent component analysis decomposing of image block , E. Menaka *et.al.* [29] recommended two schemes on change detection of remote sensing images. Simulation results depicts that application scope in second scheme is broader than that in first scheme because of parallel algorithm and robustness for massive remote sensing images.

Y. Pu *et. al*. [30] presented a novel unsupervised change detection approach based on cross-correlation coefficient. The cross-correlation coefficient is a measure of the similarity between two variables. The change detection problem can be understood as the process to partition two input images into two distinct regions, namely "changed" and "unchanged", according to the binary change detection mask. Each region in the pair of the images of the corresponding position is considered as two sets of variables, whose cross-correlation coefficient is calculated in order to provide an optimal partition of the changed and unchanged regions. In the optimal partition, it is obvious that the cross -correlation coefficient of the set of the unchanged variables should be the maximum, while the absolute -value of that of the changed variables should be the minimum, because the corresponding unchanged region s are similar while the changed regions are quite different. Genetic Algorithm is used to obtain the optimal non-dominated solution as the change detection using cross-correlation coefficient is a multi -objective optimization problem. The simulation experiment shows that the result using the new method is effective and robust to radiometric difference.

2.2 SATELLITE IMAGE CHANGE DETECTION

A novel technique for unsupervised change detection of multi temporal satellite images using Gaussian mixture model (GMM), local gradual descent, and *k*-means clustering was proposed by Z.Yetgin [31]. Data distribution of the difference image was first modeled by bimodal GMM with "changed" and "unchanged" modules. The neighborhood data around each pixel form a sample and are modified by the so-called local gradual descent matrix (LGDM), values of which are plunging from center toward outside. LGDM visited each sample and caused slight variations in pixel values of the sample in an attempt to shift the sample toward the accurate Gaussian component center in the feature space. It is a general method that could ably explore both local and global changes for unsupervised change detections if desired and is also a parameter selection method without using the ground truth image. The proposed change detection method was tested for both optical and advanced synthetic aperture radar satellite images and related with the recent works based on the same input set. The proposed method outperformed the others qualitatively and quantitatively.

S.lee *et al.* [32] proposed an unsupervised approach for change detection in multi temporal satellite images based on a novel detail enhancing algorithm. The multi temporal source images are first used to produce the difference image, which is decomposed into low-pass approximation and high-pass directional sub-bands by the non-sub-sampled contourlet transform. The coefficients from the directional sub bands are merged at intra scale and inter scale to extract the important details of the difference image. After that, the extracted details are introduced to one base image selected from the estimate sub-bands, which results in a detail-enhanced difference image. For every pixel in the enhanced difference image, a dimension-reduced feature vector is created with the help of principal component analysis (PCA). The final change detection map is realized by clustering the feature vectors using a PCA-guided *k*-means algorithm into "changed" and "unchanged" classes. Experimental results show the superior performance of the proposed approach compared with several well-known change detection techniques.

F.Pop *et al.* [33] presented a solution for real-time satellite image processing. The emphasis was on the detection of changes in MODIS images by presenting a distributed algorithm for change detection which was based upon extracting relevant parameters from MODIS spectral bands. The algorithm, able to run in a Grid system, is mountable and fault-tolerant.

A novel method was proposed for jointly unsupervised change detection and image registration over multi-temporal optical remote sensing images by W. Luo *et al.* [34]. An iterative energy minimization scheme is engaged to extract the pixel opacity. The seed nodes will be updated according to the analysis of the changed and unchanged regions. Experimental results show that the proposed method can perform change detection as well as the state of the art methods. In particular, it can perform change detection rapidly and automatically over unregistered optical remote sensing images.

Detection of appearance/disappearance of objects from satellite images is generally very tedious task since background pixels also change their intensity values owing to various factors. So, Y. Kita [35] proposed a method to estimate such background intensity changes by examining the joint intensity histogram of compared images. Keeping in mind that background intensity changes tend to make clusters with ridges on the joint histogram, they detected dominant ridges using Hough transformation. After that, the joint histogram was classified into clusters according to the dominant ridges. Covariance of each cluster was used to distinguish them. Pixels showing intensity change other than the background intensity changes are extracted as candidates of significant change. The results were tested with the help of real satellite images.

Unmanned aerial vehicles (UAV) were widely used to capture and down-link real-time videos/images. However, their role for a low-cost airborne platform for capturing high-resolution, geo-referenced still imagery was not fully utilized. The images obtained from UAV are better as compared to remote sensing images as they can be obtained at a low cost and potentially no risk to human life. But these images were distorted due to the noise generated by the rotary wings. Although UAVs can provide images with high resolution in a portable and easy way, such images only cover small parts of the entire field of interest and are often with high deformation. The traditional pixel-based change detection methods did not give satisfactory results for such images also the applications using UAV images were quite less. J. Shi *et al.* [36] proposed a novel object-based method for change detection using UAV images which overcame the effect of deformation and can fully utilized the high resolution capability of UAV images. The developed method can be divided into five main blocks: pre-processing, image matching, image segmentation and feature extraction, change detection and accuracy evaluation. The results confirm the effectiveness of the proposed approach.

In [37] I. Misra *et al*. proposed an Automatic satellite image registration which is a competitive task of overlaying two images for geometric conformity aligning similar features by forming a transformation model using distinguishable feature points collected simultaneously in both the images in a completely un assisted manner. Remote sensed images occupy terrain features in a natural condition subjected to seasonal changes, sun illumination conditions, and cloud presence. The vital steps in image registration are collection of feature points and estimating a spatial transformation especially when outliers are present. In this paper, the details and merit of employing automatic Harris corner detection and building a transformation model using Random Sample Consensus (RANSAC) algorithm was brought out while registering a pair of LISS-3 or AWIFS images from Indian Remote Sensing Satellite (IRS) platform.

X. Zhang *et al.* proposed a letter [38] in which a robust and fast unsupervised change-detection framework was proposed for synthetic aperture radar (SAR) images. It contained three aspects: (a) a vigorous difference image is constructed with the idea of probability patch-based, and it can suppress the speckle effects on the changed regions and enhance the change information synchronously. (b) Then, each class of the difference image is modeled by generalized Gaussian distribution (GGD), and its parameters are learned by the expectation-maximization algorithm. Moreover, the graph-cut algorithm is employed on the difference image to extract the spatial prior information, based on which the parameters of GGD are initialized well via the fuzzy c-means algorithm. (c) Finally, the Bayesian inference for maximum a posteriori performs the final detection. Experimental results on simulated and real SAR data sets confirm the robustness and accuracy of the proposed algorithm in which graph-cut and GGD make great contribution on improving the accuracy of detection and speed of algorithm.

Changes in atmosphere, ground conditions, and sensor response between multi temporal airborne imaging sessions have reduced the use of fixed target hyper spectral libraries in order to identify targets in heterogeneous (cluttered) back-grounds. This hyper spectral target signature instability has consequence in using anomaly detection algorithms to detect targets in real time applications.

The study of Object Detection Using Transformed Signatures in Multi temporal Hyper spectral Imagery by R. Mayer *et al.* in [39] examined mathematical transforms of target spectral signatures. The study analyzed statistical information regarding background clutter taken from one long-wave infrared (LWIR) hyper spectral (8–12 m) airborne imagery flown on one day, to find the target spectral signature flown on another day (with significantly dissimilar weather conditions). Their work analyzed image cubes collected during the November 1998 Hyper spectral Day/Night Radiometry Assessment (HYDRA) data collect. The transformed signatures used in matched filter searches successfully find targets (even targets nearly covered) with low false alarm rates (1 FA/kilometer 2) and remained sensitive to targets using a reduced number of pixels in the overlap region. This work demonstrated the transformation of target spectral signatures to search for candidate targets using multi temporal hyper spectral images without requiring accurate geo-registration.

Change detection from bi temporal satellite images (taken from the same region in different times) may be used in various applications such as forest monitoring, earthquake damage assessment, and unlawful occupation. In [40], M. Ilsever *et al.* proposed a novel change detection method based on structure information. There method can be called as structural change detection. To summarize the structure in an image, from local features and their graph based representation. Extracting the structure from both images, they benefitted from graph matching to detect changes. The method was tested on 18 Ikonos image pairs and its strengths and weaknesses were also discussed.

Multi-date acquisitions of high-resolution imaging satellites (e.g. GeoEye and WorldView), can display local changes of current economic interest. But problem lies in the fact that their large data volume precludes effective manual analysis, demanding image co-registration followed by image-to-image change detection, preferably with minimal analyst attention. In [41], N. Bryant *et al*. developed an automatic change detection procedure that minimizes false-positives. The processing steps include 1) Conversion of both the pre- and post- images to reflectance values, reflectance values can be either top-of-atmosphere units or have full aerosol optical depth calibration applied using bi-directional reflectance knowledge. (2) Panchromatic band image-to-image co-registration, using an ortho rectified base reference image (e.g. Digital Ortho photo Quadrangle) and a digital elevation model; this step can be improved if a stereo-pair of images have been acquired on one of the image dates. (3) Pan-sharpening of the multispectral data to assure recognition of change objects at the highest resolution. (4) Characterization of multispectral data in the post-image (i.e. the background) using unsupervised cluster analysis. (5) Band ratio selection in the post-image to separate surface materials of interest from the background. (6) Preparing a pre-to-post change image. (7) Identifying locations where change has occurred involving materials of interest.

In the satellite images the noise is present such as mist, clouds etc., to remove the noise, the Haar wavelet transform was applied by E. Menaka *et al.* [42]. Using the Image segmentation algorithm the major issue of Deforestation is analyzed by comparing the image taken from the year 1939 and 2000. Deforestation is a serious issue that most nations face today. Most nations that are presently under the scanner for deforestation had immense forest stretch. In this study, they proposed polygon segmentation and 2D Haar wavelet for adaptive regional forest change detection. First in order to detect the forest types, 2D Haar wavelet is applied to image at different threshold level and identifies the kind of forest. The polygon segmentation was applied to low dense forest and segregate forest with non-forest region. Results were also compared with data sets and found the decreasing forest cover. The proposed technique is in real time, given the exigencies of forest urbanization.

2.3 FRACTIONAL FOURIER TRANSFORM

V. Namias [43] first introduced the Fractional order of Fourier Transform in 1980. Here the integral demonstration of this transform has been used for the construction of fractional order Fourier transform. A generalized operational calculus was established, paralleling the familiar one for the ordinary transform. Its application offers convenient procedure for solving the certain class of ordinary and partial differential equations which arise in quantum mechanics from classical quadratic Hamiltonians. Basically the method has been applied in quantum mechanics for describing quantum mechanical dynamics of electrons in time varying magnetic field.

In the applications such as linear algebra and matrix, B. W. Dickinson proposed his work in 1982 [44]. In this publication Dickinson studied the Eigen vectors using commuting matrices and they also efficiently computed fractional powers of DFT. They suggested new multiplexing and transform coding with the use of this fractionalized DFT.

A couple of decades later L. B. Almedia interpreted this fractional Fourier transform as rotation operator that rotates the signal in time-frequency plane depending on the value of a parameter alpha. Before publication in [45] the FrFT remained as unfamiliar to Signal Processing Community. Almedia familiarized some properties of the FrFT and also related this Fractional Fourier Transform with other time-frequency representations as Wigner distribution, the short time Fourier transform, ambiguity function, and the spectrogram. In this publication examples of FrFT of some simple signals were specified. He also explained the application, showing that how the use of FrFT allowed a treatment of swept-frequency filters that is similar to classical treatment of shift-invariant filter with the Fourier transform.

The Fourier transform and Fractional Fourier transform are related by the A. I. Zayed in [46] for understanding properties and to find its use in the areas where the conventional Fourier transform have been used.

In 1994, H. M. Ozaktas introduced applications of FrFT in [47] by interpreting Fractional Fourier Transform as time-frequency representation. The convolution, filtering and multiplexing applications that are useful in optical information processing are covered in this work. In his filtering application he described how to get rid of the noise that may overlap in both conventional space and frequency domain.

B. Santhanam represented the DFrFT as angular generalization of DFT in [48]. In this work the angular parameter values of $0^0$and 360^0 as identity operation, and 90^0 as DFT Operation were presented by him. He described the DFrFT signal as equivalent to mixture of signal, its DFT, time inversion of the signal and it’s DFT.

S. C. Pei *et al.* [49] scrutinizing the continuous fractional Fourier transform (FrFT) proposed a rotation of signal in time-frequency plane, and it became an important tool for signal analysis. A discrete version of Fractional Fourier transform had already been developed but its results did not match with those of continuous version. In this paper, authors proposed a new version of discrete fractional Fourier transform (DFrFT). This new DFrFT delivers similar transforms as those of continuous fractional Fourier transform and also clinch the rotation properties.

C. Candan *et al.* [50] presented a definition of the discrete fractional Fourier transform that generalizes the discrete Fourier transform (DFT) in the similar sense that the continuous fractional Fourier transform generalizes the continuous ordinary Fourier transform (FT). This definition is modeled using a particular set of eigenvectors of the DFT matrix, which constitutes the discrete equivalent of the set of Hermite-Gaussian functions. The definition is unitary, index additive, and reduces to the DFT for unit order.

S. C. Pei *et al.* [51] developed a 2D-DFrFT which preserved the rotation properties and provided similar results to continuous FrFT. Because of the importance of fractional Fourier transform, the implementation of discrete fractional Fourier transform was an important issue. Although recently a DFrFT with discrete Hermite eigenvectors has been proposed which had similar results as compared to continuous case, but sill there was need of FrFT for 2D signal analysis which was proposed in this paper.

The fractional Fourier transform is a time – frequency distribution and an extension of the classical Fourier transform. V. A. Narayanan [52] provided an introduction to the Fractional Fourier transform and its applications. These applications demanded the implementation of the discrete fractional Fourier transform on a digital signal processor (DSP). The effect of finite register length on implementation of discrete fractional Fourier transform matrix is discussed in some detail. This is followed by the details of the implementation and a theoretical model for the fixed-point errors involved in the implementation of this algorithm.

2.4 GAPS IN STUDY

The following gaps have been observed during study:

- The most common techniques for change detection are: Image differencing, PCA, CVA, Post-classification comparison. There is still no conclusion that which method is best suited for a specific application.
- As previous research has shown that a combination of two techniques can often improve the results like a parallel implementation of several change detection methods followed by an integration of the results may be the most effective way to detect change in a wide range of environments. So there is a lot of scope for improvements.

- Mixing data types is a problem with change detection. The assumption that similar land covers look the same in both images will be invalid.
- Different spatial resolution can also be a problem as a given land cover is not necessarily seen in the same way at different resolutions
- Due to its simplicity, image differencing represents a popular approach for change detection. To separate the “change” and “no-change” classes in the difference image, a thresholding-based procedure can be applied. However, the main weakness of an unsupervised change detection approach is the absence of prior information about the scene as it resorts to the spectral information, only, which does not allow the analysis of the typologies of changes occurring between the acquisition dates. In the monitoring of a given study area, the main problem is that the ground truth collection does not usually follow the image acquisitions at the different dates. However, it is easier if we have at least one image for which the ground truth is available.
- Detection of appearance/disappearance of objects from satellite images is generally very difficult since background pixels also change their intensity values owing to various factors.
- Recently, researchers have introduced image registration techniques using the log-polar transform (LPT) for its rotation and scale invariant properties. However, it suffers from non-uniform sampling which makes it not suitable for applications in which the registered images are altered or occluded.
- Effective foreground detection under sudden illumination change is an active research topic. However, most existing background subtraction approaches, which are intensity based, fail to handle the sudden illumination change situation.
- Given a set of high-resolution images of a scene, it is often desirable to predict the scene’s appearance from viewpoints not present in the original data for purposes of change detection. When significant 3-D relief is present, a model of the scene geometry is necessary for accurate prediction to determine surface visibility relationships. In the absence of an *a priori* high-resolution model (such as those provided by LIDAR), scene geometry can be estimated from the imagery itself. These estimates, however, cannot, in general, be exact due to uncertainties and ambiguities present in image data. Unfortunately, existing data structures used for probabilistic reconstruction do not scale well to large and complex scenes, primarily due to their dependence on large 3-D voxel arrays.

- There are no major works in the frequency domain for image change detection. Since, because FFT is rapid and accurate and more due to matrices inputs, best for dealing with images, no work has been established using FFT to find correlation of images in change detection.

3. IMAGE CHANGE DETECTION

3.1 INTRODUCTION

In the comprehensive possible sense, **images** are *pictures:* a way of recording and presenting information visually. Pictures are significant to us because they can be an extraordinarily effective medium for the storage and communication of information. We use photography in daily life to create a permanent record of our visual experiences, and to help us share those experiences with others. In showing somebody a photograph, we avoid the need for a lengthy, tedious and, ambiguous verbal narration of what was seen. We rely on our eyes for most of the information we receive regarding our surroundings, and our brains are particularly adept at visual data processing. There is thus a scientific basis for the well-known saying that *'a picture is worth a thousand words'*.

Image Change Detection (CD) is the ability to spot and characterize changes in images of the same scene taken at altered times. Change processing on imagery data includes the detection of a set of pixels that have undergone a significant change relative in a previous data sequence. This change in time is typically referred to as temporal change and is performed as a systematic CD study involving two sets of data prepared at different times. These changes may arise due to object movement, addition, deletion, removal or distortion etc. The consequence of these changes is the variation in the spectral signatures at same pixel locations of two sets of images of the same scene.

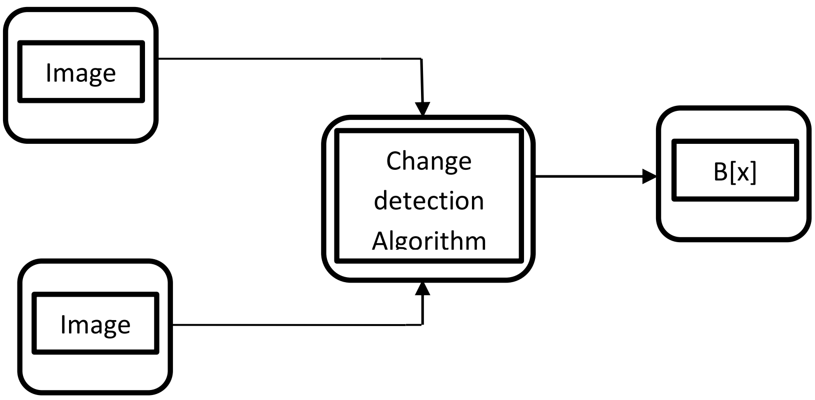


Figure 3.1: Block Diagram of Image Change Detection

Usually, in the comparison process, two corresponding pixels belonging to the same locality in an image pair are specified on the basis of a quantitative measure. If this measure exceeds a predefined threshold a change is labeled. A binary image, B identifies the changed region.

Two images or set of images is the minimum requisite to identify change however the pair can be a consecutive series of images. The capability to detect regions of change in images is a powerful tool that can be used in a diverse kind of applications. Changes that are of concern typically result from the appearance, disappearance, motion or change in the shape of a target object. Objects can also vary in brightness or color. Timely and precise change detection of Earth's surface features provides the base for better understanding relationships and exchanges between human and natural phenomena for managing resources effectively and using them to full potential.. Because of the advantages of repetitive data acquisition, its synoptic view, and digital format makes it appropriate for computer processing, remotely sensed data.

3.2 CHANGE DETECTION TECHNIQUES

Change Detection techniques play a very significant role in modern infrastructure. Although there are a number of methods, their applicability is restrained by limitation of the information they are evaluated upon, the type of image acquisition available, need of information to be retrieved after change detection etc. These techniques can be broadly classified under two main approaches:

1. Unsupervised Change Detection (no ground truth)
2. Supervised Change Detection (ground truth)

3.2.1 UNSUPERVISED CHANGE DETECTION

Produce a change detection map in which changed areas are parted from unchanged ones. The changes sought are expected to result in larger changes in radiance values than other factors. Comparison is performed directly on the spectral data. This results in a difference image which is analyzed to separate insignificant from significant changes.

Classes of techniques/algorithm based classification:

▪ Image math

- Transformations
- Image regression
- Spectral change vectors

Some of the above stated methods of Supervised Change Detection are explained below:

3.2.1.1 IMAGE MATH

Image math includes simple algebraic functions to be performed on images to get the resultant change detected image. Some common techniques include Image difference, Image ratio, Background subtraction etc. These methods are relatively simple, straightforward, easy to implement and interpret, but these cannot provide complete matrices of change information. Details of these methods are given below:

Image Differencing

Image differencing involves subtracting of the intensity values at same pixel locations of two images taken at two different periods of time. The two co-registered images are compared pixel-by-pixel and pixels related with changed areas produce values considerably different from those pixels associated to unchanged areas. The subtraction outcomes in positive and negative values in areas of change and zero values in areas of no change in a new third image. The difference image is analyzed to acquire a change or no change classification by applying a threshold. The decision rule is the most critical step of any CD method. Only the pixels above the threshold will correspond to a change at that location. After threshold, a difference binary image (B_{xy}) is obtained, all pixels in which show change with a value 1 (white) and the pixels with no change have a value of 0 (black).

$$B_{xy} = 1 \text{ if } |I_\lambda - I_{\lambda+1}| > \text{threshold}$$
$$0, \text{ other wise}$$

An illustration to image differencing by using threshold levels is shown with the help of following figures:

(a) (b)

Figure 3.2: Images to illustrate Image differencing

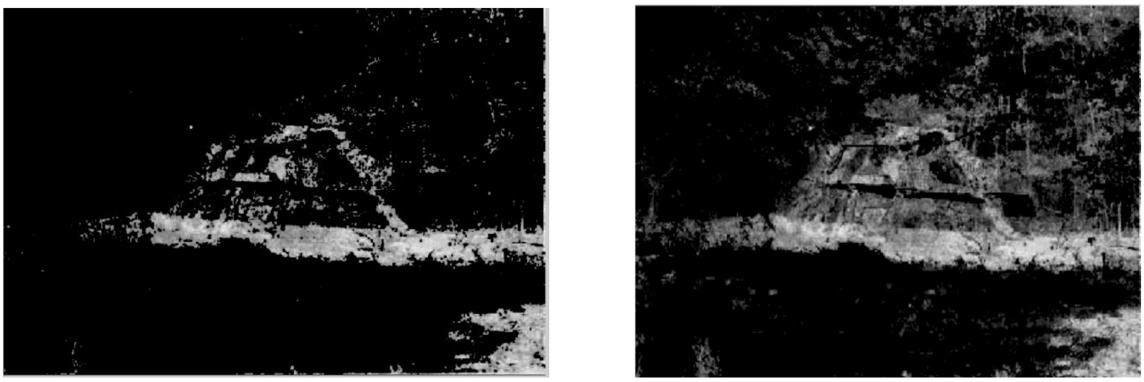
Here in above example, figure 3.2(a) shows the M1E1 Abrams MBT positioned at site S1 without Camouflage and figure 3.2 (b) shows the M1E1 Abrams MBT positioned at site S1 with woodland Camouflage. This is generally done to disguise the enemies.

(a) (b)

Figure 3.3: Binary Difference image with lower and higher threshold values

Figure 3.3 (a) and 3.3 (b) illustrate the effect of image differencing along with varying threshold values. For figure 3.3 (a), pixels in the resultant difference image having value low than 25 are all set to zero and rest are kept brightened and the threshold limit for the second figure 3.3 (b) is set to a value of 115. These arbitrary values are only chosen to show the effect of low and high threshold on image differencing. We can summarize in the following way:

Figure 3.3 (a), Lower threshold of ‘25’ intensity value, i.e. below 25 all are set to zero
Figure 3.3 (b), Higher threshold of ‘115’ intensity value, i.e. below 115 all are set to zero.



(a) (b)

Figure 3.4: Difference image with lower and higher threshold values shown on grayscale view

Pixels that are not bright enough to meet our threshold of 25 are set to black. The remaining pixels are colored in white. Since the black areas in the change image have brightness values of 0, they don't change anything on the original image. Only the areas in white are highlighted in the resulting image. Figure 3.4 (a) and 3.4 (b) illustrate the gray scale view which provides more realistic and enhanced view analogues to original images.

Image differencing is the simplest and most commonly used of all techniques however, a number of shortcomings go with the method.

- Differencing requires accurate registration and does not account for the presence of mixed pixels.
- It usually fails to consider the initial and final point of a pixel in feature space.
- Differencing often loses information. For instance, two differenced pixels can have the same value (degree of change), but this says nothing about the type of change that has occurred. For example, a change of 40 may be caused by differencing two pixels from 160 to 120 or from 90 to 50.

Image Ratios

Image ratios or band ratio method comprises of the same logic, except a ratio is calculated and the pixels that did not alter have a ratio value near 1 in the ratio image. This method divides brightness values of pixels in one group by the brightness values of their corresponding pixels in another group to generate the output image. These ratios may enhance or soothe certain attributes found in the image, liable to the spectral characteristics in each of the two bands or images.

$$Ratio\ Image = a\frac{I_{\lambda}}{I_{\lambda+1}}$$

In the equation [53] above the parameter, 'a' represents a likely scaling factor which can vary depending on the application. The ratio binary image is the new image created by the division of a set of bands for each pixel after introduction of a decision rule. The operator should be aware of the risk of division by zeros. This method has a vital advantage that ratios minimize the variations in illumination.

3.2.1.2 TRANSFORMATIONS BASED

The transformation category includes PCA, Gramm–Schmidt (GS), and Chi-square transformations etc. One advantage of these methods is in decreasing data redundancy between bands and laying emphasis on different information in derived components. However, they cannot arrange for detailed change matrices and require selection of thresholds to recognize changed areas. Another disadvantage is the difficulty in interpreting and labeling the change information. GS and Chi-square methods are not available in most of the commercial remote sensing image processing software.

Principal Component analysis (PCA)

Principal Component Analysis is a linear transformation technique and perhaps the most common of these techniques. The main principal of the PCA methodology is to use as input a set of images and to rearrange them via a linear transformation, such that the 19 output images are linearly independent. The new coordinate system for the data is projected such that the maximum variance lies on the first axis or the first principal component and the second greatest variance on the second axis.

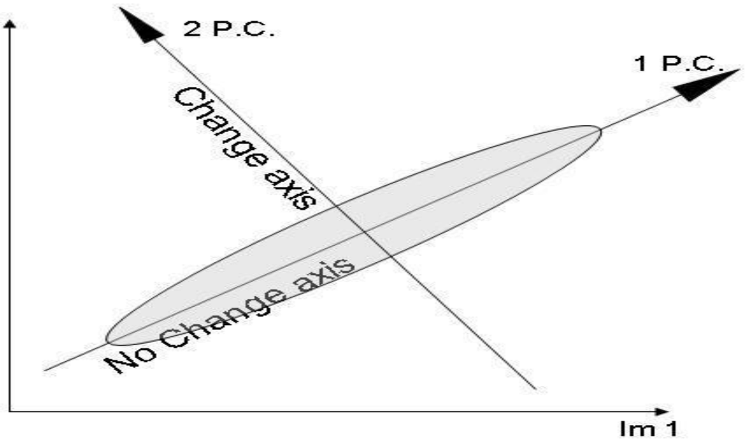


Figure 3.5: Change Detection using PCA [53]

This technique is normally used to reduce the number of spectral bands or in compression schemes. In CD studies, the consequence of this linearization is that unaffected pixels or common information shared by a pair of images are estimated to lie in a narrow elongated cluster along a principal axis equivalent to the first component (PC1). On the contrary, pixels comprising a change would be more unique in their spectral appearance and would be likely to lie far away from this axis (PC2. Thus the use of PCA for CD consists of examining the least-correlated components as represented by the 2nd principal component, which reflects the changes in the data under examination. Several approaches to PCA exist for change detection purpose.

3.2.1.3 IMAGE REGRESSION

In this approach a relationship between pixel values of two dates is accomplished by using a regression function. The dimension of the residuals is an indicator of where change occurred. Pixels from time t_1 are supposed to be a linear feature of time t_2 pixels. This method considers differences in mean and variance between pixel values from two dates. It has advantages of reducing impact of atmospheric, sensor and environmental differences.

It has the following shortcomings:

1. Requires development of accurate regression functions.
2. Does not provide change matrix.

3.2.1.4 CHANGE VECTOR ANALYSIS

In change vector analysis, each pixel is referred to as a vector in N-dimensional space where N signifies the number of bands in the image. This method is demonstrated in Figure 3.6 using a two-band example. From two images, a change vector is obtained by subtracting the vector of the image at time, t_1, from the vector of the image at time, t_2. The direction of the subsequent vector contains information about the type of change that has happened. This generally equates to spectral change. The magnitude of the resultant vector comprises of information about changes in radiance [5].

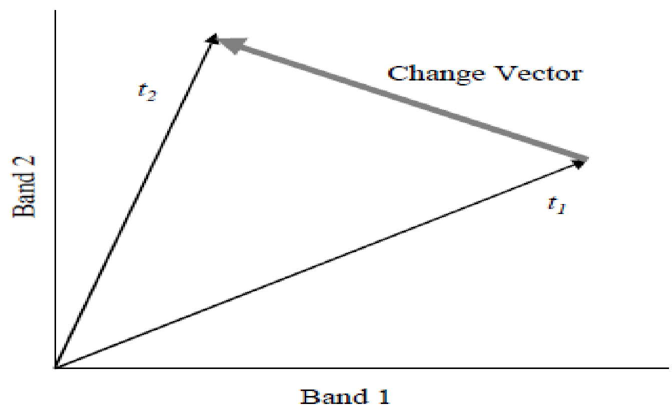
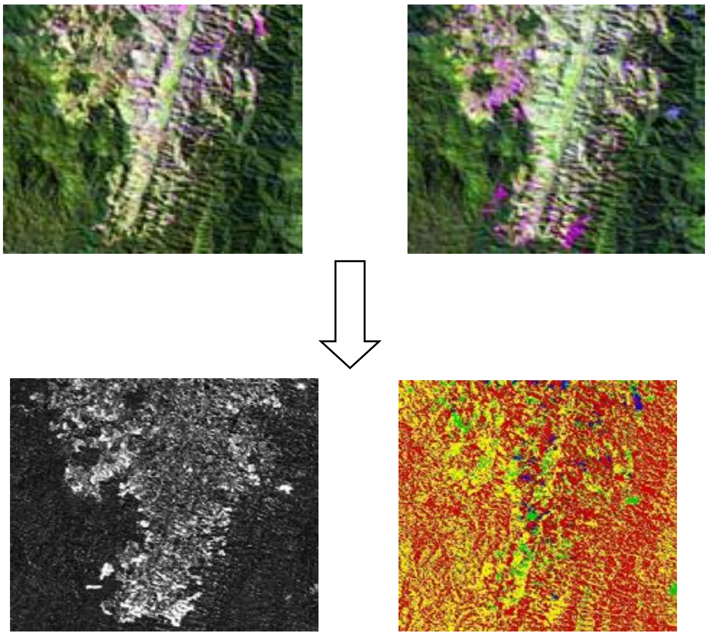


Figure 3.6: Formation of a change vector using two-band image vectors [53]

In essence, change vector analysis consists of two parts. The first is nothing more than band-by-band image differencing. A change vector can be formed by making an N band image where each band is the difference of two images of the same band. This is the lone way to represent all dimensions of a change vector; however, demonstrating more than three dimensions is difficult – if not impossible.



Magnitude **Direction**

Figure 3.7: Image Change Detection Using Change Vector Analysis

Since the direction of the change vector refers to the type of change, it is often desired to represent the change vector as a one-band spectral angle image. The final result is a change image that is dependent on spectral change and not on changes in global brightness. A modest way of obtaining the same result is to use a common reference spectrum for both images in producing individual SAM results. The difference in the two SAM results is the spectral angle difference and represents spectral change. The spectral angle difference also eliminates mean differences in radiance such as that related with sensor gain differences, but since vector magnitude is not accounted for, it is possible that main changes could be missed. It may be essential to have amplifying information from the N-band change vector image in order to conduct a full analysis.

3.2.2 SUPERVISED IMAGE CHANGE DETECTION

Generate a change detection map where changed areas are recognized and the land-cover transition type can also be identified. The changes are detected and labeled using supervised classification methods.

Main techniques:

- Post-classification comparison.
- Multi date direct classification.

3.3.2.1 Post Classification Comparison

Post classification comparison produces change maps by comparing segmented classes produced from two images [5]. Figure 3.8 illustrates the technique. Similar classes from both images are subtracted to produce change classes which are then merged into one result.

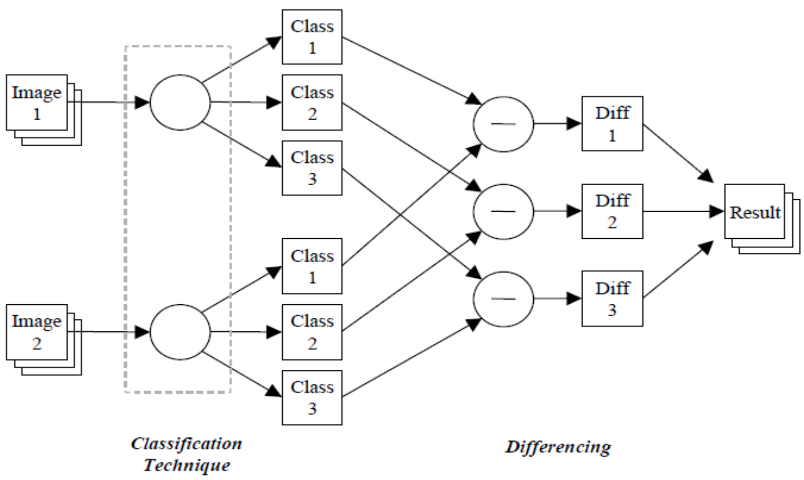


Figure 3.8: A flow diagram illustrating post classification [54]

This technique reduces the effects of differences in atmospheric conditions, solar angle, and sensor gain. It also lessens the need for accurate registration because the classes generally represent larger areas. It is likely; however, that registration would become more of an issue while making an attempt to observe smaller targets (i.e. tanks and trucks). The rules of joint probability are applicable to post classification comparison. Errors can be multiplied through to the change end result.

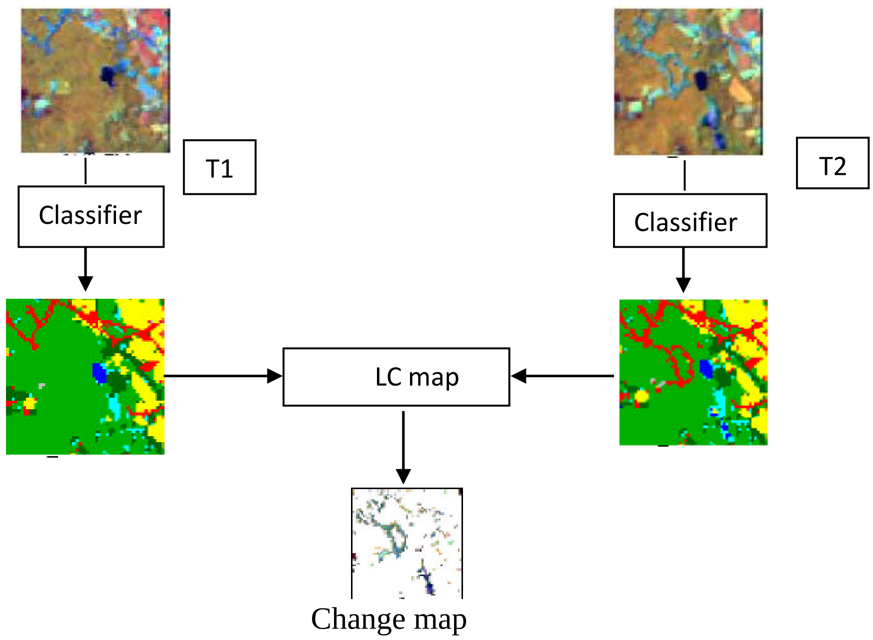


Figure 3.9: A Post classification comparison technique

3.3.2.2 Multi date direct classification: Two dates are combined into one multi temporal image and classified. It executes joint classification of the two images by using a stacked feature vector.

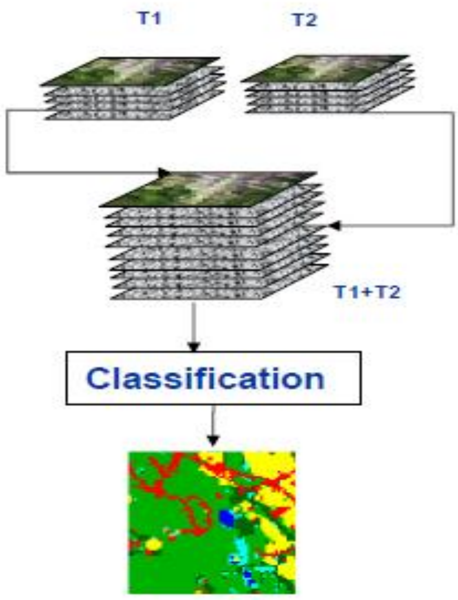


Figure 3.10: Multi date direct classification

Change detection is performed by considering each transition as a class, and training the classifier to identify all classes and all transitions.

Advantage:

- Adventures the multi temporal information.
- Error rate not accumulative.
- Offers change matrix.

Drawback

- Ground truth necessary also for transitions.

3.2.3 LIST OF VARIOUS CHANGE DETECTION TECHNIQUES
]

Apart from above techniques and classification of the change detection, a reasonable study which demonstrates various aspects of different change detection techniques was provided by D. Lu *et al.* in [55], which is shown in the following table. This table lists several selective methods of image change detection.

Table 3.1: List of various Change Detection Techniques [55]

S. no.	**Techniques/ Methods**	**Characteristics**	**Advantages**	**Disadvantages**	**Key Factors**
1. .	Image differencing	Subtracts the first-date image from a second-date image, pixel by pixel	Simple and straightforward, easy to interpret the results	Cannot provide a detailed change matrix, requires selection of thresholds	Cannot provide a detailed change matrix, requires selection of thresholds

2.	Image regression	Establishes relationships between bi- temporal images, then estimates pixel values of the second-date image by use of a regression function, subtracts the regressed image from the first-date image	Reduces impacts of the atmospheric, sensor and environmental differences between two-date images	Requires to develop accurate regression functions for the selected bands before implementing change detection	Develops the regression function identifies suitable bands and thresholds
3.	Image Ratios	Calculates the ratio of registered images of two dates, band by band.	Reduces impacts of Sun angle, shadow and topography	Non-normal distribution of the result is often criticized	Identifies the image bands and thresholds
4.	Vegetation index differencing	Produces vegetation index separately, then subtracts the second-date vegetation index from the first-date vegetation index	Emphasizes differences in the spectral response of different features and reduces impacts of topographic effects and illumination	Enhances random noise or coherence noise	Identifies suitable vegetation index and thresholds
5.	Change Vector Analysis	Generates two outputs: (1) the spectral change vector describes the direction and magnitude of change from the first to the second date;	Ability to process any number of spectral bands desired and to produce detailed change detection information	Difficult to identify land cover change trajectories	Defines thresholds and identifies change trajectories

		and (2) the total change magnitude per pixel is computed by determining the Euclidean distance between end points through n-dimensional change space.			
6.	Background subtraction	Non-change areas have slowly varying background grey levels. A low-pass filtered variant of the original image is used to approximate the variations to the background image. A new image is produced through subtracting the background image from the original image	Easy to implement	Low accuracy	Develops the background image
7.	Principal Component analysis	Assumes that multi-temporal data are highly correlated and change information can be highlighted in the new components. Two ways to apply	Reduces data redundancy between bands and emphasizes different information in the derived components	PCA is scene dependent, thus the change detection results between different dates are often difficult to interpret and Label.	Analyst's skill in identifying which component best represents the change and selecting thresholds

		PCA for change detection are: (1) put two or more dates of images into a single file, then perform PCA and analyse the minor component images for change information; and (2) perform PCA separately, then subtract the second-date PC image from the corresponding to PC image of first date.		It cannot provide a complete matrix of change class information and requires determining thresholds to identify the changed areas	
8.	Tasselled cap (KT)	The principle of this method is similar to PCA. The only difference from PCA is that PCA depends on the image scene, and KT transformation is independent of the scene. The change detection is implemented based on the three components: brightness, greenness and wetness	Reduces data redundancy between bands and emphasizes different information in the derived components. KT is scene independent.	Difficult to interpret and label change information, cannot provide a complete change matrix; requires determining thresholds to identify the changed areas. Accurate atmospheric calibration for each date of image is required	Analyst's skill is needed in identifying which component best represents the change and selecting thresholds.

9.	EM detection	The EM detection is a classification-based method using an expectation–maximization (EM) algorithm to estimate the a priori joint class probabilities at two times. These probabilities are estimated directly from the images under analysis	This method was reported to provide higher change detection accuracy than other change detection methods	Requires estimating the a priori joint class probability.	Estimates the a priori joint class probability.
10.	Unsupervised change detection	Selects spectrally similar groups of pixels and clusters date 1 image into primary clusters, then labels spectrally similar groups in date 2 image into primary clusters in date 2 image, and finally detects and identifies changes and output results	This method makes use of the unsupervised nature and automation of the change analysis process	Difficulty in identifying and labeling change trajectories	Identifies the spectrally similar or relatively Homogeneous units
11.	Hybrid change detection	Uses an overlay enhancement from a selected image to isolate changed pixels, then uses supervised	This method excludes Unchanged pixels from classification to reduce classification errors	Requires selection of thresholds to implement classification; somewhat complicated to	Selects suitable thresholds to identify the change and non-change areas and develops accurate

		classification. A binary change mask is constructed from the classification results. This change mask sieves out the changed themes from the LULC maps produced for each date.		identify change trajectories	classification results.
13.	Artificial neural networks (ANN)	The input used to train the neural network is the spectral data of the period of change. A back- propagation algorithm is often used to train the multi-layer perceptron neural network model	ANN is a non-parametric supervised method and has the ability to estimate the properties of data based on the training samples	The nature of hidden layers is poorly known; a long training time is required. ANN is often sensitive to the amount of training data used. ANN functions are not common in image processing software	The architecture used such as the number of hidden layers, and training samples
14.	Li–Strahler Reflectance model	The Li–Strahler canopy model is used to estimate each conifer stand crown cover for two dates of imageries separately. Comparison of the stand crown covers for two dates is	This method combines the techniques of digital image processing of remotely sensed data with traditional sampling and field observation methods. It provides statistical results and	This method requires a large number of field measurement data. It is complex and not available in commercial image processing software. It is only suitable for	Develops the stand crown cover images and identifies the Crown characteristics of vegetation types

		conducted to produce the change detection results	maps showing the geometric distribution of changed patterns	vegetation change detection	
15.	Spectral mixture model	Use spectral measures analysis to derive fraction images. End members are selected from training areas on the image or from spectra of materials occurring in the study area or from a relevant spectral library. Changes are detected by comparing the 'before' and 'after' fraction images of each end member. The quantitative changes can be measured by classifying images based on the end member fractions	The Fractions have biophysical meanings, representing the areal proportion of each end member within the pixel. The results are stable, accurate and repeatable.	Regarded as an advanced image processing analysis and is somewhat complex.	Identifies suitable end members; defines suitable thresholds for each land-cover class based on fractions.

16.	Biophysical Parameter method	Develops a biophysical parameter estimation model through integration of field measurements and remotely sensed data and estimates the parameter for the study area. The vegetation types are classified based on the biophysical parameter. The model is also transferred to other image data with different dates to estimate the selected parameters after reflectance calibration or normalization. Change detection is implemented through comparing the biophysical parameters	This method can accurately detect vegetation change based on vegetation physical structures	Requires great effort to develop the model and implement accurate image calibration to eliminate the difference in reflectance caused by different atmospheric and environmental conditions. Requires a large number of field measurement data. The method is only suitable for vegetation change detection.	Develops relevant models for estimation of biophysical parameters and defines each vegetation class based on biophysical parameters
17	Integrated GIS and remote sensing method	Incorporates image data and GIS data, such as the overlay of GIS layers	Allows access of ancillary data to aid interpretation and analysis and has the	Different data quality from various sources often degrades the	The accuracy of different data sources and their registration

		directly on image data; moves results of image processing into GIS system for further analysis	ability to directly update land-use information in GIS	results of LULC change detection	accuracies between the thematic images
18.	GIS approach	Integrates past and current maps of land use with topographic and geological data. The image overlaying and binary masking techniques are useful in revealing quantitatively the change dynamics in each category of the image map.	This method allows incorporation of aerial photographic data of current and past land-use data with other map data.	Different GIS data with different geometric accuracy and classification system degrades the quality of results	The accuracy of different data sources and their registration accuracies between the thematic images
19.	Visual interpretation	One band (or VI) from date1 image as red, the same band (or VI) from date2 image as green, and the same band (or VI) from date3 image as blue if available. An alternative is to implement on-screen digitizing of changed areas using visual interpretation based	Human experience and knowledge are useful during visual interpretation. Two or three dates of images can be analyzed at one time. The analyst can incorporate texture, shape, size and patterns into visual interpretation to make a decision on the LULC	Cannot provide detailed change information. The results depend on the analyst's skill in image interpretation. Time-consuming and difficulty in updating the results	Analyst's skill and familiarity with the study area

		on overlaid images of different dates	change.		

3.3 SATELLITE IMAGE CHANGE DETECTION

Satellites provide a great deal of the remote sensing imagery commonly used today. Satellites have a number of unique characteristics which make them particularly useful for remote sensing of the Earth's surface. The path trailed by a satellite is referred to as its orbit. Many remote sensing satellite are designed to follow an orbit (basically north-south) which, in conjunction with the Earth's rotation (west-east), allows them to cover maximum of the Earth's surface over a certain period of time. The availability of high-resolution satellite images increases the remote sensing applications to such a level that may cause traditional methods and aerial photogrammetry to be replaced by the new technology of satellite imagery. Satellite data is particularly beneficial for detecting changes in urban planning, land-cover and land-use because of periodically (repeated) coverage, low cost and extra details. The change detection technology brings together a significant relief in terms of the volume of data to be handled for automated analysis tasks as generally the change regions constitute the objects of interest only. Change detection is one of the prime uses of remotely sensed images from Earth-orbiting satellites, due to their repetitive coverage at short intervals and reliable image quality. Remote sensing satellites which monitor forest change in a repetitive manner provide the ideal opportunity for estimating forest structure changes. However, in satellite image change detection, it is generally difficult to discriminate significant intensity changes, such as produced by the appearance/disappearance of building structures, from intensity changes of the background. Although, in most cases Principle Component Analysis based linear transformation of intensity is applied to decrease the influence of the change in environmental illumination, the effect is usually insufficient since factors which changes the intensity of background pixels are often more complex in actual scenes. The significant feature of discrete fractional fourier domain in image processing benefits from its extra degree of freedom that is provided by its fractional orders. This varying fractional order can be used to produce distinct difference images captured from satellite at different instants of time.

Satellite imagery is now commonly used, map scan be produced using satellite imagery instead of traditional surveying and aerial photogrammetry, The IKONOS satellite has made revolution in the field of remote sensing. Earth's features like buildings, streets, cars and walls become visible with high resolution images. Now satellite imagery provides a rapid, high-quality data source to produce maps with more details. Change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times. It involves the ability to quantify changes using multi-source imagery captured at different epochs. Traditional change detection methodologies are based on visual/manual comparison of temporal datasets.

Satellite imagery has become increasingly available in recent years. Many satellites around the globe collect petabytes of imagery daily. This mass volume of data is analyzed continually for various environmental, humanitarian, educational, disaster relief/response and military uses. For most of these tasks, manual analysis of this amount of data is simply impossible other than for small regions. Automated tools to identify various objects of interest such as new buildings under construction, vehicles in motion, growth in vegetation, changes in glaciers are badly needed. The change detection technology introduces a significant relief in terms of the volume of data to be processed for automated analysis tasks as mostly the change regions constitute the objects of interest. These change maps contain all the genuine changes like vehicles in motion, new buildings, etc. in the scene as well as noise. In this thesis, the goal is to identify changes due to one particular source, the vehicles. More specifically, the problem is to measure the probability of being a foreground pixel and being on a vehicle in a test image. Vehicle motion constitutes a significant source of change especially in urban scenes. Once the vehicles are detected, this information can be utilized in various ways depending on the application. Some applications require removal of changes due to normal traffic flow from the change map, like measurement of affected areas due to some other genuine source of change like a hurricane. Some applications rely on the accurate characterization of vehicles such as collecting statistics related to the traffic in the urban areas, monitoring convoys for military surveillance. The vehicle detection algorithm presented in this thesis can be used for both types of applications. The modern satellites like Quickbird and Ikonos provide digital panchromatic imagery of the Earth's surface which has a much improved spatial resolution than multispectral imagery and imagery from other satellites. For example, Quickbird satellite produces panchromatic imagery having a pixel equivalent to an area 0.66m × 0.66m, while the multispectral pixels represent an area of 2.4m × 2.4m. Thanks to this improvement in resolution, it has become possible for analysts to identify individual vehicles in satellite imagery. Automation of this task entails an object recognition approach where the objects of interest are vehicles as observed in satellite imagery. More specifically, classification of each pixel as vehicle or non-vehicle would yield an output detection map to aid in further analysis of the scene depending on afore mentioned applications.

3.4 SUMMARY

Change detection analysis remains an active research topic and new techniques continue to be developed. For a new change detection technique, it is important to be able to implement it easily and for it to provide accurate change detection results associated with change trajectories. Although a variety of change detection techniques have been developed, it is still difficult to select a suitable method to implement accurate change detection for a specific research purpose or study area. Selection of a suitable change detection method requires careful consideration of major impact factors. In practice, several change detection techniques are often used to implement change detection, whose results are then compared to identify the best product through visual assessment or quantitative accurate assessment. Despite many factors affecting the selection of suitable change detection methods, image differencing, PCA and post-classification are, in practice, the most commonly used. In recent years, LSMA, ANN and GIS have become important techniques to improve change detection accuracy.

4. FRACTIONAL TRANSFORM

4.1 INTRODUCTION TO FRACTIONAL CONCEPT

During the last two decades, the process of going from the whole of an entity to fractions of it underlies several interesting applications such as fractal objects, fuzzy logic and fractional signal processing [56]. The fourth power of 8 may be defined as 8^4= 8x8x8x8, but it is not apparent to define $8^{3.5}$ in a similar way. It must have taken sometime before the common definition $8^{3.5} = 8^{7/2} = \sqrt{8^7}$ emerged.

The first and second derivatives of the function $f(x)$ are commonly denoted by:

$$\frac{df(x)}{dx} \quad \text{and} \quad \frac{d^2 f(x)}{dx} = \frac{d}{dx}\left[\frac{df(x)}{dx}\right] = \frac{d[df(x)/dx]}{dx} = \left(\frac{d}{dx}\right)^2 f(x) \quad \text{respectively.}$$

And higher order derivatives are defined similarly. But it is not obvious that what will be 0.9^{th} order derivative using above definition. We know that by using differentiation property of Fourier Transform, the a^{th} derivative of $f(x)$ i.e. $\frac{d^a f(x)}{dx^a}$ is equivalent to the inverse Fourier transform of $(i2\pi\mu_a)^a$ F (μ_a) where F (μ_a) is the Fourier Transform(FT) (of real order 'a') of the function $f(x)$. FT is widely used in many areas of science and engineering like optics, physics, acoustics, statistics, heat conduction and diffusion, electrical engineering, antenna and array processing etc. FT is a linear transform used to solve linear system problems. However, the FT is unable to solve certain classes of ordinary and partial differential equations of optics, signal processing and quantum mechanics [57]. Looking into the applicability of FT the concept of fraction was introduced in the FT in the year 1929 [58] and lead to the development of fractional Fourier transform (FrFT). If we go on to map the history of fractional thought it is found that in 17th century, Bernoulli (1695) formulated a question about the meaning of a non-integer order derivative. This was the start of the fractional calculus which is the base of the continuous time fractional systems described by the fractional differential equations. Since then, the concept of fractional calculus has evolved in pure mathematics and developed by famous mathematicians [56]. In spite of the advancement in pure mathematics this concept had been applied in applied sciences only in 1920's. Furthermore, it is only in the last three decades that the applications of fractional calculus have emerged in engineering field which lead to a significant impact in several areas and attracted the scientific and technical community to the fractional objects [56].

4.2 FRACTIONAL FOURIER TRANSFORM

4.2.1 INTRODUCTION

The Fourier Transform (FT) is undoubtedly one of the most appreciated and frequently used tools in signal processing and analysis. Little need be said of the prominence and ubiquity of the ordinary Fourier transform in many areas of science and engineering. The FrFT, which is a generalization of the simple Fourier transform, was introduced 75 years ago but only in the last two decades, it has gained prominence in signal processing, optics and quantum mechanics. FrFT was introduced in 1980 by Victor Namias [43] and it was established in the same year that the other transforms could also be fractionalized [59]. McBride and Keer explored the refinement and mathematical definition in 1987 [60]. In a very short span of time, FrFT has established itself as a commanding tool for the analysis of time varying signals [61]. Mathematically the a^{th} order Fractional Fourier transform operator is the a^{th} power of the conventional Fourier transform operator. The fractional Fourier transform with parameter $a = 1$ corresponds to the orthodox Fourier transform. It is noticeable to bring in mind that the ordinary Fourier transform is a special case of a continuum of fractional Fourier domains. Essentially, the a^{th} order fractional Fourier transform is an intermediate between any function $x(t)$ and its Fourier transform$X(f)$. The 0^{th} order transform is merely the function itself, whereas the 1^{st} order transform is its Fourier transform. In all the time–frequency representations, one typically uses a plane with two orthogonal axes that usually are time and frequency. If we consider a signal $x(t)$ to be represented along the time axis and its ordinary Fourier transform $X(f)$ to be represented along the frequency axis, then the Fourier transform operator (denoted by F) can be visualized as a change in representation of the signal corresponding to a counter clockwise rotation of the axis by an angle $\pi/2$ [59]. This is reliable with some of the pragmatic properties of the Fourier transform (FT). For example, two successive rotations of the signal through $\pi/2$ will outcome in an inversion of the time axis. Moreover, four consecutive rotations will leave the signal unchanged since a rotation through 2π of the signal should leave the signal same.

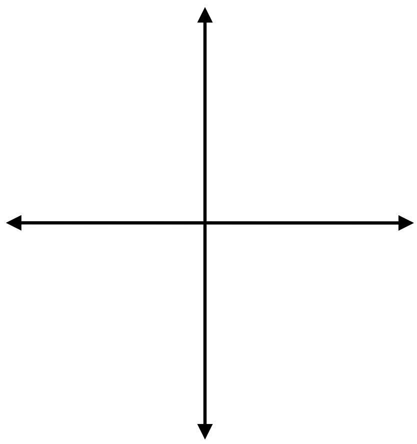


Figure 4.1: FRFT domain in time-frequency plane

The Fig 4.1 shows the FRFT domain in Time-frequency plain. The FRFT is a linear operator that corresponds to the rotation of the signal through an angle which is not a multiple of π/2, i.e. it is the representation of the signal along the axis making an angle α with the time axis. Some important cases of the FRFT operator for $\alpha = a\frac{\pi}{2}$ are listed below:

- For $\alpha = 0$ or 4; i.e. $a = 0$ or 2π, one acquires the identify operator: $F^0 = F^4 = I$ (Identity Operator)
- For $\alpha = \frac{\pi}{2}$; i.e. $a = 1$,one gets the Fourier operator: $F^1 = F$ (Fourier Operator)
- For $\alpha = \pi$; i.e. $a = 2$, one achieves the reflection operator: $F^2 = FF = I -$(Reflection Operator shown by time inversion).

- For $\alpha = \frac{3\pi}{2}$; i.e. a=3, one gets the inverse Fourier operator $F^3 = FF^2 = F^{-1}$ (Inverse Fourier Operator)

So for an angle from 0 to 2 π, we have the values of 'a' from 0 to 4 and it can be shown that the transform kernel is periodic with a period 4.

The FRFT of a signal x(t) as can be computed by four steps process [45]:

1. Multiplying the function with a chirp,
2. Taking its Fourier transform,
3. Again multiplying with a chirp, and
4. Then multiplication with an amplitude factor.

It is found that the FRFT of a signal x (t) exists under the same conditions in which its Fourier transform exists.

The FrFT have a number of applications in the areas of signal and image processing applications as signal detectors, correlation, pattern recognition, time variant filtering, multiplexing, image encryption, and signal and image recovery, restoration.

4.2.2 PROPERTIES OF FrFT

In order to discuss the various properties of the FRFT, it would be ideal to denote the FRFT in an operator notation. Some important properties of the DFrFT are listed below in the following table:

Table 4.1: Properties of FrFT

Sr. No.	**Operation**	**Signal, $x(t)$**	**Fractional Fourier Transform, $X_\alpha(u)$**
1	Time shifting	$x(t-\tau)$	$e^{j\left(\frac{\tau^2}{2}\right)\sin\alpha\cos\alpha - ju\tau\sin\alpha} X_\alpha(u-\cos\alpha)$
2	Modulation	$x(t)\, e^{jvt}$	$e^{-jv^2(\sin\alpha\cos\alpha)/2 + juv\cos\alpha} X_\alpha(u-\sin\alpha)$
3	Scaling of time axis	$x(ct)$	$\sqrt{\frac{1-j\cot\alpha}{c^2-j\cot\alpha}}\, e^{ju^2/2\cot\alpha(1-(cos^2\beta/cos^2\alpha))}$

4	Differentiation	*X'(t)*	$X'_a(u)\cos\alpha + ju\sin\alpha\, X_a(u)$
5	Integration	$\int_a^t x(t')dt'$	$\sec\alpha\, e^{-j(u^2/2)\tan\alpha} \int_a^u X_a(z) e^{j(z^2/2)\tan\alpha}\, dz$ if α- π / 2 is not a multiple of π
6	Multiplication with ramp	*tx(t)*	$u\cos\alpha\, X_a(u) + j\sin\alpha\, X'_a(u)$
7	Convolution	*x(t) *g(t)*	$F^{-a}[(F^a x)(F^a g)]$

4.3 DISCRETE FRACTIOANL FOURIER TRANSFORM

4.3.1 INTRODUCTION

After the development of FrFT, there was always a need to discretize the fractional transform application. The sampled or the discrete version is quite handy for the tenacity in the current signal processing environment. The real time implementation of fractional transforms is essential requirement for all above mentioned applications of FrFT. Particularly to implement a versatile device for all above real time applications, the real time computation of FrFT can be accomplished by implementing its discrete form known as Discrete Fractional Fourier transform (DFrFT).

It basically involves rotation of a discrete signal by an angle α in the time-frequency plane. But for analysis of 2D signals such as images, a two dimensional version of DFrFT is required. For an M x N matrix, the 2D DFrFT is computed in an unpretentious way. The 1D DFrFT is applied to each row of given matrix and then same is applied to each column of the result matrix. Thus, the generalization of the DFrFT to 2D is given by taking the DFrFT of the rows of the matrix i.e. image in a fractional domain and then taking the DFrFT of the subsequent column wise. In case of 2D DFrFT, two angles of rotation $\alpha=\pi/2$ and $\beta=\pi/2$ have to be taken.

It has been recently observed that DFrFT can be used in the field of image processing .The vital feature of Discrete Fractional Fourier domain Image compression aids from its extra degree of freedom that is provided by its fractional orders.

4.3.2 MATHEMATICAL DEFINITION

When FrFT is considered in discrete domain there are many definitions of Discrete Fractional Fourier Transform (DFrFT) [61-62]. Therefore, many attempts have been made to find the discrete version of the FrFT [50, 61]. The first work on discrete fractional Fourier transform (DFrFT) is claimed by Santhanam [48] in 1995. After that many researchers are trying to discretize this linear integral transform. Though quite a few different algorithms were suggested by various researchers, the most appropriate definition that agrees with the various properties of the FrFT and approximates to the FrFT is the one proposed by Candan et al. [50]. This is defined in terms of particular set of Eigen vectors. This Eigen vectors are discrete version of the continuous Hermite Gaussian functions. This definition fulfills all the vital properties such as unitary, index additive, reduction to DFT when order is equal to unity and approximation of Continuous FrFT. If we let $\mathcal{F}^{a}$ be the $N \times N$ matrix representing the discrete fractional Fourier transform, this definition can be stated as follows:

$$\mathcal{F}^{a} = \sum_{n=0}^{3} e^{j\frac{3\pi}{4}(n-a)} \frac{\sin\pi(n-a)}{4\sin\frac{\pi}{4}(n-a)} \mathcal{F}^{n} \qquad (3)$$

where, $\mathcal{F}^{n}$ is the nth (integer) power of the DFT matrix. Now the emphasis would be on finding an eigenvector set of the DFT matrix which can serve as discrete versions of the Hermite–Gaussian functions. The Hermite–Gaussian generating differential equation [50] is

$$\frac{d^2 f(t)}{dt^2} - 4\pi t^2 f(t) = \lambda f(t) \qquad (4)$$

Note that as $h \rightarrow 0$ the difference equation following approximates

$$\frac{f(u+h) - 2f(u) + f(u-h)}{h^2} + \frac{2(\cos(2\pi hu) - 1)}{h^2} f(u) = \lambda f(u) \qquad (5)$$

When $h = \frac{1}{\sqrt{N}}$, the difference equation (4) has periodic coefficients. Therefore, the solutions of the difference equation are periodic and can be jotted down as the eigenvectors of the following matrix [50], denoted by S:

$$S = \begin{bmatrix} 2 & 1 & 0 & \cdots & 0 & 1 \\ 1 & 2\cos(2\pi/N) & 1 & \cdots & 0 & 0 \\ 0 & 1 & 2\cos(2\pi/N) & \cdots & 0 & 0 \\ \vdots & \vdots & \vdots & \ddots & \vdots & \vdots \\ 1 & 0 & 0 & \cdots & 1 & 2\cos(2\pi(n-1)/N) \end{bmatrix}$$

or, the difference equation can also be written as $Sf = \lambda f$. It can also been shown that S commutes with DFT matrix. Having got an appropriate set of eigenvectors, the DFrFT matrix can now be defined as follows:

$$\mathcal{F}^a = \begin{cases} \sum_{k=0, k\neq N-1}^{N} u_k e^{-j\frac{\pi k a}{2}} u_k^T , & \text{when N even} \\ \sum_{k=0, k\neq N}^{N} u_k e^{-j\frac{\pi k a}{2}} u_k^T , & \text{when N odd} \end{cases}$$

where, u_k corresponds to the eigenvector of the S matrix with k zero-crossings.

4.3.3 PROPERTIES OF DFrFT

Few properties of the DFrFT are listed below in the following table:

Table 4.2: Properties of DFrFT

S no.	Property	Description
1.	Inverse	$(F^{a})^{-1} \Leftrightarrow F^{-a}$
2.	Unitary	$(F^{a})^{-1} \Leftrightarrow (F^{a})^{H}$
3.	Commutative	$F^{a2}\ F^{a1} \Leftrightarrow F^{a1}\ F^{a2}$
4.	Index Additive	$F^{a1}\ F^{a2} \Leftrightarrow F^{a1+a2}$

5.	Associative	$F^{a3}(F^{a1}\ F^{a2}) \Leftrightarrow (F^{a3}F^{a2})\ F^{a1}$
6.	Periodicity	$F^{a+2\pi} \Leftrightarrow F^{a}$

4.4 SUMMARY

Transforms play vital roles in the analysis of signal processing. Transforms help in finding out the hidden properties of a signal, which are unrecognizable from the time domain representation of the signal. The choice of the transform depends on the type of the signal and the application. Due to significant applications of FT, concept of fraction was introduced to it resulting in the development of FrFT. A need to discretize FrFT, so as to bring it into a digitally processed form, lead to introduction of DFrFT. DFrFT has been widely used in various applications like optical, image and other signal processing applications.

5. IMAGE CHANGE DETECTION USING FRACTIONAL FOURIER TRANSFORM

5.1 INTRODUCTION

Change detection is a technique used to determine change between two images which may arise due to various changing factors. It is an important process in monitoring natural resources, detecting out region of interest which are mainly the change objects in the two images taken at different instants of time. Change detection between images of the same scene taken at different times is important in various applications, such as the detection of abnormalities in medical or factory examination, event detection from surveillance images, and change detection from aerial/satellite images [4]. When images are taken consecutively with small time intervals, as with frame-rate video surveillance, the adaptive background subtraction strategy works well when using a series of previous frames [63-64].However, there are also several situations in which images are taken with a long time interval. In such cases, it is not easy to discriminate “significant” changes, such as the appearance/disappearance of objects, from “insignificant” changes, such as those induced by illumination variation. For simple techniques which work directly on image data, like simple image differencing, the output is not very reliable except for artificially simplified cases or for highly controlled scenarios [12]. To improve reliability, one slowly moves from using direct image data to single or multi-step-derived information like information generated after segmentation or object classification. The transform domain techniques may include change detection using DCT, Discrete Fourier Transform (DFT) but in this chapter, a new change detection algorithm using the Fractional transforms is proposed and compared with the other techniques.

5.2 METHODOLOGY

Three different methods have been used in the research work for obtaining change detection:

1. Image Change Detection using Joint Intensity Histogram (JIH).
2. Image Change Detection using Discrete Cosine Transform (DCT).
3. Image Change Detection using Discrete Fractional Transform (DFrFT).

The joint histogram is a two-dimensional (2D) histogram of combinatorial intensity levels ($I_{1(x),}$ $I_{2(x)}$), where I_1, I_2 and x represent the intensity level (0-255) of each image and the positions of pixels on images, respectively. In the case in which a background with insignificant changes is dominant in the images, on the joint histogram, background pixels tend to form large clusters that spread over the (I_1,I_2) plane. The combinations of (I_1, I_2) covered by the clusters are determined as insignificant changes. By assuming the remaining combinations to be significant changes, pixels with significant changes are extracted from the images and hence we acquire the results for important change detection. If there is no change in intensity between two images, then the pixels are plotted on the line $I_2 = I_1$. Use of a global threshold technique is incorporated for selection of significant clusters in the JIH.

DCT is a real part of the DFT. This frequency transform containing only the cosine coefficients is used to obtain change detection by means of selection of suitable coefficients. Block by block quantization threshold technique is used to select the required coefficients which results in the vital change detection portion of the image. A further filtering approach by checking gradient correlation between the images for each region consisting of sizable connected groups of these pixels, results in the classification of the selected candidate regions.

But by using DFrFT, we have the additional advantage to vary the parameter 'a' to get the required results in terms of accurate change detection. By varying the fractional parameter, we can look for results flexibly until we obtain maximum of change regions efficiently. The complete procedure to obtain image change detection using DFrFT is presented as follows:

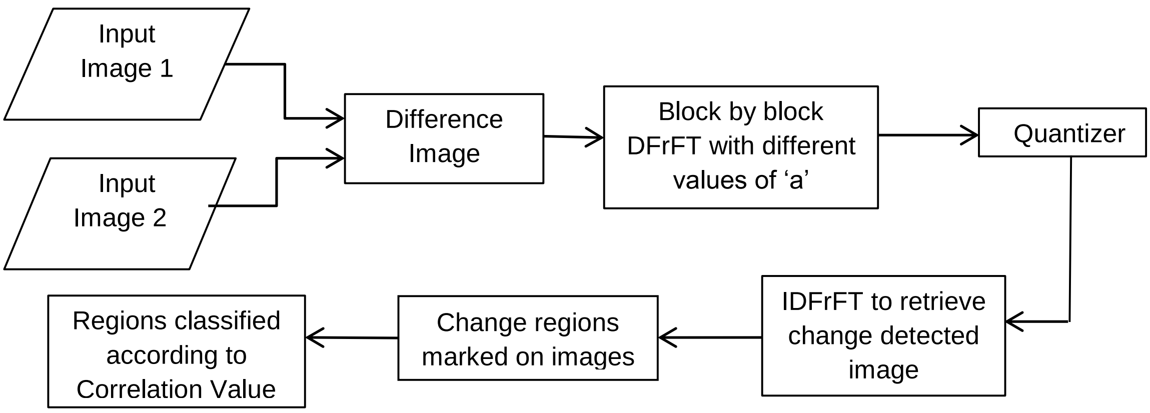


Figure 5.1: Block diagram of change detection using DFrFT

Step 1: **Differencing**: In the initial change detection step, the simple difference image is obtained by algebraically subtracting the first image from the second image. The resultant simple difference image is itself a raw changed image that is to be used for further proceedings.

Step 2: **Transform**: This difference image is then Discrete fractionally Fourier transformed with different fractions in the frequency domain by varying parameter 'a'= 'ar' (for rows) ='ac' (for columns).

Step 3: **Quantizer**: After applying Transform i.e. DFrFT, the equivalent transform matrix is passed through a quantizer which selects only appropriate coefficients and round of the other to zero.

Step 4: **Change detected image**: In order to retrieve the change image, IDFrFT is applied on the selected coefficients with parameter 'a'= -a. This task is performed with various values of 'a' to get consequent different change images.

Step 5: **Region marking on the image**: The changes in the image have been detected and then are categorized into regions by defining a particular region size according to the size of images. Hence proper change regions are obtained which are highlighted by drawing red rectangles.

Step 6: **Classification of regions according to the correlation coefficient value**: We adopt gradient correlation checking as an additional filtering process for further discrimination of significant change regions obtained in above processes. A gradient measure of similarity, Se or correlation is defined for the particular region by taking gradient images in the above regions as in [24] and is given by:

Se=min (Ex,Ey)

$$\text{Ex} = \frac{\sum(e_{1,x}(x) - \mu_{e_{1,x}})(e_{2,x}(x) - \mu_{e_{2,x}})}{\left(\max\left(\sigma_{e_{1,x}}, \sigma_{e_{2,x}}\right)\right)2}$$

$$\text{Ey} = \frac{\sum(e_{1,y}(y) - \mu_{e_{1,y}})(e_{2,y}(y) - \mu_{e_{2,y}})}{\left(\max\left(\sigma_{e_{1,y}}, \sigma_{e_{2,y}}\right)\right)2}$$

where $\mu_{e_{i,k}}$ and $\sigma_{e_{i,k}}$ represents the average and standard distribution of the gradient image in the kth direction of image in a candidate region and Ex and Ey are the gradient similarity measures of the input images in the candidate regions in the X and Y directions respectively and $e_{i,k}(k)$ represents the pixel value in the kth direction of input images in candidate regions. The candidate regions are classified into the three classes according to Se: change with high certainty ($0.0 \leq Se \leq 0.1$), change with low certainty ($0.1 < Se \leq 0.3$), and no change ($0.3 < Se \leq 1.0$) [24]. The partial movement of objects, such as waving trees, often occurs between images, and the detection of such movement is undesirable. When such partial translation occurs, a similar gradient pattern is observed in the locality of the corresponding position [24]. Therefore, if we take the maximum of Se while translating one region over the corresponding region in the other image, such regions should show large Se (high correlation) and thus can be rejected. The three classes, high certainty, low certainty and no change, are represented using red, yellow and green squares, respectively.

5.3 PARAMETERS USED FOR IMAGE CHANGE DETECTION

In order to find change detection between two images, simulations have been performed for three different set of images. After obtaining the change regions in the images, the correct detected regions (C_d), false detected regions (F_d) have been categorized and results are compared using two parameters viz. precision and recall.

Precision: Precision is the fraction of retrieved instances that are relevant [65]. In other words, precision can be seen as a measure of correctness or quality. Mathematically it is given by:

$$\text{Precision,P} = \frac{C_d}{(C_d+F_d)}, \text{ where}$$

C_d= No. of correctly detected change regions

F_d= No. of false detected change regions

Recall: Recall is a measure of completeness or quantity or it is the fraction of relevant instances that are retrieved [65]. Formula for recall is given by:

$$\text{Recall, R} = \frac{C_d}{C_d+M_d}, \text{ where}$$

C_d= No. of correctly detected change regions

M_d= No. of Missed Regions

For e.g. suppose a scene change contain 9 objects. If the detection algorithm identifies 7 objects and among them 4 recognized are correct, then the precision value is 4/7 and recall value is 4/9.

5.4 RESULTS AND DISCUSSIONS

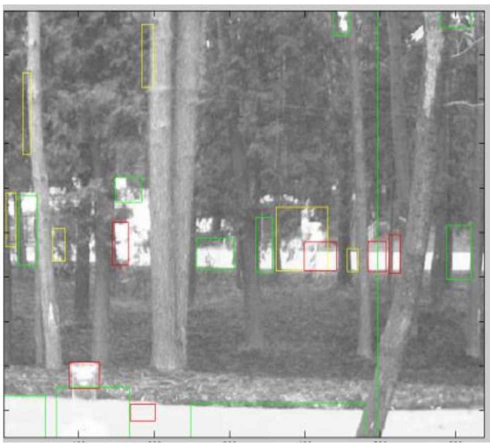
Three image sets have been chosen for the experimental resolutions. The simulations were performed in MATLAB software and following results have been obtained.

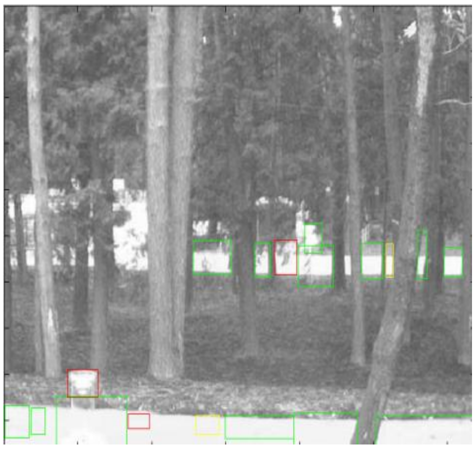
5.4.1 IMAGE SET 1

(a) (b)

Figure 5.2: (a), (b) Original images set to be change detected (set 1)

Figures 5.2 (a) and 5.2 (b) provide a typical example in which two images of the same scene do not show simple brightness changes. These images were taken at 7:06 AM and at 11:59 AM, respectively, using a Field Monitoring Server (FMS) camera used as a node of a sensor network [66].



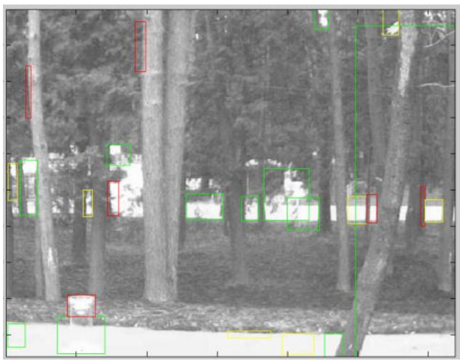


(a) (b)

Figure 5.3: (a) Change regions obtained using JIH, (b) Change regions using DCT

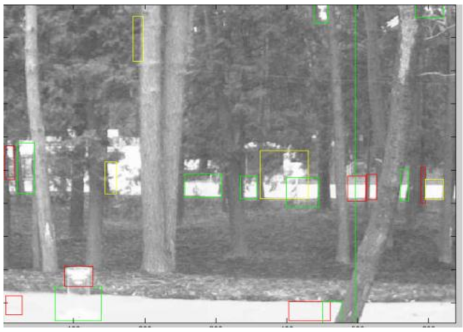
Change Detection between these two images using joint intensity histogram technique with a threshold of ±30 [24] and with a region size of area greater than 200 pixels is carried out and the result is shown in Figure 5.3 (a). Figure 5.3 (b) shows the Change Detection carried out using DCT (Discrete Cosine Transform) by using quantization threshold technique and having the same region size. In above figures 5.3 (a) and 5.3 (b), we show the regions classified as main change region (red rectangles), low certainty change regions (yellow rectangle), and no change or non-significant regions (green rectangle).

1) Changes with High Certainty (Red) $0<Se<0.1$
2) Changes with low certainty (yellow) $0.1<Se<0.3$
3) No change (green) $0.3<Se<1$



(a) (b)

(c)



(d)

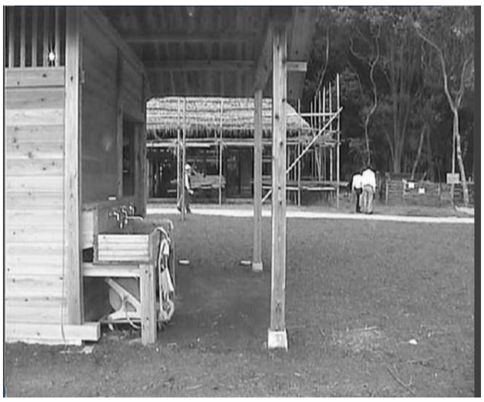
Figure 5.4: (a), (c) Change images obtained using DFrFT with a=0.2, 0.9

(b), (d) Change regions obtained using DFrFT with a=0.2, 0.9

The same work is carried out using DFrFT, in which the output change region is obtained for various values of parameter 'a'. The region size boundary limit and the correlation classification values chosen are identical as taken for above two methods. Figure 5.4 (a) and 5.4 (c) shows the change image retrieved after applying IDFrFT and corresponding figures 5.4 (b) and 5.4 (d) shows the final change regions marked on the original image, i.e., figure 5.2 (a). The same procedure is reiterated for three different image sets with varying size. Here arbitrary values are chosen for the demonstration purpose. Among different values tried for fractional parameter, value of a at 0.9 gives out the best results with DFrFT.

5.4.2 IMAGE SET 2

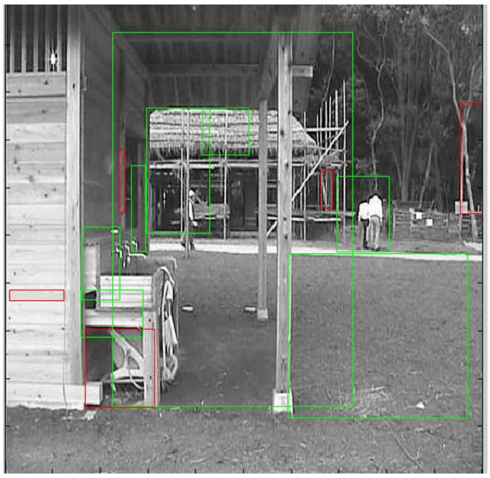
(a)

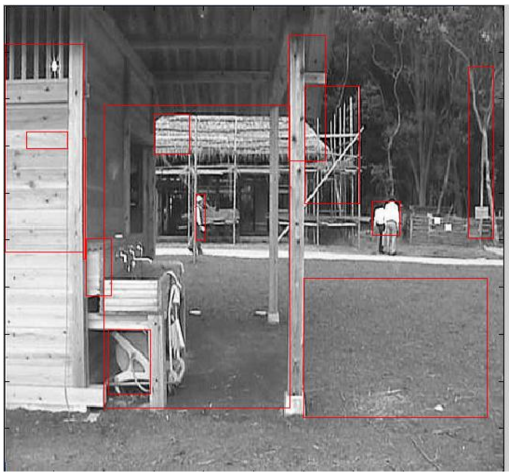


(b)

Figure 5.5: (a), (b) Original images set to be change detected (set 2)

Figures 5.5 (a) and 5.5 (b) were captured with a five minute interval between images. These images provide an example of a rapid change in daylight that causes difficulty with respect to change detection.

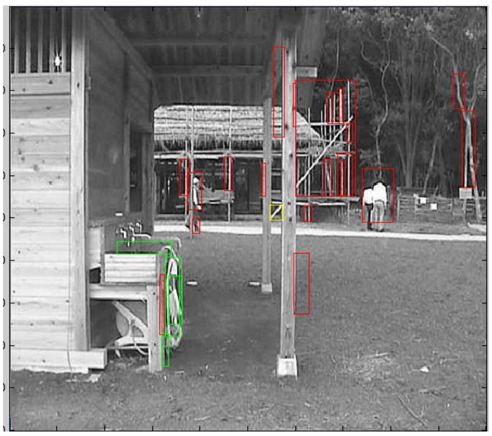




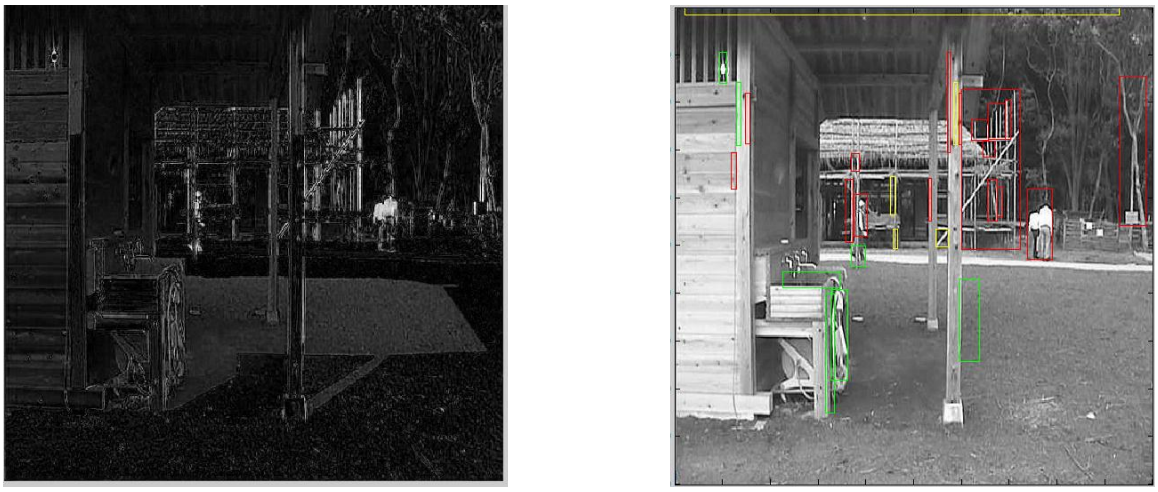
(a) (b)

Figure 5.6: (a) Change regions obtained using JIH, (b) Change regions using DCT

The similar exercise is repeated with image set 2 like the previous image, but the region size here chosen is 150 pixels depending upon the size and nature of the change objects and the input images. Figure 5.6 (a) shows the results with JIH and 5.6 (b) shows the results with DCT.



(a) (b)



(c) (d)

Figure 5.7: (a), (c) Change images obtained using DFrFT with a=0.3, 0.98

(b), (d) Change regions obtained using DFrFT with a=0.3, 0.98

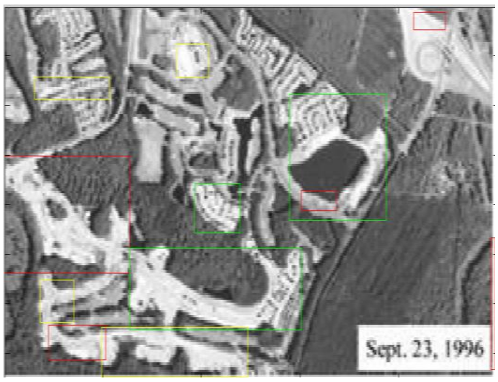
Similarly here, Figure 5.7 (a) and 5.7 (c) shows the change image retrieved after applying IDFrFT and corresponding figures 5.7 (b) and 5.7 (d) shows the final change regions marked on the original image, i.e., figure 5.5 (b). The results of this image set are showing maximum values of precision and recall at value a =0.98. Another value of a = 0.3 is shown for demonstrating varying nature of results obtained with respect to the variation in the fractional parameter. Clearly the two objects missed one change in the bulb intensity and the other close to roof are only detected when we apply DFrFT with a = 0.98.

5.4.3 IMAGE SET 3

(a) (b)

Figure 5.8: (a), (b) Original images set to be change detected (set 3)

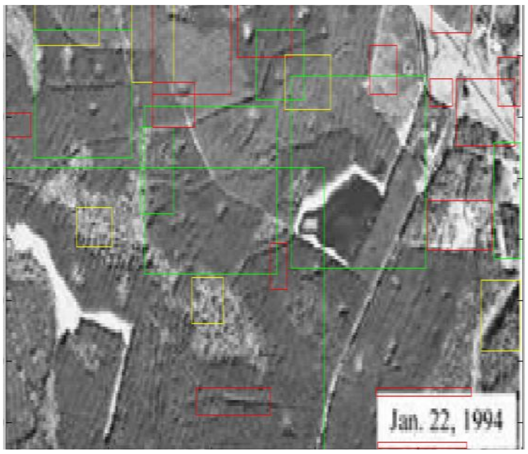
(a)



(b)

Figure 5.9: (a) Change regions obtained using JIH, (b) Change regions using DCT

Here the region size chosen is very small due to small dimensions of the image. With region size-50 pixels we obtain the results as shown in the above Figure 5 and the following Figure 6 respectively.



(a)

(b)

Figure 5.10: (a), (b) Change regions obtained using DFrFT with a=0.5, 0.88

Here the parameter value acquiring the best outcomes is of a = 0.88. Along with it the outcome for a = 0.5 is also shown in above Figure 5.7 (a) and Figure 5.7 (b). Apart from these individual results, the comparative analysis will be shown in the following section.

5.4.4 COMPARITIVE ANALYSIS

This section introduces with the comparative analysis of the three techniques used for change detection which gives the following results for different image sets used:

TABLE 5.1: Results comparing different change detection techniques

Image sets	Method	T_a (Total Actual Change Regions)	T_d (Total Detected Regions)	C_d (Correctly Detected Regions)	F_d (False detected Regions)	M_d (Regions missed)	P (Precision)	R (Recall)
Image set (1) / [638 x 479]	JIH	15	23	10	13	5	0.43	0.67
	DCT	15	18	10	8	5	0.56	0.67
	DFrFT(0.9)	15	21	13	8	2	0.62	0.87
Image set (2) / [500 x 500]	JIH	8	13	2	11	6	0.15	0.25
	DCT	8	9	3	6	5	0.33	0.38
	DFrFT(0.98)	8	10	6	4	2	0.60	0.75
Image set (3) / [241 x 304]	JIH	18	13	8	5	10	0.62	0.44
	DCT	18	15	9	6	9	0.60	0.50
	DFrFT(0.88)	18	20	14	6	4	0.70	0.78

5.5 Summary

Image change detection is an important requisite for various applications like video surveillance, remote sensing, medical diagnosis and treatment, civil infrastructure, underwater sensing and driver assistance systems etc. In this chapter Image change detection using fractional transform has been proposed. It provides a flexible approach by varying its fractional parameters so as to get the best possible results. Change regions were marked on difference image depending upon a particular size limit that may vary according to image dimensions. Further, a gradient correlation filtering technique was used for categorization of these obtained regions. These regions were classified into different classes depending upon gradient similarity measure value obtained in a particular change region. A global threshold technique for JIH and block by block quantization threshold technique was used for DCT to obtain results. The experiments were performed for three sets of change images and results of change detections were analyzed comparatively using values of precision and recall parameters. For image set (1), the precision and recall values obtained were 0.43 and 0.67 (using JIH [24]), 0.56 and 0.67 (using DCT) and with DFrFT (at parameter ‘a’ value=0.9), we obtained 0.62 and 0.87. Finally, the results show that image change detection using DFrFT improves the results by 30-80%.

6. SATELLITE IMAGE CHANGE DETECTION USING FRACTIOINAL FOURIER TRANSFORM

6.1 INTRODUCTION

Detecting changes in images of the same geographical area taken at different times from satellite is of huge interest due to enormous applications in diverse domains. Finding appearance/ disappearance of objects from satellite images is generally very tedious task since background pixels also change their intensity values owing to various factors. The proposed research will analyze a method of image change detection using Fractional transform. The methods used here are Discrete Fractional Fourier Transform (DFrFT). The prospect of this method is examined through experiments using real satellite images.

6.2METHODOLOGY

The main approach towards achieving Change Detection in satellite images includes taking transform of the image acquired after an initial differencing step. This transform is taken flexibly with its different values of fraction parameter to acquire different resultants. And after taking the inverse transform of the processed data, we develop the required output. The perfection of the output achieved is evaluated by parameters viz. recall, precision and F measure. The following block diagram illustrates the working action flow.

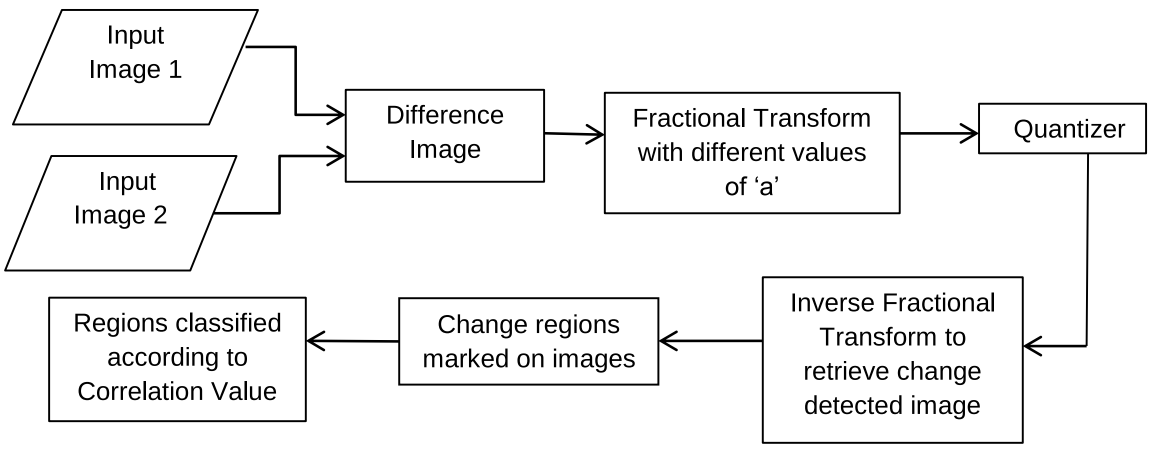


Figure 6.1: Satellite image change detection using fractional transforms

The above block diagram can be explained with the help of following stages:

Step 1: **Differencing**: In the initial change detection step, the simple difference image is obtained by algebraically subtracting the first image from the second image. The resultant simple difference image is itself a raw changed image that is to be used for further proceedings.

Step 2: **Transform**: This difference image is then transformed with DFrFT, i.e. the image is fractionally transformed in the frequency domain by varying the fractional parameter 'a'.

Step 3: **Quantizer**: After applying Transform, the equivalent transform matrix is passed through a quantizer which selects only appropriate coefficients and round of the other to zero.

Step 4: **Change detected image**: In order to retrieve the change image, IDFrFT is applied on the selected coefficients with parameter 'a'= -a. This task is performed with various values of 'a' to get consequent different change images.

Step 5: **Region marking on the image**: The changes in the image have been detected and then are categorized into regions by defining a particular region size according to the size of images. Hence proper change regions are obtained which are highlighted by drawing red rectangles.

6.3 PARAMETERS USED FOR SATELLITE IMAGES CHANGE DETECTION

1) Precision: Precision is the average probability of relevant retrieval; it is also referred to as Positive predictive value [65].

$$P = \frac{C_d}{(C_d + F_d)}, \text{ where}$$

C_d= No. of correctly detected change regions

F_d= No. of false detected change regions

2) Recall: Recall is the average probability of complete retrieval, Recall in this context is also referred to as the True Positive Rate or Sensitivity [65].

$$R = \frac{C_d}{C_d + M_d}, \text{ where}$$

C_d= No. of correctly detected change regions

M_d= No. of Missed Regions

3) F measure: A measure that combines precision and recall is the harmonic mean of precision and recall, the traditional F-measure or balanced F-score. In statistics, the F1 score (same as F-score or F-measure) is a measure of a test's accuracy. The F1 score can be interpreted as a weighted average of the precision and recall, where an F1 score reaches its best value at 1 and worst score at 0 [67], Mathematically it is calculated as:

$$F = 2 \cdot \frac{Precision . Recall}{Precision + Recall}$$

6.4 RESULTS AND DISCUSSIONS

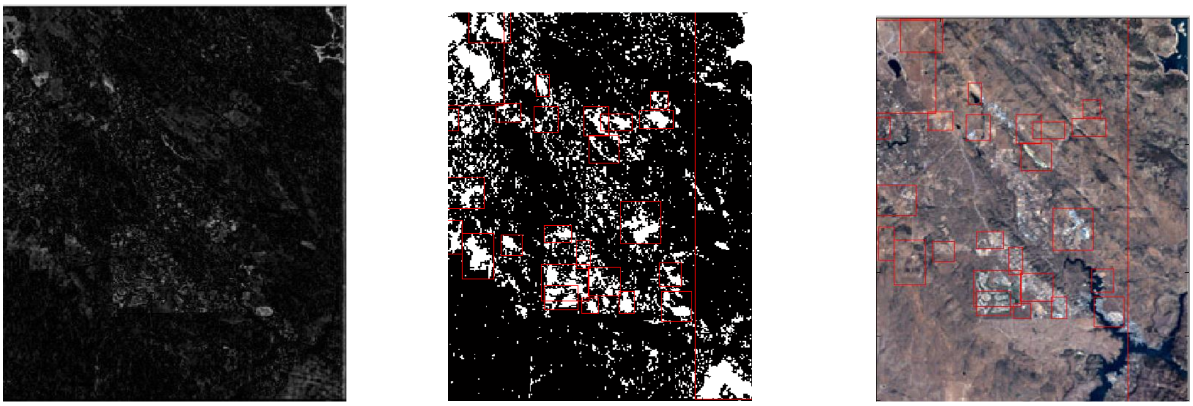
Experimental Results: The simulations for various set of satellite images are performed in MATLAB and following outcomes are acquired.

6.4.1 IMAGE SET 1

(a) (b) (c)

Figure 6.2: (a), (b) Satellite images to be change detected (Image set (1)), (c) Simple difference Image

Figure 6.2 (a) and 6.2 (b) are the images taken from satellite (These *images show a portion of Calaveras County, in the Sierra foothills east of Stockton. The left image was captured on July 28, 1989; the right image is from July 19, 2009).* If I_1 be the first image and I_2 be the second image, then figure 6.2 (c) demonstrates the simple difference image given by $I_3 = I_1 - I_2$.



(a) (b) (c)

Figure 6.3: (a) Image Obtained after IDFrFT, (b) Regions Marking on Change Detected image, (c) Regions Shown on original image I2

The difference image shown in figure 6.2 (c) is then Discrete Fractionally Fourier transformed with different fractions in the frequency domain by varying parameter $'a'$ and then passed through a quantizer which selects only appropriate coefficients and round of the other to zero. The Inverse DFrFT of the resultant data is obtained and the resultant Change Detected image is acquired. Figure 6.3 (a) shows the change detected image at value of a = 0.98. This value of 'a' provided best output in terms of the deciding parameters used. The same is also illustrated later in the paper by means of graphical representation. Figure 6.3 (b) shows the regions chosen with minimum region size of 60 pixels on the binary image obtained from figure 6.3 (a). The change regions are highlighted with red rectangles on the original images as shown in figure 6.3 (c).

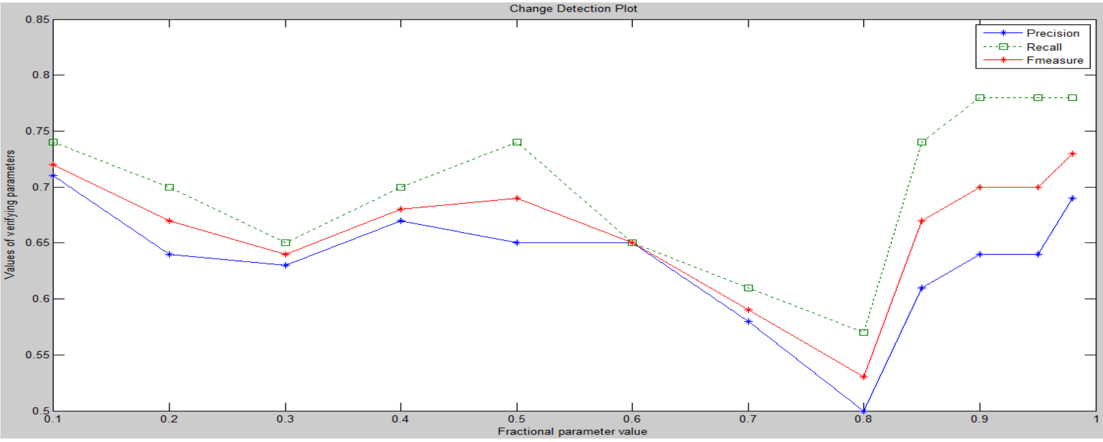


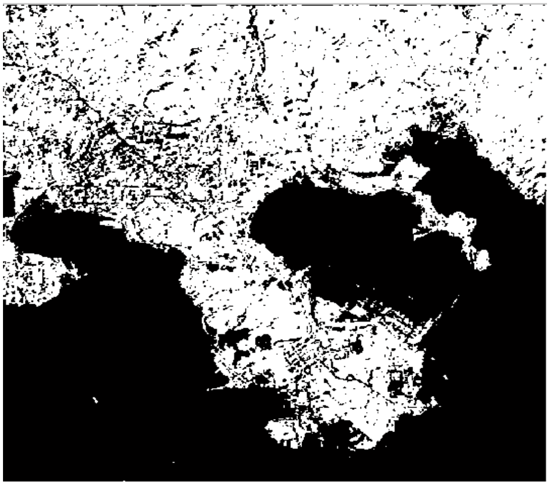
Figure 6.4: Graph showing variation of the decisive parameters verses fractional order 'a'

Figure 6.4 graphically illustrate the variation of the change detection results with respect to varying fractional orders of DFrFT respectively. As seen from above graphs, the optimum value is for and 'a' =0.98 for DFrFT. An identical procedure is repeated for three different image sets obtained from satellite imagery which is demonstrated in the following sections.

6.4.2 IMAGE SET 2

(a)

(b)



(c)

Figure 6.5: (a), (b) Satellite images to be change detected (Image set (2)), (c) Simple Difference Image

The above shown figures demonstrate the location of the Dalian Development Area (DDA). These images were taken from SPOT-5 (Satellite for earth observation-5). Figure 6.5 (a) was the image of DDA taken in 2003 and Figure 6.5 (b) demonstrates the same geographical area in 2007. Figure 6.5 demonstrates the basic difference image of the above two figures.

Figure 6.6: Result using DFrFT

Figure 6.6 shows the results calculated by applying DFrFT with value of fractional parameter = 0.95 which is providing out the best results in terms of the deciding parameters. This value of fractional parameter is chosen since it provides us the best output amongst other values of the parameter used.

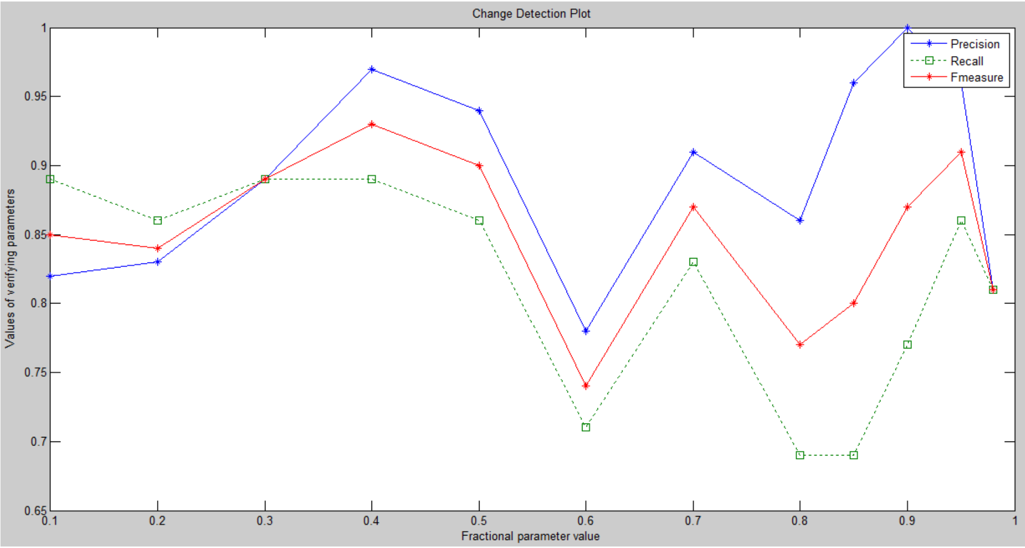


Figure 6.7: Graph showing variation of the decisive parameters verses fractional order ‘a’

Figure 6.7 graphically illustrate the variation of the change detection results with respect to varying fractional orders of DFrFT respectively. As seen from above graphs, the optimum value is for and ‘a’ =0.95 for DFrFT. The corresponding values of precision, recall and F-measure are 0.96, 0.86 and 0.91 respectively. It is interesting to see that although, at 0.9, we have a value of precision =1, which is maximum value, but recalling the total no. of regions is less at this point. Hence the combined effect of precision and recall is chosen to be best at ‘a’ =0.95.

6.4.3 IMAGE SET 3

(a)

(b)

(c)

Figure 6.8: (a), (b) Satellite images to be change detected (Image set (3)), (c) Simple Difference Image

Figure 6.8 (a) and 6.8 (b) gives a view of Tsukuba city taken in March of 2000 and in December of 2004 respectively from Ikonos satellite. The Figure 6.8 (c) represents the simple subtraction image.

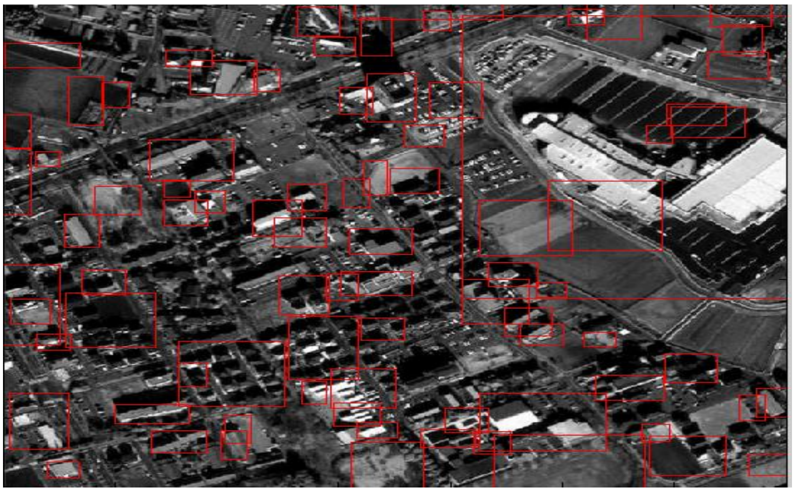


Figure 6.9: Result using DFrFT with value of ‘a’=0.98

The change regions are highlighted with red rectangles on the original images as shown in figure 6.9. There are total of 83 regions detected in the above satellite image out of which 68 are correct detected.

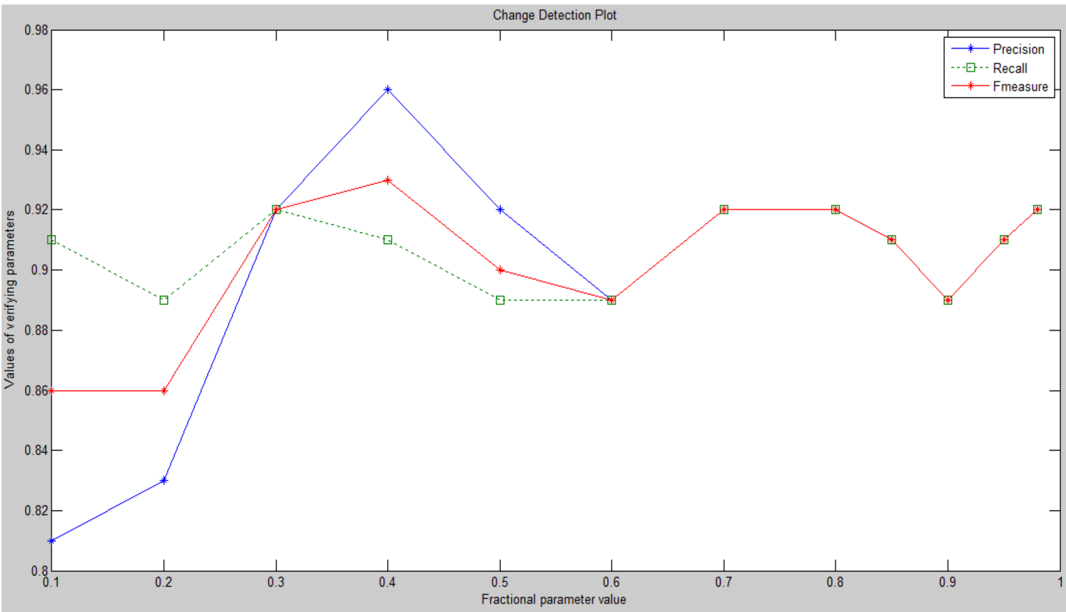


Figure 6.10: Graph showing variation of the decisive parameters verses fractional order ‘a’

As shown in Figure 6.10, which is a graphical demonstration of varying nature of the outcomes with respect to the fractional parameter value, the F score, shown with red plot, is acquiring a maximum value of 0.92 at value of a = 0.98.

6.4.4 COMBINED RESULTS

Results using DFrFT are combined in tabular form and demonstrated as following:

TABLE 6.1: Results of Satellite Image Change Detection using FrFT

Image sets	Transform	T_a (Total Actual Change Regions)	T_d (Total Detected Regions)	C_d (Correctly Detected Regions)	F_d (False detected Regions)	M_d (Regions missed)	P (Precision)	R (Recall)	F measure
Image set (1) [241 x 304]	DFrFT (0.98)	23	26	18	8	5	0.69	0.78	0.73
Image set (2) / [600 x 600]	DFrFT (0.95)	35	32	30	2	5	0.94	0.86	0.91
Image set (3) / [241 x 304]	DFrFT (0.98)	74	83	68	6	6	0.92	0.92	0.92

If the above results are compared with the method given in [35] using the image set (3), we obtain 0.95 precision, 0.86 recall value which gives us 0.90 F measure value as compared to 0.92 with the DFrFT approach. Hence our method obtained better results as compared to [35].

6.5 SUMMARY

In the present scenario, remote sensing and satellite imagery has become an important requisite because of the advantages provided by the monitoring satellites in the imagery field. Owing to a number of unique characteristics of satellites make them particularly useful for remote sensing of the Earth's surface. Change Detection from satellite images is very vital for managing natural resources and keeping a check on the relationship between human and nature. Various works have been carried out in the past for this task. The proposed method obtains Change detection of images from satellite using fractional transform. The discrete version of fractional fourier transform i.e. DFrFT had been applied to acquire the changes. Firstly, the raw variations in the images were accomplished using a method of image subtraction. The Difference image was then fractionally fourier transformed with different values of fractional parameter in pursuit of best possible outcome. After quantizing the coefficients of transform, the inverse transform provided the change detected image. Region marking on the images was done by choosing appropriate region size and change regions were highlighted using red rectangles. For three different set of images obtained from satellite, DFrFT provided the best results for fractional value of 0.98, 0.95 and 0.98 respectively among its different possible outcomes. The results were judged in terms of precision, recall and F measure values. The values of F measure obtained for the three different image sets were 0.73, 0.9, and 0.92 corresponding to precision value of 0.69, 0.94, 0.92 and recall values of 0.78, 0.86 and 0.92 respectively. DFrFT has given better output as shown by the results when compared with [35] for image set (3).

7. CONCLUSION

7.1 CONCLUSION

The contemporary world is one in which every kind of data is present in the form of information. Images, in this regard, are a way of presenting information visually. The visual is rapidly becoming the most basic form to transfer and receive information. In this scenario, it is very important to trace the changes in the visual topography of the image via a mathematical analysis of the available information. The capability to detect regions of change in images is a powerful tool that can be used in a diverse kind of applications. Changes that are of concern typically result from the appearance, disappearance, motion or change in the shape of a target object. Key applications which need change detection include video surveillance, remote sensing, medical diagnosis and treatment, civil infrastructure, underwater sensing and driver assistance systems. For instance, timely and accurate change detection of Earth's surface features is extremely important for understanding relationships and interactions between human and natural phenomena in order to promote better decision making. With advancements in remote sensing technologies, change detection based on high resolution satellite images provides an efficient tool for monitoring infrastructural development within vast premises. In medical analysis, detection of missing part of organs and comparative analysis of scans become easy with image change detection. Detection or appearance of objects in video frames, along with security systems of surveillance cameras, incorporate change detection for fast and efficient working. In Satellite images (acquired at different times/dates), change detection is an important practice that can lead to valuable information about deforestation, water level - imminent floods, tree mortality due to droughts or forest fires, urban infrastructure change.

There are various methods to carry out image change detection, but their applicability is restrained by the limitation of the information they are evaluated upon, the type of image acquisition available, need of information to be retrieved after change detection etc. The main methods that have been used for image change detection are Image math (image differencing, image subtraction and image ratio), Principle Component Analysis, Post-Classification Comparison, Change Vector Analysis and Artificial Neural networks etc.

The current research work used DFrFT for image change detection. The method has never been used for image change detection, though it has been certainly in use for other image processing tasks such as image compression and image encryption. The purpose behind using this method was the availability of fractional parameter whose value can vary very discretely and up to small decimal places, as a result of which, we can have a large variability of output while keeping the rest of parameters constant.

In the first part of the thesis, the experiments were performed for three sets of images. Results of change detections were analyzed comparatively using values of precision and recall parameters. For image set (1), while using JIH, the precision and recall values achieved were 0.43 and 0.67, and using DCT, the values obtained were 0.56 and 0.67. But when DFrFT (at parameter ‘a’ value=0.9) was applied, the obtained values of precision and recall were 0.62 and 0.87. Similar was the case of the other images and the improved results were tabulated. Overall, the results indicated that image change detection using DFrFT improves the results by 30-80%.

In the second part, the method of fractional transforms was applied for images taken from a satellite. For three different set of images obtained from satellite, DFrFT provided the best results for fractional value of 0.98, 0.95 and 0.98 respectively among its different possible outcomes. The results were judged in terms of precision, recall and F measure values. The values of F measure obtained for the three different image sets were 0.73, 0.9, and 0.92 corresponding to precision value of 0.69, 0.94, 0.92 and recall values of 0.78, 0.86 and 0.92 respectively. DFrFT has given better output as shown by the results when compared with [35] for image set (3).

To conclude, the dissertation was undertaken to apply a novel method of image change detection. And it has been found that the method used gives relatively optimal results in comparison to other previously given methods. The ease of application, that is, only a single parameter is to be varied to obtain multiple outputs with high precision, is one of the best advantages of the method. Hence, the dissertation concludes that the method of Fractional Fourier Transform proves to be a simpler and better way of detecting changes in images, also which gives improved and precise results.

7.2 FUTURE SCOPE

The method of image change detection using Fractional Fourier Transform can be further applied to the supervised change mechanism in which we have ground base reference information against which the given images are to be analyzed because it helps in identifying land-cover transition types. Moreover, the same method can be also applied in more sophisticated image gathering mechanism where the angle, aperture, image indexing and texture of images vary in great detail.

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