

**PERFORMANCE EVOLUTION OF IMPROVEMENT IN
CHANGE DETECTION TECHNIQUES BASED ON EDGE
ENHANCED IMAGES**

*A thesis submitted in partial fulfilment of the requirement for the award of
the degree of*

MASTER OF ENGINEERING

In

ELECTRONICS AND COMMUNICATION

Submitted by

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**DEPARTMENT OF ELECTRONICS AND COMMUNICATION
ENGINEERING**

THAPAR UNIVERSITY, PATIALA

(Established under the section 3 of UGC Act, 1956)

PATIALA – 147004 (PUNJAB)

July 2015

DECLARATION

I hereby declare that the work, which is being presented in the dissertation, entitled "**Performance Evolution of Improvement in Change Detection Techniques based on Edge Enhanced Images**" in partial fulfilment of the requirements for the award of degree of Master of Engineering in Electronics and Communication Engineering submitted at the Department of Electronics and Communication Engineering of Thapar University, Patiala, is an authentic record of my own work carried out under the guidance of **Ankush Kansal, Assistant Professor**, Department of Electronics and Communication Engineering and refers other research's work which are duly listed in reference section.

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

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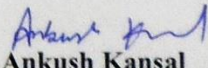
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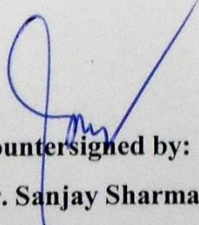
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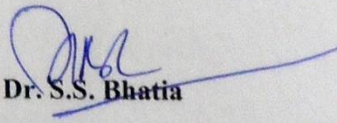
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ACKNOWLEDGEMENT

I would like to express my deep sense of gratitude to my supervisor **Ankush Kansal, Assistant Professor**, Department of Electronics and Communication Engineering, Thapar University, Patiala, for kind assistance, motivation and invaluable guidance. It has been a great honour to work under him. I am also thankful to **Dr. Sanjay Sharma, Professor and Head**, Department of Electronics and Communication Engineering, Thapar University, Patiala, for providing us with adequate infrastructure in carrying the work.

I am also thankful to **Dr. Amit Kohli, Associate Professor & P.G. Coordinator**, Department of Electronics and Communication Engineering, Thapar University, Patiala, for the his advice and inspiration that triggered me for this work.

I am greatly indebted to all of my friends who constantly encouraged me and also would like to thank all the faculty members of Department of Electronics and Communication Engineering, Thapar University, Patiala, for the full support of my work. I am also thankful to the authors whose work have been consulted and quoted in this work.

Finally, I would like to thank my parents for allowing me to realize my own potential. All the support they have provided me over the years was the greatest gift anyone has ever given me.

Nishant Kush

ABSTRACT

Digital Image Processing is the branch of Digital Signal Processing in which, various Image Processing algorithms are applied on digital images. Digital Image Processing allows the use of much more complex algorithms and hence, can offer both sophisticated performance at simple tasks and the implementation of methods which would be impossible by analog means. Satellite images are the images of the whole or part of the earth taken using artificial satellites. Satellite images can either be visible light images, water vapour images or infrared images. Image Change Detection is a very important parameter in Digital Image Processing. Image Change Detection is the process of finding pixels of two images of same area taken at different times, which corresponds to real changes. Without Image Change Detection algorithms, it is very difficult to detect the changes in the earth's geographical areas and also in the other applications like missing part of the organ in medical imaging. Another important parameter in Digital Image Processing is Edge Detection. Edges extracts features like corners, line etc. from an image. Edges are generally defined as the lines present in the picture. Various steps to identify edge in an image are smoothing, enhancement, detection, localization. Sobel operator, Prewitt operator, Compass Edge detection, Zero Crossing and Unsharp are some techniques to detect the edges. Its applications include automated driving and many machine vision systems etc.

In this research work, first of all satellite images are enhanced using Edge Detection algorithms and after that Image Change Detection algorithms are applied on enhanced images to detect the better change. The best result is obtained by applying Unsharp edge enhancement operator on satellite images and then calculating the difference between those enhanced satellite images using Image Mean Ratio change detection algorithm and achieved an improvement of 4.356 dB.

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List of Abbreviations

AIP	Analog Image Processing
ATR	Automatic Target Recognition
DIP	Digital Image Processing
DVI	Digital Visual Interface
2D	Two Dimensional
FPGA	Field Programmable Gate Arrays
GeoCDX	Geostationary Change Detection and Exploitation
GA	Genetic Algorithm
HM	High Efficiency Video Coding Model
HMBQME	Hierarchical Model Based Quarter-Pixel Motion Estimation
ILR	Image Log Ratio
IMR	Image Mean Ratio
LIP	Logarithmic Image Processing
LPF	Low Pass Filter
LoG	Laplacian of Gaussian filter
MATLAB	Matrix Laboratory
MBQME	Model Based Quarter-Pixel Motion Estimation
MRI	Magnetic resonance imaging
MSE	Mean Square Error
PSNR	Peak Signal to Noise Ratio
PLIP	Parametric Logarithmic Image processing
PSO	Particle Swarm Optimization algorithm
RGB	Red, Green and Blue
SAR	Synthetic Aperture Radar
SCE	Stochastic Computational Elements
UMF	Unsharp Masking Filter
WFL	Weber Fechner law
ZC	Zero Crossing

CHAPTER 1

INTRODUCTION

1.1 Digital Image Processing

Method of converting a picture or image into digital form and performing operations on it is termed as Digital Image Processing (DIP). It is performed to get enhanced image and also to extract useful data from an image [1]. It is signal dispensation having image as input, like photograph or video frame and output is image or some type of characteristics related to that image. Image Processing treats images as 2D signal, and applies the already defined signal processing methods on the images. In Digital Image Processing, manipulating of images is done using various computer tools such as MATLAB, for specific needs such as Image Enhancement, Image Recognition and Image Compression etc. Due to advancement in technology, Digital Image Processing created many applications in fields such as Digital Media, Medical Image, Robotics, Navigation, Industrial Automation, Agriculture, Satellite Imaginary, Military Science and Security etc. [2] In real world scene a Digital Image is a 2D signal. Any image $a[k, w]$ is digital version of a picture i.e. analog version $a(k, w)$. A 2D image $a[k, w]$ is divided into k rows and w columns and amplitude of 'a' is intensity of image. Finite number of elements is composed in a digital image, having particular value and location [3]. The term pixel is intersection of a row and a column. Generally dimensions of image are 256×256 , 2154×2154 etc. Gray-scale images, Indexed images, RGB images and Binary images are the types of images [4].

Image Processing generally have following steps:

- Importing the image with the help of digital photography or by optical scanner.
- Manipulating and analyzing the image or simply data compression.
- Image Enhancement, Edge Detection, Change Detection [5].

1.1.1 Advantages of Image Processing

The main advantages of Image Processing are [6]:

1. Visualization – Observe the non-visible objects.
2. Image Restoration and Sharpening – To get a better image.
3. Image Retrieval – Look for the picture or image of interest.
4. Measurement of Pattern – Measure objects in image.
5. Image Recognition – Distinguish objects present in the image.

6. Change Detection Algorithm between two images.

1.1.2 Types of Image Processing

Two methods are used for the image processing:

- Analog Image Processing (AIP)
- Digital Image Processing (DIP)

Visual or analog techniques are used for hard copies like photographs and printouts. Fundamental of interpretation is used to analyze image in visual technique [7]. Another important tool is association in visual techniques. So the combination of collateral data and personal knowledge is applied by the analyst, to process the image.

While with the help of computer, the Digital Processing manipulate digital images. Some images obtained from image sensors contains deficiencies. To overcome this type of flaws and to obtain the originality of information, it undergoes a series of processing [5]. The general phases of processing are pre-processing, display and enhancement, extraction of information.

1.1.3 Applications of Image Processing

- Intelligent Transportation System – Used in traffic sign recognition and number plate recognition.
- Remote Sensing – Used in resource mobilization, flood control, agricultural production monitoring and city planning etc.
- Moving Object Tracking – Recognition based tracking and motion based tracking.
- Defense Surveillance – To keep eye on oceans and land.
- Biomedical Imaging Techniques – Digital mammograms, heart and lung disease identification.
- Automatic Visual Inspection System – Automatic surface inspection, incandescent lamp filament's inspection, faulty component identification [8].

1.2 Image Change Detection

Image Change Detection technique finds the pixels, which corresponds to real changes, in two images, over the same area at different times. With two images, Image Change Detection computes the difference image and this difference image is segmented into two regions i.e. changed and unchanged classes [9]. The main aim of Image Change Detection

is to find out the change mask, containing the set of different pixels present in current image and previous image. An issue arises during the estimation of change mask, i.e. only significant changes should be include, insignificant changes such as sensor noise, camera motion and illumination should not be included [10].

Image Change Detection Algorithm have following steps:

- ❖ *Preprocessing* – Some images are of very low resolution, just like satellite images, which may liable to different errors. Inner geometric errors, i.e. errors generated by remote sensing satellite itself, Earth’s curvature or rotation. Due to tangential scale distortion or relief displacement image can be distorted. These errors are systematic and can be redressed and identified. Before applying Change Algorithm to images, atmospheric and geometric differences have to be amended. Preprocessing is the method to correct it. It include geometric and radiometric correction with classification:[11]
 - In geometric correction, motivation is to uproot the effect in images due to different geometries.
 - Radiometric correction can be done in two ways, i.e. absolute and relative. Relative correction is used instead of absolute correction, where pixels of images changed typically.
 - On the basis of requirement of Change Detection Algorithm, images can be classified. Pixels are divided into certain groups, on the spectral basis it can be possible.
- ❖ *Change Detection Algorithm* – Methods of calculating the difference image is termed Change Detection algorithms. It is the basic building block among all. Lots of methods are present, based on the method of processing, these are classified in supervised and unsupervised. For classifier’s learning process, training set is required. With the help of ground truth data training set is obtained. Supervised approach is better than unsupervised one as [12]:
 - Capable of identifying sorts of land cover explicitly.
 - Robustness nature to different light and atmospheric conditions at acquisition times.
 - Ability to process the multisource/multisensor images.
- ❖ *Accuracy Assessments* – It has two classes, change & no change. The change pixel which is treated as unchanged is termed as a miss or false negative, on the other side

no change pixel which is taken as changed is marked as false positive. True negatives are presented as unchanged pixels, which was earlier distinguished as unchanged. True presented as changed pixels, earlier which was recognized as changed [13].

1.3 Need of Change Detection

- Exact and timely Change Detection of surface of earth is very important. In remote sensing technologies, an effective and efficient tool in many applications is Change Detection [5].
- People left in vehicles and automatically recognizing objects is highly desirable, because human monitoring is low efficiency and high cost associated with it.
- In video frames, detection of items alongside in security systems, Change Detection work efficiently [13].
- Detection of organ's missing part becomes easy with the help of Change Detection, e.g. importance of Change Detection in medical scanners like MRI.
- For geographical area development, with the help of Change Detection used with classification algorithms obtained statistics. Hence planning becomes easy.
- To record and identify changes in forest, desert and agricultural areas.
- With the help of using satellite images, by applying change detection methods, valuable information about the deforestation, floods, forest fires, new buildings etc. may be obtained [14].

1.4 Types of Image Change Detection

1.4.1 Image Differencing

Image Differencing is a pixel subtraction process. In this technique two images are taken as input and after image differencing third image is output [13]. Output image's pixel value is the pixel value of one image minus corresponding pixel value of other image. Image Differencing generally involves same area images, taken at two different times and these images are subtracted pixelwise. Pixel by pixel, images are compared and pixels of changed areas, shows different values to the pixels related to unchanged areas [15]. Third image is produced by subtraction method, in which negative and positive numerical values of pixels represents the area of change and zero pixel values shows the area of no change. Mathematically, Subtraction of two images [16]:

$$id(k, w) = fi(k, w) - si(k, w) \quad (1.1)$$

$$id(k, w) = \text{output image}$$

$f_i(k, w)$ = reference input image

$s_i(k, w)$ = inspected input image

Steps used in image subtraction are:

- a. Image Acquisition
- b. Suppression of noise and distortions from input images.
- c. Image Alignment
- d. Image Subtraction

Image Differencing algorithm of Change Detection is easy to implement and very simple execute, the output of this method can be easily interpret. But the shortcomes of this method are [17]:

- Detailed change matrix cannot be provided and selection of threshold in the images is required.
- Some information may lose during differencing operation. Same value can be obtained by two differencing pixels, but it doesn't represent anything, which type of change has occurred.

1.4.2 Image Log Ratio

Image Log Ratio (ILR) is another operator which indicates the change areas in image. In this technique, transformation of multiplicative speckle noise is done into the additive noise [18]. In this technique pixelwise comparison of image is done as in image differencing [19-20]. Intensity values of pixels present in one group is divided by corresponding pixel values of another group obtained the output image [21-22]. One of the advantage of using ratio method is that, it reduces illumination variations. Mathematically, it is represented as [23]:

$$X_l = \left| \log \left(\frac{X_2}{X_1} \right) \right| = |\log X_2 - X_1| \quad (1.2)$$

Here, the image X_l takes values ranging from zero to infinity. For the equal intensity values, it takes value 1. The unchanged portion of a difference image obtained by log ratio operator is more uniform.

1.4.3 Image Mean Ratio

Another operator used to detect the change areas is Image Mean Ratio (IMR). During the operation of this method unchanged pixels are shown by small values [11], on the other hand larger values shows the changed area [24]. Changed region is shown with the help of

Mean Ratio but it doesn't enhance it. It provides better results than log ratio operator in some applications. This operator is applied on images for the generation of Mean Ratio image. Mathematically [23]:

$$X_m(k, w) = 1 - \min [\mu_1(k, w)/\mu_2(k, w), \mu_2(k, w)/\mu_1(k, w)] \quad (1.3)$$

$\mu_1(k, w)$ and $\mu_2(k, w)$ Are the local mean values of pixel of point (k, w) in X_1 and X_2 , Equation (3) shows that it produces difference image using local mean information of collocated pixels [25].

1.5 Edge Detection

Edge of any image is the sudden change of intensity in image. In binary images, it is sudden change in intensity from 0 to 1 and vice versa. It represents high frequency components in image. Edge Detection is a high pass operation with threshold added to it [26-27]. High frequency components in image are threshold to logic 1, and other pixels set to zero. Many edges in image represents rough image, few edges in image represents smoother image. Edge Detection algorithms are based on gradient value. In this algorithm, if computed gradient pixel value is higher than threshold that is identified as edge pixel. Edge Detection rate can be increased by changing threshold values, but accuracy of locating edge decrease at same time. The various steps to segment the image are: Smoothing or Filtering, Enhancement, Detection, Localization [28].

In lot of ways Edge Detection may be performed, and may be grouped as:

- Gradient based Edge Detection – This method detects by looking the minimum and maximum in 1st derivative of image.
- Laplacian based Edge Detection – This method looks for the zero crossing in 2nd derivative of image, to detect the edges.

1.6 Goal of Edge Detection

- From an image, to obtain line drawing of the picture.
- Extraction of important features from edges, like curves, corners, lines etc.
- For recognition, in computer vision algorithms [29].

1.7 Steps of Edge Detection

- Smoothing – Suppress the noise as much as possible, without disturbing the edges.
- Enhancement – Apply sharpening filter to enhance the edge's quality of image.

- Detection – Determine the pixel edges and on the basis of that decide which pixel discarded as noise and which pixel should retained.
- Localization – Calculation of exact edge's location. Edge linking and thinning are required in localization process [30-31].

1.8 Types of Edge Detection

1.8.1 Sobel Operator

This type of operator detects edges in the image from different directions. It has two operators, one detects the level edge and other detects vertical flat edge. It finds the approximate gradient magnitude at each point. This operator consists of 3×3 convolution kernels, second kernel is obtained by rotating the first kernel by 90 degree [32-33] and the gradient magnitude is threshold. Using this operator, at any point in the image, it is possible to generate the corresponding gradient vector [34].

$$L_x = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix}; L_y = \begin{bmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix}$$

$$|\nabla L| = \sqrt{L_x^2 + L_y^2} \quad (1.4)$$

$$\theta = \tan^{-1}(L_y/L_x) \quad (1.5)$$

L_x, L_y are convolution kernels, $|\nabla L|$ is gradient magnitude, θ is angle of orientation of edge.

1.8.2 Prewitt Operator

Prewitt Operator's working is similar to the Sobel Operator; the only difference is in the kernels. It is first order differential operator [35]. To get the extreme edge, it employs gray difference from left to right and top to bottom neighboring pixels [36-37]. It detects vertical and horizontal edges in image. Kernels of Prewitt Operator are [34]:

$$P_x = \begin{bmatrix} -1 & -1 & -1 \\ 0 & 0 & 0 \\ 1 & 1 & 1 \end{bmatrix}; P_y = \begin{bmatrix} 1 & 0 & -1 \\ 1 & 0 & -1 \\ 1 & 0 & -1 \end{bmatrix}$$

1.8.3 Compass Edge

Compass Edge operator outputs two images, one estimate the edge orientation and other estimate the local edge gradient magnitude. A set of convolution kernels with different orientation is convolved with source image [38]. As discussed previous operators, Sobel and Prewitt uses only two masks, but in this case eight different masks are used. Maximum response of all kernels is local edge gradient magnitude [39].

$$|G| = \max (|G_i|; i = 1 \text{ to } n) \quad (1.6)$$

$$N = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix}; W = \begin{bmatrix} 0 & 1 & 2 \\ -1 & 0 & 1 \\ -2 & -1 & 0 \end{bmatrix}; S = \begin{bmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix}; E = \begin{bmatrix} 2 & 1 & 0 \\ 1 & 0 & -1 \\ 0 & -1 & -2 \end{bmatrix};$$

$$NW = \begin{bmatrix} 1 & 0 & -1 \\ 2 & 0 & -2 \\ 1 & 0 & -1 \end{bmatrix}; W = \begin{bmatrix} 0 & -1 & -2 \\ 1 & 0 & -1 \\ 2 & 1 & 0 \end{bmatrix}; SE = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix}; NE = \begin{bmatrix} -2 & -1 & 0 \\ -1 & 0 & 1 \\ 0 & 1 & 2 \end{bmatrix};$$

With one standard kernel a set of n kernels is produced by rotating its coefficients circularly. The rotation range is from 0 to 360 degree.

1.8.4 Unsharp

The Unsharp filter is sharpening operator that enhances the edges of image. An Unsharp or smoothed image is subtracted from original image [40-42]. It is used in photographic industries for crispening edges [43].

$$g(m, n) = f(m, n) - f_{smooth}(m, n) \quad (1.7)$$

With the help of simple low pass filter original image $f(m, n)$ is converted to smoothed image $f_{smooth}(m, n)$

1.8.5 Zero Crossing

In this method the image is filtered by Laplacian of Gaussian filter (LoG). After the LoG filtered the Zero Crossing is detected. Locations of Zero Crossing points are boundaries between background and foreground regions [44]. The simplest way to detect Zero Crossing is by thresholding LoG output at zero and it produces a binary image. 2nd Spatial derivative of image calculated. To reduce the effect of noise, image is smoothed with LPF. The Laplacian $L(x, y)$ of image $I(x, y)$ is [45]:

$$L(x, y) = \frac{\partial^2 I}{\partial x^2} + \frac{\partial^2 I}{\partial y^2} \quad (1.8)$$

This operator highlights the regions where rapid intensity changes are present in the image. The LoG functions with Gaussian standard deviation:

$$LoG(x, y) = -\frac{1}{\pi \sigma^4} \left[1 - \frac{x^2 + y^2}{2\sigma^2} \right] e^{-\frac{[x^2 + y^2]}{2\sigma^2}} \quad (1.9)$$

To achieve the required result, first convolve Laplacian and Gaussian smoothing filters, after that convolve this hybrid filter with image [46].

❖ *Properties of Zero Crossing*

- It is a type of isotropic operator.
- Cheaper to implement.
- More sensitive to noise.
- Edge direction information not provided.

1.9 MSE & PSNR

❖ *Mean Square Error*

Mean Square Error is the average pixel difference throughout the image. It compares the original image's true pixel to our degraded image. It also shows average square error between noisy and original image [47]. Amount by which numerical values differ in original and degraded image is the error. Mathematically MSE is [48]:

$$MSE = \frac{1}{N} \sum_i \sum_j (X_{ij} - V_{ij})^2 \quad (1.10)$$

N is image size, X is processed image, V is original image.

❖ *Peak SNR*

PSNR is a parameter, which measures the performance of noise removal. It is the ratio of maximum value of signal and power of distorted noise [49]. Some signals are of wide dynamic range so PSNR is expressed in logarithmic decibel scale. Comparison of image enhancement done to check for better result [50], PSNR is the measure to that comparison.

We are using PSNR with 2D matrix. Mathematically PSNR is:

$$PSNR = 10 \log (255^2 / MSE) \quad (1.11)$$

1.10 Organisation of Thesis

This dissertation has 5 chapters, organized as below:

Chapter 1: Introduction – Concepts and basic formulas for Image Processing, Image Change Detection and its types, Image Edge Detection with its various types and study of PSNR & MSE has been discussed.

Chapter 2: Literature review – In this chapter, the work which had been done previously regarding the Image Edge and Change Detection has been discussed. Based on this chapter, gaps in literature are found.

Chapter 3: Change Detection of Edge Enhanced Images – System model and mathematical analysis of Edge and Change Detection on images has been presented along with their MSE & PSNR analysis.

Chapter 4: Result & Discussion – This chapter consists of source images and images after applying various Edge Detection algorithms. Images obtained after applying various Change Detection algorithms on edge enhanced images are also presented with tables having comparative analysis of their MSE & PSNR values.

Chapter 5: Conclusion & Future Scope– The work done in the dissertation has been concluded. Future scope are also discussed based on the observation of the experiment.

CHAPTER 2

LITERATURE SURVEY

2.1 Introduction

In this chapter, past work on Image Processing, Change Detection and Edge Detection has been discussed. On the basis of this chapter various work areas which can be explored are discussed. At the end of this chapter, on the basis of gaps in literature, the objectives has been given for the dissertation.

Image Processing

Castillo *et al.* [1] presented a virtual laboratory in Digital Imaging for computer processing. A method was designed to reconstruct/enhance the images and their optical features. Applications of Digital Image Processing in this paper were for electronic engineering and biomedical students. Also the topics related to computer vision and remote sensing discussed.

A new Stochastic Computational elements which is based on finite-state machines for Digital Image Processing had been developed. Peng Li *et al.* [2] presented five different algorithms of Digital Image Processing for the practical case study. Latency of stochastic implementations, error tolerance and hardware area were compared with the conventional implementations by the use of Binary Radix Encoding. A rigorous analysis also provided for particular such as stochastic linear gain function and also discussed that with the less hardware area more reliable computation can be performed by using different Digital Image Processing techniques.

In Digital Image Processing, Histogram results from the Image Processing of discharge. This paper proposed two types of dielectric barrier discharge modes. With the increase in exposure time, frequency and applied voltage, skewness and kurtosis of gray level decrease. In filamentary mode, some properties of image changes such as gray level's standard deviation increases. Homogenous mode have greater gray level as compared to filamentary mode. Yunfei Wu *et al.* [3] concluded that while keeping the voltage constant and decreasing the pressure, increase in gray level occurred in homogeneous mode.

Benjamin Perret *et al.* [4] presented that a very important notation in Image Processing are connections, which described the way, how pixels grouped according to gray values and their spatial relationships. In recent years these new theories and connections was

developed. This paper addressed two issues of these type of theories. The first one proposed in this paper was axiomatic which ensure the decompositions of H-connection and was consistent for Image Processing. The second one was, decompositions were shown by tree of H-connection of an image. Testing of new framework was done on various Image Processing applications such that document Image Binarization, Segmentation and Connected Filtering.

Oleksiy M. Chumak *et al.* [5] demonstrated that how Digital Image Processing can be used for plasma flow development and its investigations. Two examples were presented. In first one, an image was clearer by the post processing. Shadowgraph images was post processed to emphasize the objects in the image. In the second processing method, a map was generated which have fluctuation intensity with the analysis of images of fluctuating jet.

Logarithmic Image Processing (LIP), which provide the mathematical theory of generalized operations in Image Processing was presented in this paper. A generalized Logarithmic Image Processing model was developed by Guang Deng *et al.* [6]. New image representation was developed and operations for the problems related to the Image Processing. A Parametric Logarithmic Image processing (PLIP) model and for mapping, an energy preservation algorithm were also developed. In image dehazing that are necessary steps.

An Image Processing algorithm was presented which have high speed and applied to asymmetric radiation obtained from the Edge Detection, on joint European torus. The algorithm for Image Processing have been developed in C assembly language and tested on Linux computing platform of 64-bit. This paper implemented code and good run time with high accuracy performance obtained i.e. 93.3% correct detection rate with 650 frames per second, Image Processing rate was obtained. Performance of algorithm and overall characteristics was presented for every Image Processing module by Marcio Portes *et al.* [7].

In Digital Image Processing, histogram specification have been used over the years. Mainly used for Image Enhancement. For good contrast in an image, methods like histogram equalization have been used. These type of methods take some extra time but they were fast enough for real time applications. Gabriel Thomas *et al.* [8] proposed a new method to specify a histogram to enhance the contrast of an image. Other methods were also discussed to modify images, which helped in segmentation approaches.

Image Change Detection

Change Detection often used in image and video sequences in high level applications. A universal pixel segmentation technique was presented to detect the changes in colour image. This technique monitors segmentation noise and local model fidelity to guide the adjustments. While ignoring the illumination variations objects were detected more easily. Pixel level feedback loops were used to adjust the internal parameter in this method without user intervention as discussed by Pierre Luc *et al.* [9].

A sequential framework was presented for the Change Detection. In this type of framework used multiple images to improve the detection performance. Once the additional data available then, it added a change statistic which can be easily updated. Performance of detection can be predictable when image data were extracted from known distributions. Performance prediction was verified by simulation in this paper. Detection performance was also improved by Andrew J. Lingg *et al.* [10].

It was discussed that for the detection of different terrain changes SAR (Synthetic Aperture Radar) images were used. Change detection in these type of images become challenging problem because of the complexity of terrain and also due to presence of the speckle. An unsupervised Change Detection technique was presented by Biao Hou *et al.* [11], for the synthetic aperture radar images, which were based on compressed projection and image fusion. A different image was generated by Gauss Log Ratio Operator. First of all, by using Log Ratio difference image and Gauss Log Ratio image a better difference map was generated, and after that to reduce the noise, a transformation named nonsubsampling contourlet transform was used in fused difference image. In this paper final change detection map was obtained by partitioning vectors into unchanged and changed classes, this was done using k-means clustering. Results of the Change Detection in proposed technique was effective for synthetic aperture radar images in terms of numerical value and shape of detected portion.

A method was proposed which have robustness against noise, wavelet transformation was used to obtain the difference image, of same area take at different time instants. Unchanged and changed region in the image were also discussed. Turgay Celik *et al.* [12] presented Change Detection algorithm applied on two images i.e. the optical images and synthetic aperture radar images. The results obtained from Change Detection were compared with other techniques.

Matthew N. Klaric *et al.* [13] developed, a fully automated system which was very good for Change Detection of satellite imagery. The algorithm designed in this paper was GeoCDX i.e. Change Detection and Exploitation. This algorithm was resolution independent, sensor agnostic and designed to process the satellite images having large volume of data. In this paper, from satellite images, high level features were extracted and Change Detection performed to pinpoint pixels of change in the image. Efficiency was improved by 50% by using this model with 4 times more accuracy as compared to manual approach.

Shutao Li *et al.* [14] proposed a Change Detection method for satellite images based on detail enhancing algorithm. First of all difference image were generated by the multitemporal source images, and after that with the help of contourlet transformation, image was decomposed into high pass sub bands and low pass approximation. Meaning details were extracted by coefficients of directional sub bands of difference image. Next step presented in this paper was injection of extracted details into the base image which was selected from sub bands that results into detailed enhanced difference image. The proposed approach have superior performance as compared to other well-known Change Detection techniques.

Image Subtraction

Turgay Celik *et al.* [15] proposed a method, by using genetic algorithm, cost function was minimized, in high resolution satellite images. Difference image was obtained by partitioning the high resolution images into two regions. These regions was unchanged and changed regions. For both regions, MSE was calculated between difference image and average of difference image. The discussed method, produced the results of Difference Image without any help of priori assumptions.

Printed circuit board defects were detected with the help of Image Subtraction algorithm. Image Subtraction method presented in the paper was simplest method for detecting the defects in the printed circuited board. The defects like under etching, missing hole, over etching, missing conductor, break lines, wrong hole size defects have been detected and presented by Beant Kaur *et al.* [16]

A Background Subtraction algorithm was proposed in this paper, for image sequences of Bayer pattern. In the method proposed by Jae Kyu Suhr *et al.* [17], with the help of using mixtures of Gaussians, background was modelled in Bayer pattern domain and

classification of foreground was done in RGB (red, green, blue) domain. Experimental results of proposed method was highly accurate.

Image Log Ratio

A technique for Image Change Detection was discussed, which was termed as hybrid conditional random field algorithm. This model was constructed by the statistics of Change Detection techniques, in this case Log Ratio image was derived from two images. In this way, it is possible to integrate the image information and texture features of images, statistics of Image Log Ratio and spatial interactions into Change Detection. This approach have three parts, data modelled by Log Ratio image's statistics, pairwise potential and unary potential. Groupwise potential was constructed by Hejing Li *et al.* [18] by capturing the parameters of Log Ratio image i.e. spatial interactions.

A neighbourhood based ratio operator was presented in this paper to obtain the difference images. To reduce the effect of noise on images, a difference image was produced by proposed neighbourhood ratio operator. It was done by combining spatial information and gray level details of neighbour pixels. Proposed method's comparison was done with general Log-Ratio operator, better detection results were obtained by using neighbourhood based Ratio Operator as presented by Maoguo Gong *et al.* [19].

A method based on algorithm like wavelet fusion was proposed for Change Detection in image having very high resolution. The described method generate difference image by collecting the useful data from Mean Ratio Images. Minimum standard deviation and weight averaging were the two fusion based techniques which was used to fuse wavelet coefficients in high and low frequency bands. Experimental results were better than the Log Ratio operator as discussed by Jingjing Ma *et al.* [20].

Shawn Andrews *et al.* [21] discussed that in medical images, in the segmentation applications, probabilistic labels were used. Shape model act as important parameter in medical image segmentation, its generation can be done by applying various statistical techniques on data. In some of the techniques like principal component analysis data exist in unconstrained vector space, but in probabilistic labels, data lies in constrained unit simplex. By using probabilistic labels directly, information can be sacrificed. Use of LogOdds transformation, was done on probabilistic labels by mapping them. In one of the labels, LogOdds transformation was asymmetric. In this paper, the symmetrized LogOdds transformation was Isometric Log Ratio. In this paper it was explored that, how Aitchison

geometry was interpreted in segmentation applications in medical image applied to probabilistic labels. Demonstration of difference also discussed between Isometric Log Ratio and LogOdds transformation.

Two approaches were proposed based on a neural classifier i.e. concurrent self-organizing maps, to detect the changes in remote sensing images. In supervised way the first approach performed. In unsupervised way the second approach performed. Victor-Emil *et al.* [22] also presented that supervised approach was based on Concurrent self-organizing maps classification and Concatenation. Concurrent self-organizing maps was further classified into two modules i.e. associated with change of class and associated with no change to class. Whereas the unsupervised approach of Change Detection was based on concatenation, image comparison by Log Ratio and concurrent self-organizing maps classifications. By using any two datasets proposed method was evaluated.

Mean Ratio Operator

Maoguo Gong *et al.* [23] discussed a Change Detection approach which was free from unsupervised distributions, and used for images which was based fuzzy clustering and image fusion strategy. Image fusion technique was used in this approach to generate the images, from Mean Ratio images. To retain the background information and to enhance the useful data of changed regions in fused images, Wavelet Fusion was chosen. These were based on minimum local area energy and an average operator. A fuzzy algorithm was proposed to differentiate the unchanged and changed regions in image. Conclusion of experimental result in this paper shown that, advantage of Mean Ratio operator was integrated by image fusion strategy. By calculating the Change Detection using this approach lower the error, than its pre-existences.

A method called Bayesian Image Super Resolution was proposed with field named as Gaussian Markov random filed. In super resolution method, from the various low resolution images spatially high resolution images were estimated. In Markov random filed based model, as presented by Takayuki Katsuki *et al.* [24] for natural image having various edges, a preferable prior was supplied by the line process. Pervious image transformation model, hyper parameter prior and compound Markov random filed based model were improved. Optimal estimator was also derived. With the help of variational Bayesian method, numerical values were determined for estimator. Bayesian method determines approximately the complicated posterior distribution. As conjugate prior was required so

generally hard to use. With the help of Taylor approximations, this problem was solved. The proposed method was more accurate to pervious methods.

Conventional techniques for analysis of synthetic aperture radar images like pixel level classification and segmentation were fail in case of high level semantic description. Image patch based analysis was proposed by Shiyong Cui *et al.* [25] for interpretation of images in this paper. Inspiration for this method was taken from Ratio Edge detector. In this paper, Mean Ratio was calculated in different directions to extract the features of images. Using Mean Ratio operator, two powerful features was proposed. First one was, bag of word model, is uses basic statistics like variance and local mean and also calculate the Mean Ratio in the image in different directions. Second one was, local descriptor's adaptation. It was done by adding the values of gradient with the Mean Ratio difference in horizontal as well as in vertical directions. Image patch indexing was performed by using high resolution image database. In the proposed method, for Image Categorization, comparison with art features like texture features were shown improvement.

Edge Detection

Edge Detection according to Wenlong Fu *et al.* [26] was a subjective task. Moving window approach was used traditionally, tradeoff between noise rejection and localization accuracy in Edge Detection termed as window size. In this paper, a genetic programming system was proposed that search the pixel automatically, and for detecting edges new Edge Detector was constructed. From the small window influence of noise and from the large window problem of blurring was avoided by automatically pixel searching. In the genetic programming Edge Detectors from the high occurrence pixels, second order and linear filters were constructed. Good performance was achieved by using proposed approach.

Previously, Edge Detectors exploit interferometric phase information and singularly amplitude, height difference or looking for reflectivity between neighbouring pixels. A novel approach was proposed by Fabio Baselice *et al.* [27], which was based on exploitation of imaginary and real parts of complex acquired area. Exploiting the markov random fields, technique was developed in form of stochastic estimation theory. The proposed technique was better in scenario applicability model complexity and phase robustness.

For Binary Image Processing a reconfigurable processor was presented by Bin Zhang *et al.* [28]. A reconfigurable module was developed using Binary Image Processing which had

output control logic implementation related to algorithm, binary compute units etc. The experimental outputs and simulations showed that, this model was suitable for real time applications of Binary Image Processing.

Tian Qiu *et al.* [29] discussed the process of finding the edges of fire, it was done by recognising the edge between area of thermochemical reaction and area without thermochemical reaction. It was also presented that, when traditional Edge Detection methods was tested to find the flame edges, result was not up to the mark i.e. clarity of the fire edges was not there. In this paper, an algorithm was proposed which detect the fire edges continuously and clearly. In this approach, first if all detection of superfluous edges was done then identification of fire edges performed and at the end irrelevant artefacts was removed. This type of robust and effective algorithm also ensure that, fire edge remain identical when used for different scenarios.

The use of Edge Detection techniques was discussed for location of oil slick when oil was on sea. An algorithm was proposed which can detect the edges of image i.e. oil slick infrared aerial images. In the proposed method, an energy function model was defined combining with region scalable fitting concept and also with the model named global minimization active contour model. In this approach, existence of local minima was avoided and deals with weak boundaries, intensity inhomogeneity and noise present in images as by the Yu Jing *et al.* [30]. Closed and continuous edges of image can be obtained by using this method.

For automatic detection and Edge Enhancement in images with high resolutions, a technique was presented. In high resolution images, to enhance the edge of image, first and after that Edge Detection was important step. An Edge Enhancement algorithm was presented by Marivi Tello Alonso *et al.* [31], which was based on summing of coefficients at different scales. Performance of the algorithm was tested on simulated images. Geodesic active contour was used in this paper for the completion of automatic detection chain. It was suggested during this study that, for Edge Detection, extraction of coastline should be done in images.

Sobel Operator

Peng Wan *et al.* [32] discussed about the harmful messages and virus of the spam mail. To avoid the spam filter, images was send instead of text by the spam senders. Traditionally used image spam filter was very weak in scanning photographs and documents. To transmit

information, however the text was used in image spam. In this paper, classification of images was done by configuring images and letters. A spam detection method was proposed in which Sobel Operator was used. Multiple filters were used for Edge Detection using Sobel Operators.

The focus in this study was on accuracy problem of Image Segmentation. Traditional Sobel Operator have low segmentation accuracy. Directed against these defects, an improved Sobel Operator was proposed. A Digital Image Segmentation method called 2D maximum entropy was presented. This algorithm first calculated the image segmentation then real edge was found with threshold of Sobel Operator. Finally the threshold value was applied to 2D maximum entropy. Different threshold segmentation was used for digital image goals. The proposed algorithm was robust and have high segmentation rate as concluded by Hui Zhang *et al.* [33].

N. Anandkrishnan *et al.* [34] discussed sudden change in image i.e. edge. For segmenting the images having abrupt change in intensity, Edge Detection was mostly used. Application of Edge Detection in various fields was also presented. In this paper, comparative analysis of classical or augmented Edge Detection based on Genetic Algorithm (GA), fuzzy logic or neural network and other techniques was studied.

Prewitt Operator

Under the influence of noise, calculation of object edges accurately was a big problem. By extending the basics of image perception i.e. shepherd similarity law and Weber-Fechner law (WFL), a new Edge Detection method was proposed by Joshin John Mathew *et al.* [35]. Benchmark against Prewitt Operator was robustness of edges. Application of presented approach was in face recognition and shows improvement in pixel noise tolerance and accuracy in recognition.

Chun-ling Fan *et al.* [36] studied the road detection technique. In the vision navigation for the intelligent vehicle guidance, road detection plays a very important role. Detection was affected by noise present in the image. Road Edge Detection helped in finding the speed of the obstacles and their sizes and location in the road. Various operators of Digital Image Processing were analysed theoretically in this paper which were used in road Edge Detection. By comparing the results, it was observed that using Zero Crossing Operator, Prewitt and Sobel Operator provide better road Edge Detection.

Filippo Attivissimo *et al.* [37] tried to check out the effect on computed tomography by the noise reduction filters. By the combination of Prewitt and Gaussian operators a denoising filter was proposed in this paper. An anisotropic diffusion was also proposed. With the help of presented techniques in this paper, image quality was increased and low dose computed tomography protocol was allowed.

Compass Edge

Sudeep K C *et al.* [38] studied the effect of Image Processing on FPGA (Field Programmable Gate Arrays) for computer vision problems. In this paper, explanation of implementation of algorithms like Compass Edge, Prewitt, Robert and Sobel detectors on FPGAs had been done, along with the comparative study of their performances. A model was made by using, various design tools were integrated with Edge Detection hardware, along with CMOS camera and Digital Visual Interface (DVI) display and results was verified in real time video.

The operation of Edge Detection of digital image was discussed in this paper. To find the points of discontinuity various mathematical methods was used. For estimating image gradient different algorithms were used. Edge Detection operators was implemented with convolution mask to differential operators. Image brightness function's rate of change was measured by differential operations. A single mask was taken in Compass approach and by rotating this mask to different orientations other masks were generated by Petar Cisar *et al.* [39].

Unsharp Operator

Shishir Maheshwari *et al.* [40] discussed a technique named Image Mosaicking of multiple overlapping of the images into a larger image of same scene. Image mosaic's output was the union of input images. Detection of interest point, this paper was based upon the Unsharp Masking Operator. The proposed method, produces informative output mosaicked image and which was also efficient as compared with the other point interest detection algorithms. Applications of proposed method was discussed in the fields of military Automatic Target Recognition (ATR), computer vision, medical imaging and in data from satellites.

For the Contrast Enhancement in Digital Image Processing, Unsharp Masking Filter (UMF) was commonly used. It was based on the principal of high passed and augmenting scaled version of image, which was easy to implement. The performance of Unsharp Masking was depend on the addition of high passed signal and its associated factor. The choice of optimal

filter parameters was challenging task. In this research paper, an adaptive scheme was presented which derived the scale from the pixel values of input image. Mid-range intensity pixels was assigned to comparatively large scaling factor. It was also discussed by Ngaiming Kwokl *et al.* [41] that, high pass generator window's width and optimal profile coefficients were calculated by adopting an algorithm called Particle Swarm Optimization algorithm (PSO).

The enhancement of sharpness and contrast of image and its application in many fields was studied. For the sharpness enhancement Unsharp Masking was the classical tool. An Unsharp Masking algorithm was proposed with the help of exploratory data model. The proposed method addressed some issues like, with the help of edge preserving filter halo effect was reduced, simultaneously enhancing the sharpness and contrast and solution of out of range problem with the help of tangent operations and log ratio. A new system was presented which was called tangent system, and based on specific Bregman divergence. In the presented algorithm by the Guang Deng *et al.* [42], users can adjust sharpness and contrast to attain the desired results.

Basic technique for editing and image manipulation was Unsharp Masking sharpening. Use of Unsharp Masking sharpening in the recent years was discussed. When sharpening process was done, overshoot artifacts were generated, which shape image texture along the image edges. A new method was proposed by Feng Ding *et al.* [43], to detect the sharpening, which was termed as edge perpendicular binary coding. It was done by special characteristic's utilization of texture modification, which was due to the Unsharp Masking sharpening. The presented method shows superiority over the existing methods.

Zero Crossing

The analysis of sign changes rate in discrete Fourier spectrum was presented. The sign changes of imaginary and real parts of spectrum were taken into consideration and spectral zero crossing rate was explained as rate of sign changes. It was shown that, Zero Crossing (ZC) have information related to the pixels of transients which were present in temporal observation window. Duality was shown in this paper by Ravi R. Shenoy *et al.* [44], with Zero Crossing rate observation. Comparison of localization properties was done with the localization which was based on group delay metrics.

The basic characteristic of edge present in the image was discussed. In image analysis and computer vision, edge detection contributed lot of algorithms. For the identical and useful

data present in the edge of image, the only approach to recognise and image analysis explained in this paper was Edge Detection. Different types of Edge Detection algorithms such as Sobel Operator, LOG, Roberts, Canny Operator and Prewitt Operator was studied by Li Bin *et al.* [45] and compared in this paper.

R. Muthukrishnan *et al.* [46] studied the interpretation of contents of images in computer vision technology, in Image Processing. A severe step in an image was represented by interpretation of different parts of image into background and object. The process of separation of objects and components region in an image was done by Segmentation. Fundamental tool to segment an image used in this paper was Edge Detection. Study of the performance of Zero Crossing with other Edge Detection techniques has been done by using MATLAB software.

PSNR & MSE

The monitoring of peak signal to noise ratio in the video quality assessment, a receiver side, where PSNR estimation was not essential. Mostly methods of PSNR estimation ignores the deblocking filtering effect. The main focus was only in the estimation of Mean Squared Error. In the images having large resolutions, PSNR Estimation cannot become zero, affected by deblocking filtering. Taeyoung Na *et al.* [47] studied, a Mean Squared Error estimation technique was presented. To find the accurate PSNR Estimation effect of deblocking filter was considered. MSE between reconstructed and original image was separated into parts for PSNR estimation. Experimental results in this paper presented more accurate PSNR estimations.

Changhoon Yim *et al.* [48] studied the deblocking algorithm's efficiency, to improve the visual signals, which were degraded by blocking of the some artifacts from compression. A block sensitive index was proposed which was named PSNR-B. Objective judgments was produced that accord with observations. Simple PSNR was modified by PSNR-B by adding a blocking effect factor. Simulations of the proposed method have better PSNR-B performance than PSNR.

A no reference PSNR estimation method was presented. The proposed algorithm by Bumshik Lee *et al.* [49] was based on the principle of Laplacian Mixture Distribution. Exponential regression algorithm was employed over the depths of coding units to predict the parameters of the model. The proposed method results in the more accurate result. This

model was designed to use in applications such as, single pdf based models and HM encoded bit streams.

A model was proposed which was termed as error surface considered modelling method. It was designed for the one forth pixel motion estimation in video encoding. Previously two methods were described, motion estimation based on quarter pixel based estimation and hierarchical based quarter pixel estimation. One method was interpolation free method possess minimum motion estimation time and other was based on selective interpolation as per the decision process. PSNR for HMBQME was better than MBQME, with the increased estimation time. In this paper, error surface considered method was proposed. In this algorithm as proposed by Junsang Cho *et al.* [50], error surface's tendency was assessed. In plain regions for one forth pixel estimation, simple structured and interpolation free was appropriate. In this paper, a mathematical model was modified for plain region. The proposed algorithm had better PSNR value observations as compared to previous traditional methods.

2.2 Gaps in Study & Observations

1. Development of accurate regression functions is very complex, before implementing change detection, for the selected bands [9-10].
2. Enhancement of coherence noise or random noise is done in some change detection techniques [15].
3. Extraction of more than single component is difficult related to an image in given type of change [17-18].
4. Great amount of expertise and time requires, to create classification products [23].
5. It is very difficult to label and to identify the change in the different trajectories of images [25].

2.3 Objectives

1. Study of various Image Change Detection algorithms and Image Edge Detection techniques.
2. Using traditional Change Detection techniques, implementation of Image Change Detection on Edge Enhanced Images.
3. Comparative analysis of Image Change Detection techniques implemented in previous objectives.

2.4 Methodology

Based on gaps in study, first of all, our aim is to implement various Edge Detection algorithms on two images of same place, captured at different instant of times and after that implementing Change Detection algorithm on these images and calculating the corresponding MSE and PSNR.

CHANGE DETECTION OF EDGE ENHANCED IMAGES

3.1 System Model

In this chapter, system models of Change Detection, Edge Detection and PSNR calculation is presented. First of all, method of PSNR calculation is discussed. After that, the process of Edge Enhancement on images is shown. Finally using edge enhanced images, process of Change Detection is presented. Various steps are:

Step.1 *Calculation of Mean Square Error & PSNR of two source images*

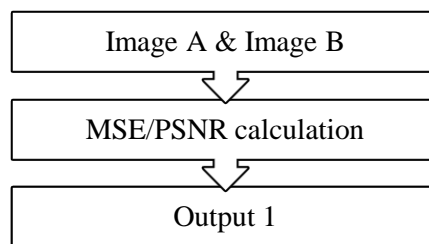


Fig. 3.1. MSE/PSNR

In this step, we calculate the Mean Square Error of source images. Image A and image B are source images. MSE and PSNR algorithms applied on these source images to get the numerical values i.e. output 1

Step. 2 *Implementation of Edge Detection Techniques and MSE/PSNR calculation.* On source image A and image B, Edge Detection Operators are applied which results in output image 1 and image2, after this step MSE/PSNR of image 1 and image 2 is calculated.

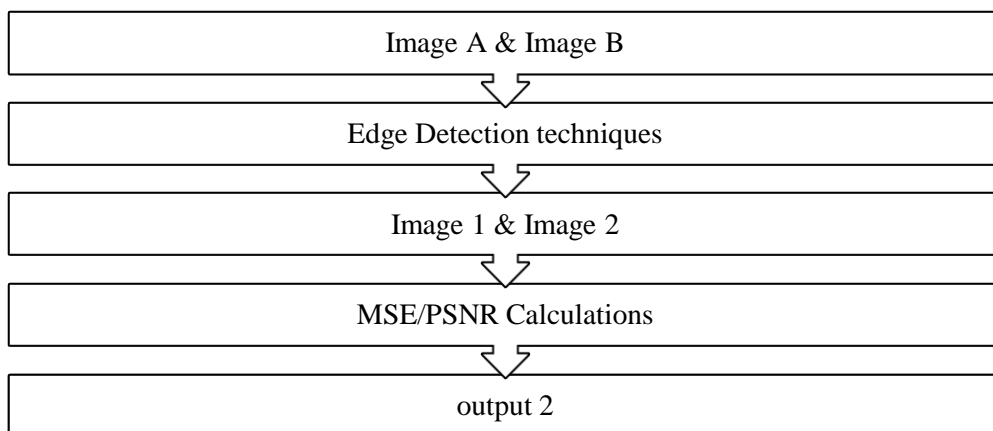


Fig. 3.2. Edge Detection technique.

We applied 5 different Edge Detection operators on two source images. Which results in 10 output images, MSE/PSNR of all these images is calculated.

Step. 3 Implementation of Change Detection Techniques and MSE/PSNR calculation

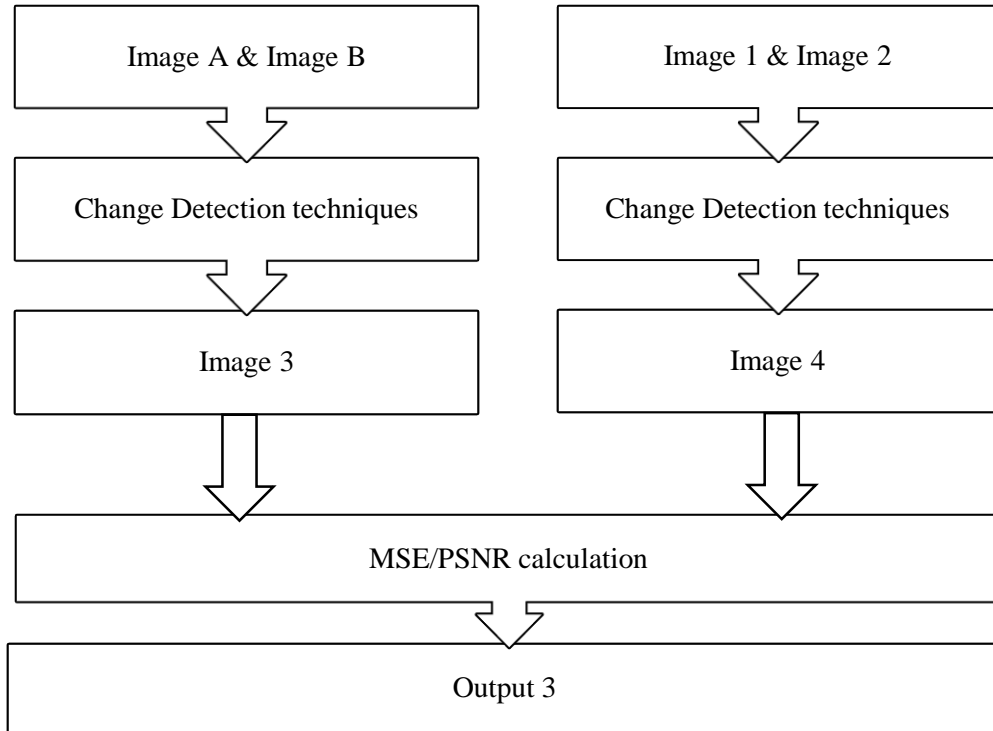


Fig. 3.3. Change Detection Technique.

In this step, Image Change Detection algorithms are applied on image A and image B, resulting in the output image 3, similarly Change Detection algorithms are also applied on images after Edge Detection i.e. image 1 and image2, resulting in output image4, finally MSE/PSNR of image 3 and image 4 is calculated. In this research work, we implement 3 types of Change Detection Techniques.

3.2 ANALYTICAL ANALYSIS

This section consists mathematical analysis of all the operations of Edge Detection operators, all Change Detection algorithms working and finally MSE & PSNR calculations of desired images.

3.2.1 Implementation of Edge Detection techniques

We use 5 different types of Edge Detection techniques, on our source images and explained as follows:

❖ *Sobel Operator*

We know that Sobel Operator use $3 * 3$ kernels so, $s_1(i, j)$ and $s_2(i, j)$ are two convolution masks,

$$s_1(i, j) = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix}; s_2(i, j) = \begin{bmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix}$$

For source image $A(k, w)$

$$M(k, w) = s_1(k, w) * A(k, w) \quad (3.1)$$

$$N(k, w) = s_2(k, w) * A(k, w) \quad (3.2)$$

For source image $B(k, w)$

$$O(k, w) = s_1(k, w) * B(k, w) \quad (3.3)$$

$$Q(k, w) = s_2(k, w) * B(k, w) \quad (3.4)$$

From equation (1.4), we know the gradient magnitude, from eq. (3.1-3.4)

$$C(k, w) = \sqrt{[M(k, w)]^2 + [N(k, w)]^2} \quad (3.5)$$

$$D(k, w) = \sqrt{[O(k, w)]^2 + [Q(k, w)]^2} \quad (3.6)$$

❖ *Prewitt Operator*

We know that Prewitt Operator also use $3 * 3$ kernels, its working is same as that of sobel operator and the only difference is in convolutions masks.

$$P_1(k, w) = \begin{bmatrix} -1 & -1 & 1 \\ 0 & 0 & 0 \\ 1 & 1 & 1 \end{bmatrix}; P_2(k, w) = \begin{bmatrix} 1 & 1 & -1 \\ 0 & 0 & -1 \\ 1 & 0 & -1 \end{bmatrix}$$

For source image $A(k, w)$

$$R(k, w) = P_1(k, w) * A(k, w) \quad (3.7)$$

$$S(k, w) = P_2(k, w) * A(k, w) \quad (3.8)$$

For source image $B(k, w)$

$$T(k, w) = P_1(k, w) * B(k, w) \quad (3.9)$$

$$U(k, w) = P_2(k, w) * B(k, w) \quad (3.10)$$

We know the gradient magnitude, so from eq. (3.7 – 3.10)

$$E(k, w) = \sqrt{R(k, w)^2 + S(k, w)^2} \quad (3.11)$$

$$F(k, w) = \sqrt{T(k, w)^2 + U(k, w)^2} \quad (3.12)$$

❖ *Compass Edge Operator*

Prewitt and sobel use two convolution masks but compass Edge Operator have 8 different kernels, each kernel is convolved with source image, mathematically compass edge operator:

For source image $A(k, w)$

$$G_{n1}(k, w) = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} * A(k, w);$$

$$G_{w1}(k, w) = \begin{bmatrix} 0 & 1 & 2 \\ -1 & 0 & 1 \\ -2 & -1 & 0 \end{bmatrix} * A(k, w);$$

$$G_{s1}(k, w) = \begin{bmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix} * A(k, w);$$

$$G_{e1}(k, w) = \begin{bmatrix} 2 & 1 & 0 \\ 1 & 0 & -1 \\ 0 & -1 & -2 \end{bmatrix} * A(k, w);$$

$$G_{n1w1}(k, w) = \begin{bmatrix} 1 & 0 & -1 \\ 2 & 0 & -2 \\ 1 & 0 & -1 \end{bmatrix} * A(k, w);$$

$$G_{s1w1}(k, w) = \begin{bmatrix} 0 & -1 & -2 \\ 1 & 0 & -1 \\ 2 & 1 & 0 \end{bmatrix} * A(k, w);$$

$$G_{s1e1}(k, w) = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix} * A(k, w);$$

$$G_{n1e1}(k, w) = \begin{bmatrix} -2 & -1 & 0 \\ -1 & 0 & 1 \\ 0 & 1 & 2 \end{bmatrix} * A(k, w);$$

From equation(1.6), we know the maximum response

$$G_{max}(k, w) = \max[G_{n1}(k, w), G_{w1}(k, w), G_{s1}(k, w), G_{e1}(k, w), \\ G_{n1w1}(k, w), G_{s1w1}(k, w), G_{s1e1}(k, w), G_{n1e1}(k, w)] \quad (3.13)$$

For source image $B(k, w)$

$$G_{n2}(k, w) = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} * B(k, w);$$

$$G_{w2}(k, w) = \begin{bmatrix} 0 & 1 & 2 \\ -1 & 0 & 1 \\ -2 & -1 & 0 \end{bmatrix} * B(k, w);$$

$$G_{s2}(k, w) = \begin{bmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix} * B(k, w);$$

$$G_{e2}(k, w) = \begin{bmatrix} 2 & 1 & 0 \\ 1 & 0 & -1 \\ 0 & -1 & -2 \end{bmatrix} * B(k, w);$$

$$G_{n2w2}(k, w) = \begin{bmatrix} 1 & 0 & -1 \\ 2 & 0 & -2 \\ 1 & 0 & -1 \end{bmatrix} * B(k, w);$$

$$G_{s2w2}(k, w) = \begin{bmatrix} 0 & -1 & -2 \\ 1 & 0 & -1 \\ 2 & 1 & 0 \end{bmatrix} * B(k, w);$$

$$G_{s2e2}(k, w) = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix} * B(k, w);$$

$$G_{n2e2}(k, w) = \begin{bmatrix} -2 & -1 & 0 \\ -1 & 0 & 1 \\ 0 & 1 & 2 \end{bmatrix} * B(k, w);$$

From equation(1.6), we know the maximum response

$$H_{max}(k, w) = \max[G_{n2}(k, w), G_{w2}(k, w), G_{s2}(k, w), G_{e2}(k, w), \\ G_{n2w2}(k, w), G_{s2w2}(k, w), G_{s2e2}(k, w), G_{n2e2}(k, w)] \quad (3.14)$$

❖ *Unsharp*

From equation (1.7) we know that smoothen image is subtracted from source image so,

For source image $A(k, w)$

$$K(k, w) = A(k, w) - A_{smooth}(k, w) \quad (3.15)$$

For source image $B(k, w)$

$$L(k, w) = B(k, w) - B_{smooth}(k, w) \quad (3.16)$$

$A(k, w)$ & $B(k, w)$ are source images and $A_{smooth}(k, w)$ & $B_{smooth}(k, w)$ are smoothened images of source images respectively.

❖ *Zero Crossing*

From equation (1.8) we know that Laplacian of an image is given by

For source image $A(k, w)$

$$I(k, w) = \frac{\partial^2 A(k, w)}{\partial k^2} + \frac{\partial^2 A(k, w)}{\partial w^2} \quad (3.17)$$

For source image $B(k, w)$

$$J(k, w) = \frac{\partial^2 B(k, w)}{\partial k^2} + \frac{\partial^2 B(k, w)}{\partial w^2} \quad (3.18)$$

3.2.2 Implementation of Change Detection techniques

❖ *Image Difference*

Using equation (1.1) we can find the various results which are as follows:

For source image $A(k, w)$ and $B(k, w)$

$$a(k, w) = A(k, w) - B(k, w) \quad (3.19)$$

From equation (3.5) and (3.6)

$$b(k, w) = C(k, w) - D(k, w) \quad (3.20)$$

From equation (3.11) and (3.12)

$$c(k, w) = E(k, w) - F(k, w) \quad (3.21)$$

From equation (3.13) and (3.14)

$$d(k, w) = G_{max}(k, w) - H_{max}(k, w) \quad (3.22)$$

From equation (3.17) and (3.18)

$$e(k, w) = I(k, w) - J(k, w) \quad (3.23)$$

From equation (3.15) and (3.16)

$$f(k, w) = K(k, w) - L(k, w) \quad (3.24)$$

❖ *Log Ratio*

Using equation (1.2) Log Ratio of any two images can be calculated.

For source image $A(k, w)$ and $B(k, w)$

$$g(k, w) = |\log[A(k, w)/B(k, w)]| \quad (3.25)$$

From equation (3.5) and (3.6)

$$h(k, w) = |\log[C(k, w)/D(k, w)]| \quad (3.26)$$

From equation (3.11) and (3.12)

$$i(k, w) = |\log[E(k, w)/F(k, w)]| \quad (3.27)$$

From equation (3.13) and (3.14)

$$j(k, w) = |\log[G_{max}(k, w)/H_{max}(k, w)]| \quad (3.28)$$

From equation (3.17) and (3.18)

$$k(k, w) = |\log[I(k, w)/J(k, w)]| \quad (3.29)$$

From equation (3.15) and (3.16)

$$l(k, w) = |\log[K(k, w)/L(k, w)]| \quad (3.30)$$

❖ *Mean Ratio*

Mean Ratio of image $A(k, w)$ and $B(k, w)$ is

$$W_1(k, w) = \text{mean } A(k, w)$$

$$X_1(k, w) = \text{mean } B(k, w)$$

$$m(k, w) = [A(k, w)/W_1(k, w)] - [B(k, w)/X_1(k, w)] \quad (3.31)$$

From equation (3.5) and (3.6)

$$W_2(k, w) = \text{mean } C(k, w);$$

$$X_2(k, w) = \text{mean } D(k, w)$$

$$n(k, w) = [C(k, w)/W_2(k, w)] - [D(k, w)/X_2(k, w)] \quad (3.32)$$

From equation (3.11) and (3.12)

$$W_3(k, w) = \text{mean } E(k, w);$$

$$X_3(k, w) = \text{mean } F(k, w)$$

$$o(k, w) = [E(k, w)/W_3(k, w)] - [F(k, w)/X_3(k, w)] \quad (3.33)$$

From equation (3.13) and (3.14)

$$W_4(k, w) = \text{mean } G_{max}(k, w);$$

$$X_4(k, w) = \text{mean } H_{max}(k, w)$$

$$p(k, w) = [G_{max}(k, w)/W_4(k, w)] - H_{max}(k, w)/X_4(k, w) \quad (3.34)$$

From equation (3.17) and (3.18)

$$W_5(k, w) = \text{mean } I(k, w);$$

$$X_5(k, w) = \text{mean } J(k, w)$$

$$q(k, w) = [I(k, w)/W_5(k, w)] - [J(k, w)/X_5(k, w)] \quad (3.35)$$

From equation (3.15) and (3.16)

$$W_6(k, w) = \text{mean } K(k, w);$$

$$X_6(k, w) = \text{mean } L(k, w)$$

$$r(k, w) = [K(k, w)/W_6(k, w)] - [L(k, w)/X_6(k, w)] \quad (3.36)$$

3.2.3 MSE and PSNR

From equation 1.10 we know that:

For image $A(k, w)$ and $B(k, w)$

$$MSE = \frac{1}{N} \sum_k \sum_w [A(k, w) - B(k, w)]^2 \quad (3.37)$$

Using equation (3.37)

$$PSNR1 = 10 \log_{10}[255^2/MSE] \quad (3.38)$$

For image $C(k, w)$ and $D(k, w)$

$$MSE = \frac{1}{N} \sum_k \sum_w [C(k, w) - D(k, w)]^2 \quad (3.39)$$

Using equation (3.39)

$$PSNR2 = 10 \log_{10}[255^2/MSE] \quad (3.40)$$

For image $E(k, w)$ and $F(k, w)$

$$MSE = \frac{1}{N} \sum_k \sum_w [E(k, w) - F(k, w)]^2 \quad (3.41)$$

Using equation (3.41)

$$PSNR3 = 10 \log_{10}[255^2/MSE] \quad (3.42)$$

For image $G_{max}(k, w)$ and $H_{max}(k, w)$

$$MSE = \frac{1}{N} \sum_k \sum_w [G_{max}(k, w) - H_{max}(k, w)]^2 \quad (3.43)$$

Using equation (3.43)

$$PSNR4 = 10 \log_{10}[255^2/MSE] \quad (3.44)$$

For image $I(k, w)$ and $J(k, w)$

$$MSE = \frac{1}{N} \sum_k \sum_w [I(k, w) - J(k, w)]^2 \quad (3.45)$$

Using equation (3.45)

$$PSNR5 = 10 \log_{10}[255^2/MSE] \quad (3.46)$$

For image $K(k, w)$ and $L(k, w)$

$$MSE = \frac{1}{N} \sum_k \sum_w [K(k, w) - L(k, w)]^2 \quad (3.47)$$

Using equation (3.47)

$$PSNR6 = 10 \log_{10}[255^2/MSE] \quad (3.48)$$

For image $a(k, w)$ and $b(k, w)$

$$MSE = \frac{1}{N} \sum_k \sum_w [a(k, w) - b(k, w)]^2 \quad (3.49)$$

Using equation (3.49)

$$PSNR7 = 10 \log_{10}[255^2/MSE] \quad (3.50)$$

For image $a(k, w)$ and $c(k, w)$

$$MSE = \frac{1}{N} \sum_k \sum_w [a(k, w) - c(k, w)]^2 \quad (3.51)$$

Using equation (3.51)

$$PSNR8 = 10 \log_{10}[255^2/MSE] \quad (3.52)$$

For image $a(k, w)$ and $d(k, w)$

$$MSE = \frac{1}{N} \sum_k \sum_w [a(k, w) - d(k, w)]^2 \quad (3.53)$$

Using equation (3.53)

$$PSNR9 = 10 \log_{10}[255^2/MSE] \quad (3.54)$$

For image $a(k, w)$ and $e(k, w)$

$$MSE = \frac{1}{N} \sum_k \sum_w [a(k, w) - e(k, w)]^2 \quad (3.55)$$

Using equation (3.55)

$$PSNR10 = 10 \log_{10}[255^2/MSE] \quad (3.56)$$

For image $a(k, w)$ and $f(k, w)$

$$MSE = \frac{1}{N} \sum_k \sum_w [a(k, w) - f(k, w)]^2 \quad (3.57)$$

Using equation (3.57)

$$PSNR11 = 10 \log_{10}[255^2/MSE] \quad (3.58)$$

For image $g(k, w)$ and $h(k, w)$

$$MSE = \frac{1}{N} \sum_k \sum_w [g(k, w) - h(k, w)]^2 \quad (3.59)$$

Using equation (3.59)

$$PSNR12 = 10 \log_{10}[255^2/MSE] \quad (3.60)$$

For image $g(k, w)$ and $i(k, w)$

$$MSE = \frac{1}{N} \sum_k \sum_w [g(k, w) - i(k, w)]^2 \quad (3.61)$$

Using equation (3.61)

$$PSNR13 = 10 \log_{10}[255^2/MSE] \quad (3.62)$$

For image $g(k, w)$ and $j(k, w)$

$$MSE = \frac{1}{N} \sum_k \sum_w [g(k, w) - j(k, w)]^2 \quad (3.63)$$

Using equation (3.63)

$$PSNR14 = 10 \log_{10}[255^2/MSE] \quad (3.64)$$

For image $g(k, w)$ and $k(k, w)$, from Equation (3.23) and (3.27)

$$MSE = \frac{1}{N} \sum_k \sum_w [g(k, w) - k(k, w)]^2 \quad (3.65)$$

Using equation (3.65)

$$PSNR15 = 10 \log_{10}[255^2 / MSE] \quad (3.66)$$

For image $g(k, w)$ and $l(k, w)$

$$MSE = \frac{1}{N} \sum_k \sum_w [g(k, w) - l(k, w)]^2 \quad (3.67)$$

Using equation (3.67)

$$PSNR16 = 10 \log_{10}[255^2 / MSE] \quad (3.68)$$

For image $m(k, w)$ and $n(k, w)$

$$MSE = \frac{1}{N} \sum_k \sum_w [m(k, w) - n(k, w)]^2 \quad (3.69)$$

Using equation (3.69)

$$PSNR17 = 10 \log_{10}[255^2 / MSE] \quad (3.70)$$

For image $m(k, w)$ and $o(k, w)$

$$MSE = \frac{1}{N} \sum_k \sum_w [m(k, w) - o(k, w)]^2 \quad (3.71)$$

Using equation (3.71)

$$PSNR18 = 10 \log_{10}[255^2 / MSE] \quad (3.72)$$

For image $m(k, w)$ and $p(k, w)$

$$MSE = \frac{1}{N} \sum_k \sum_w [m(k, w) - p(k, w)]^2 \quad (3.73)$$

Using equation (3.73)

$$PSNR19 = 10 \log_{10}[255^2 / MSE] \quad (3.74)$$

For image $m(k, w)$ and $q(k, w)$

$$MSE = \frac{1}{N} \sum_k \sum_w [m(k, w) - q(k, w)]^2 \quad (3.75)$$

Using equation (3.75)

$$PSNR20 = 10 \log_{10}[255^2 / MSE] \quad (3.76)$$

For image $m(k, w)$ and $r(k, w)$

$$MSE = \frac{1}{N} \sum_k \sum_w [m(k, w) - r(k, w)]^2 \quad (3.77)$$

Using equation (3.77)

$$PSNR21 = 10 \log_{10}[255^2/MSE] \quad (3.78)$$

3.3 Summary

In section 3.2.1, five different edge enhancement operators are applied on source images. In Sobel Operator, the convolution masks are convolved with the source images to produce more images and now from these images gradient magnitude is calculated and that results in edge enhanced images as shown in equations (3.5-3.6), similarly use of Prewitt Operator is same as that of Sobel Operator, the only difference is in the convolution masks, Prewitt Operator use different convolution masks. Two convolution masks are convolved with source images and then after convolution, with the help of new images, gradient magnitude is calculated and equations (3.11-3.12) shows edge enhanced images after Prewitt Operator enhancement. As discussed above, Sobel and Prewitt algorithms uses two convolution masks, in Compass Edge Operator instead of using two kernels, it uses 8 different kernels. These 8 kernels are convolved with source images and maximum response of all outcomes is calculated and shown in equations (3.13-3.14). Unsharp operator is a simple edge enhanced operator, first of all using source image, smoothen image is calculated and after that subtraction of smoothen image from the original image has been done in order to get enhanced images, as presented in equations (3.15-3.16) and finally using Zero Crossing edge enhancement operator, the enhanced images are calculated & shown by equations (3.17-3.18). In section 3.2.2, three different Image Change Detection algorithms are applied on source images and edge enhanced images. In Image Difference Change Detection algorithm, images are simply subtracted to get the final images as shown from equations (3.19-3.24). Using Log Ratio technique is different from the Image Subtraction, in this algorithm log of ratio of two images is calculated to get the difference image. As shown from equations (3.25-3.30) Log Ratio technique has been applied on source images and on images after Edge Enhancement. In Mean Ratio Change Detection algorithm, from the source images and edge detected images, mean of ratio of images are calculated to obtain the difference images as presented from equations (3.31-3.36). In section 3.2.3, MSE and PSNR of all the images are calculated.

CHAPTER 4

RESULTS & DISCUSSION

This chapter consists of source images, on which various Image Processing algorithms are applied. Images obtained after implementing Edge Enhancement algorithms such as Sobel operator, Prewitt operator, Compass Edge, Unsharp and Zero Crossing on source images are shown. Resulted Images after applying Change Detection algorithms such as image difference, image log ratio and image mean ratio on edge enhanced images are also shown.

4.1 Source Images

Source images used in this dissertation are satellite images of Lakepowell reservoir. First image contains the water level of the reservoir [51] and second image is taken at different time, have snow and change in water level [52].

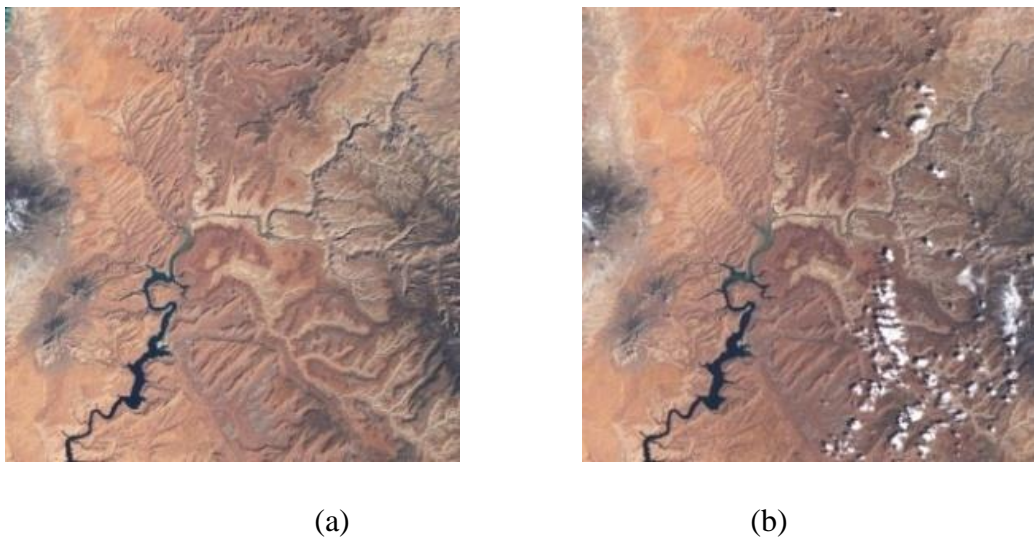
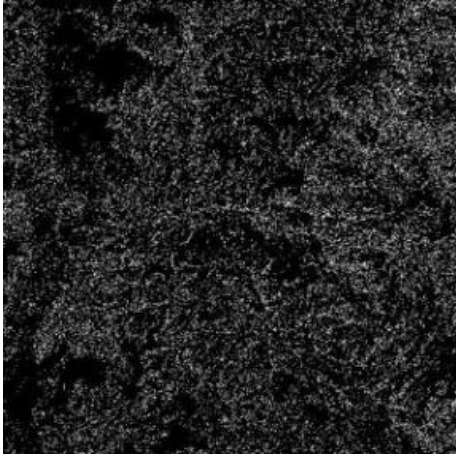


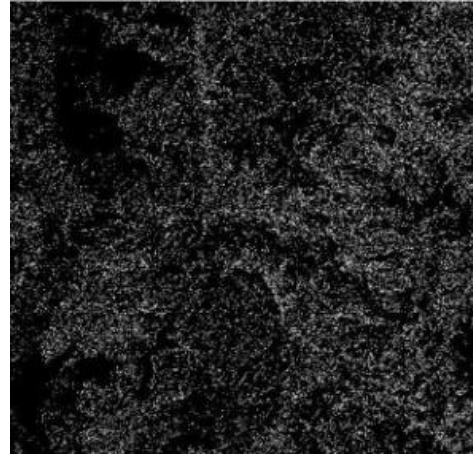
Fig. 4.1. Source images (a) $A(k, w)$ is source image without snow (b) $B(k, w)$ is source image with snow

4.2 Image Enhancement after Edge Detection

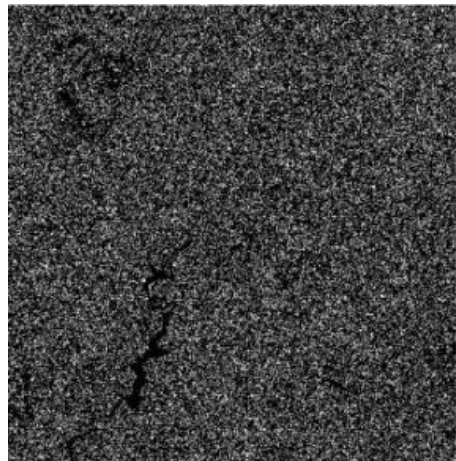
Images obtained after applying various Edge Detection techniques on source images are as follows:



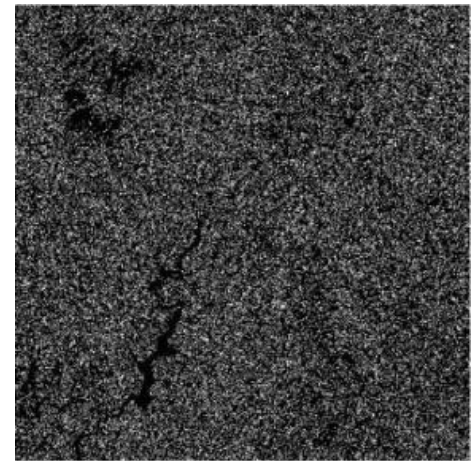
(a)



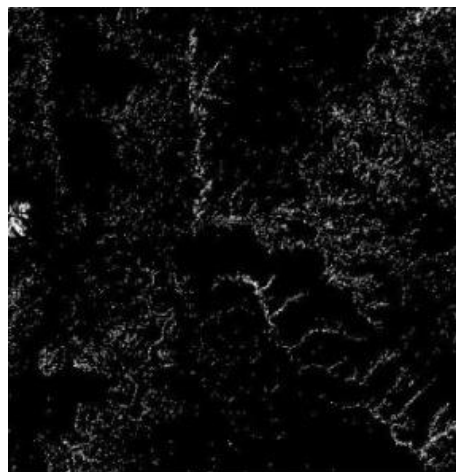
(b)



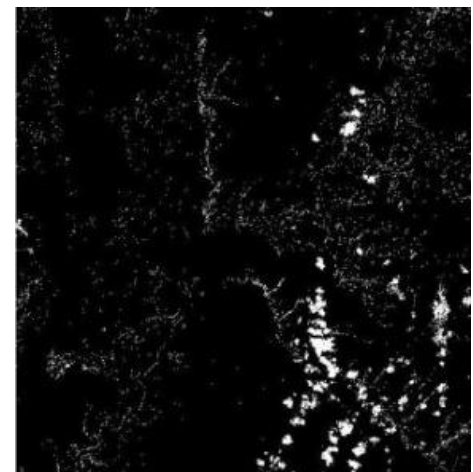
(c)



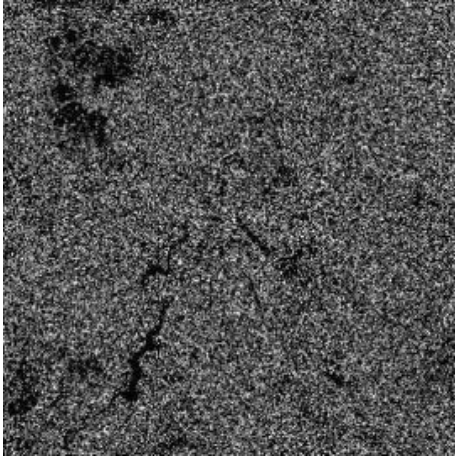
(d)



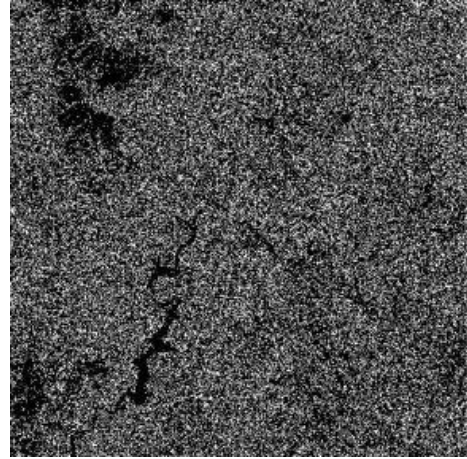
(e)



(f)



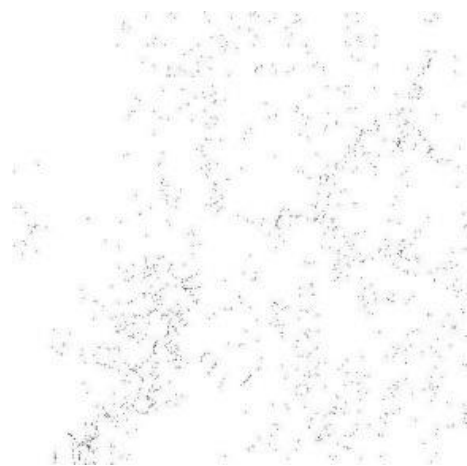
(g)



(h)



(i)



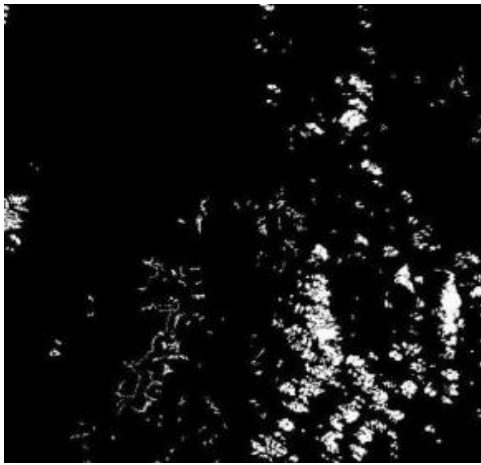
(j)

Fig. 4.2. Images after Edge Detection (a) Image $C(k, w)$ obtained after applying Sobel Operator on image $A(k, w)$; (b) Image $D(k, w)$ obtained after applying Sobel Operator on image $B(k, w)$; (c) Image $E(k, w)$ obtained after applying Prewitt Operator on image $A(k, w)$; (d) Image $F(k, w)$ obtained after applying Prewitt Operator on image $B(k, w)$; (e) Image $G_{max}(k, w)$ obtained after applying Compass Operator on image $A(k, w)$; (f) Image $H_{max}(k, w)$ obtained after applying Compass Operator on image $B(k, w)$; (g) Image $I(k, w)$ obtained after applying Zero Crossing Operator on image $A(k, w)$; (h) Image $J(k, w)$ obtained after applying Zero Crossing Operator on image $B(k, w)$; (i) Image $K(k, w)$ obtained after applying Unsharp Operator on image $A(k, w)$; (j) Image $L(k, w)$ obtained after applying Unsharp Operator on image $B(k, w)$

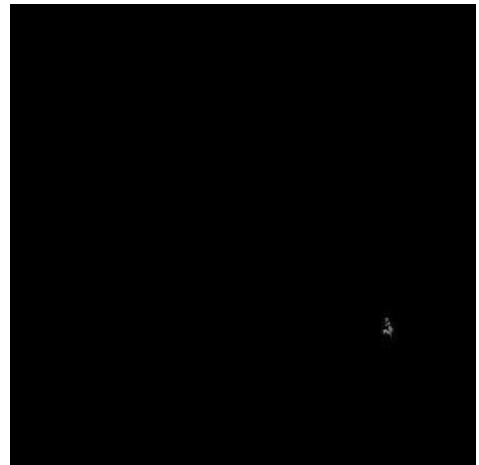
4.3 Change Detection in Edge Enhanced Images

4.3.1 Image Difference technique

Results of applying Image Difference technique on Edge Enhanced images are as follows:



(a)



(b)



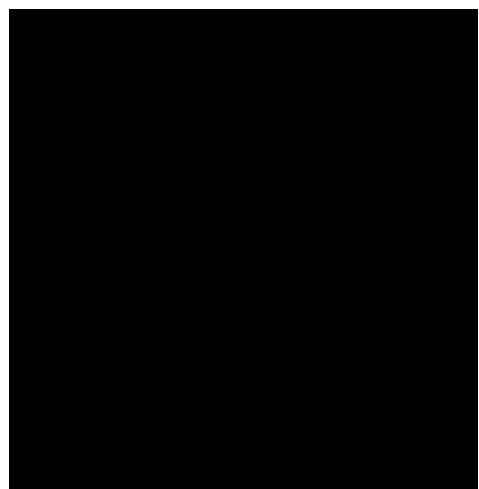
(c)



(d)



(e)



(f)

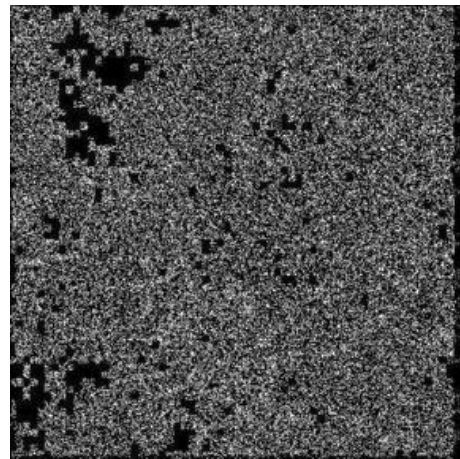
Fig. 4.3. Images after Image Difference Algorithm (a) Image Difference on images $A(k, w)$ & $B(k, w)$ results image $a(k, w)$; (b) Image Difference on images $C(k, w)$ & $D(k, w)$ results image $b(k, w)$; (c) Image Difference on images $E(k, w)$ & $F(k, w)$ results image $c(k, w)$; (d) Image Difference on images $G_{max}(k, w)$ & $H_{max}(k, w)$ results image $d(k, w)$; (e) Image Difference on images $I(k, w)$ & $J(k, w)$ results image $e(k, w)$; (f) Image Difference on images $K(k, w)$ & $L(k, w)$ results image $f(k, w)$

4.3.2 Log Ratio technique

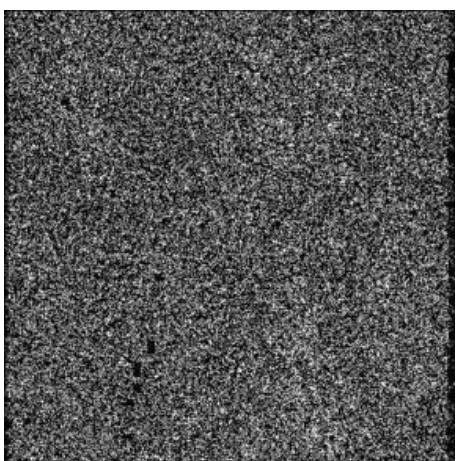
Images obtained after applying Image Log Ratio technique on Edge Enhanced images are as follows:



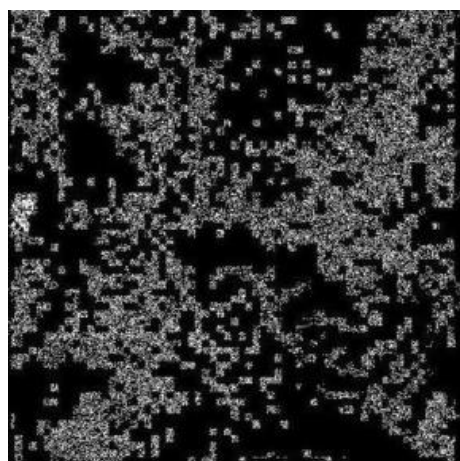
(a)



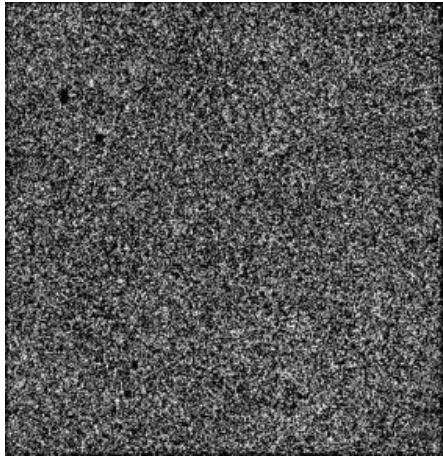
(b)



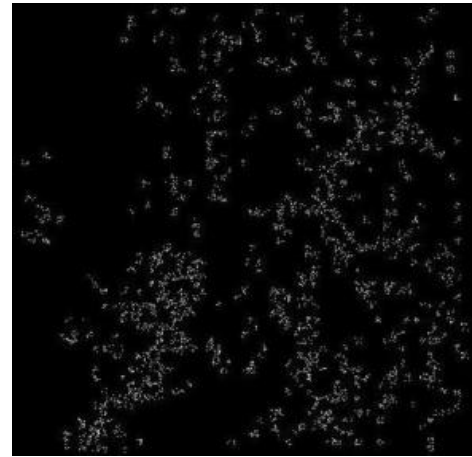
(c)



(d)



(e)



(f)

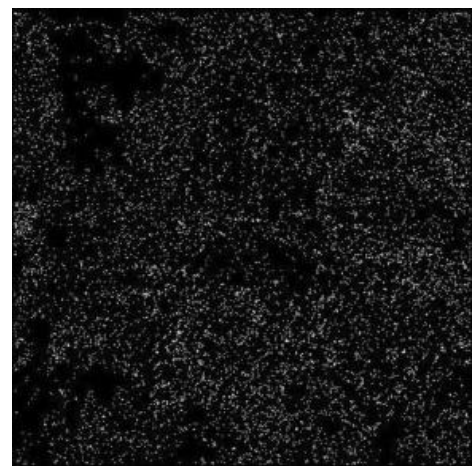
Fig.4.4. Images after Image Log Ratio Algorithm (a) Image Log Ratio on images $A(k, w)$ & $B(k, w)$ results image $g(k, w)$; (b) Image Log Ratio on images $C(k, w)$ & $D(k, w)$ results image $h(k, w)$; (c) Image Log Ratio on images $E(k, w)$ & $F(k, w)$ results image $i(k, w)$; (d) Image Log Ratio on images $G_{max}(k, w)$ & $H_{max}(k, w)$ results image $j(k, w)$; (e) Image Log Ratio on images $I(k, w)$ & $J(k, w)$ results image $k(k, w)$; (f) Image Log Ratio on images $K(k, w)$ & $L(k, w)$ results image $l(k, w)$

4.3.3 Mean Ratio technique

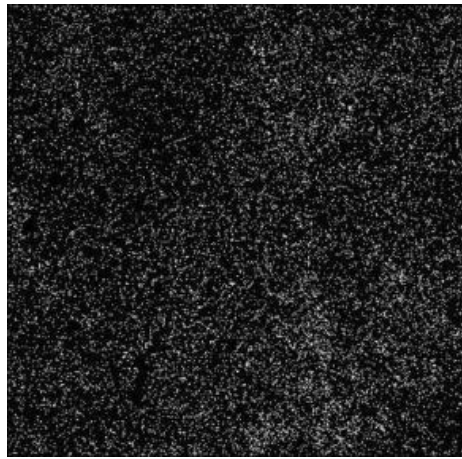
Images obtained after applying Image Mean Ratio technique on Edge Enhanced images are as follows:



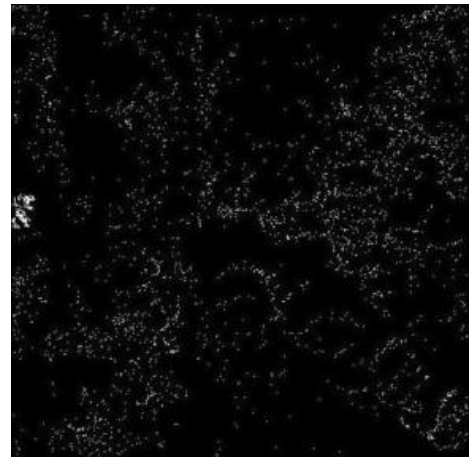
(a)



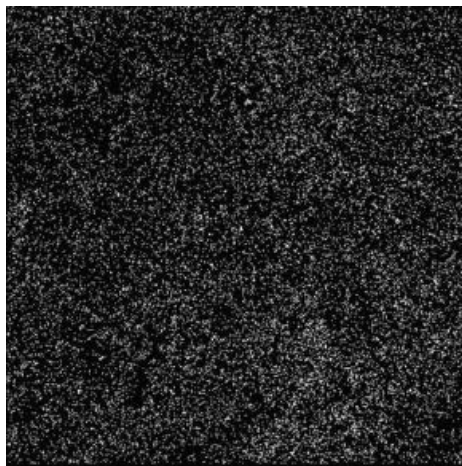
(b)



(c)



(d)



(e)



(f)

Fig. 4.5. Images after Image Mean Ratio Algorithm (a) Image Mean Ratio on images $A(k, w)$ & $B(k, w)$ results image $m(k, w)$; (b) Image Mean Ratio on images $C(k, w)$ & $D(k, w)$ results image $n(k, w)$; (c) Image Mean Ratio on images $E(k, w)$ & $F(k, w)$ results image $o(k, w)$; (d) Image Mean Ratio on images $G_{max}(k, w)$ & $H_{max}(k, w)$ results image $p(k, w)$; (e) Image Mean Ratio on images $I(k, w)$ & $J(k, w)$ results image $q(k, w)$; (f) Image Mean Ratio on images $K(k, w)$ & $L(k, w)$ results image $r(k, w)$

In this research work, we applied various Image Processing algorithms on source images as shown in Figure 4.1. First of all, Edge Detection techniques are implemented on source images. Implementation of edge enhancement operators like Sobel Operator, Prewitt Operator, Compass Edge Operator, Zero Crossing Method and Unsharp Operator is done on source images and results in output images shown in Figure 4.2. Now various image

Change Detection techniques are applied on these edge enhanced images. Implementation of Image Difference Algorithm on source images and edge enhanced images is done in order to get the output images as shown in Figure 4.3. Operation of Image Log Ratio algorithm on edge enhanced images and source images is performed which results in output images as shown in Figure 4.4. Similarly implementation of Image Mean Ratio algorithm on source images and edge enhanced images is performed in order to get the output images as shown in Figure 4.5.

4.4 Comparative Analysis

This section contain the all the numerical value results, obtained by different Digital Image Processing algorithms such as Edge Enhanced and Image Change Detection and are presented in tabular form.

Results after applying edge enhancement algorithms on source images are:

Table 1 Edge Detection Algorithm

Edge detection operator	MSE of Image $A(k,w)$ & $B(k,w)$	PSNR of Image $A(k,w)$ & $B(k,w)$
No operator	693.3806	19.7211
Sobel	1.8023e+03	15.5726
Prewitt	3.1712e+03	13.1186
Compass	738.7177	19.4460
Unsharp	171.1339	25.7974
Zero crossing	4.0586e+03	12.0470

In Table 1, the result of implementing Unsharp operator on source images $A(k,w)$ & $B(k,w)$ are images $K(k,w)$ & $L(k,w)$. The maximum PSNR value obtained from image $K(k,w)$ & $L(k,w)$ is **25.7974 dB**

Results obtained after applying Image Difference algorithm on edge enhanced images are shown as:

Table 2 Image Difference Algorithm

Edge detection operator	MSE of Image	PSNR of Image
Sobel	2.4578e+04	4.2253
Prewitt	2.4601e+04	4.2213
Compass	2.4661e+04	4.2108
Unsharp	2.4575e+04	4.2258
Zero crossing	2.4701e+04	4.2036

In Table 2, With Image Difference Algorithm, the result of implementing Image Difference algorithm on source images $A(k, w)$ & $B(k, w)$ is image $a(k, w)$ and that of Unsharp operator output images $K(k, w)$ & $L(k, w)$ is image $f(k, w)$. The maximum PSNR value obtained from images $a(k, w)$ & $f(k, w)$ is 4.2258 dB

Results obtained after applying Image Log Ratio algorithm on edge enhanced images are shown as:

Table 3 Image Log Ratio Algorithm

Edge detection operator	MSE of Image	PSNR of Image
Sobel	2.7489e+04	3.7393
Prewitt	2.7676e+04	3.7098
Compass	2.6137e+04	3.9583
Unsharp	2.4536e+04	4.2328
Zero crossing	2.7709e+04	3.7047

In Table 3, With Image Log Ratio algorithm, the result of implementing Image Log Ratio algorithm on source images $A(k, w)$ & $B(k, w)$ is image $g(k, w)$ and that of Unsharp operator output images $K(k, w)$ & $L(k, w)$ is image $l(k, w)$. The maximum PSNR value obtained from images $g(k, w)$ & $l(k, w)$ is 4.2328 dB

Results obtained after applying Image Mean Ratio algorithm on edge enhanced images are shown as:

Table 4 Image Mean Ratio Algorithm

Edge detection operator	MSE of Image	PSNR of Image
Sobel	2.4458e+04	4.2465
Prewitt	2.4917e+04	4.1659
Compass	2.4025e+04	4.3241
Unsharp	2.3846e+04	4.3567
Zero crossing	2.5203e+04	4.1163

In Table 4, With Image Mean Ratio algorithm, the result of implementing Image Mean Ratio algorithm on source images $A(k, w)$ & $B(k, w)$ is image $m(k, w)$ and that of Unsharp operator output images $K(k, w)$ & $L(k, w)$ is image $r(k, w)$. The maximum PSNR value obtained from images $m(k, w)$ & $r(k, w)$ is **4.3567 dB**

When edge enhanced operators are applied on source images then there corresponding PSNR & MSE values are shown in Table 1, Change Detection algorithm is not applied in table. The maximum PSNR value is from the images obtained after applying Unsharp edge enhance operator. On the other hand Table 2 consisting of PSNR & MSE values obtained after applying Image Difference algorithm on edge detected images and result is also maximum for Unsharp images. Table 3 and Table 4 are the tables consisting of MSE & PSNR values after applying Log Ratio and Mean Ratio change detection algorithm on edge detected images respectively and in these tables, maximum PSNR values is of Unsharp enhanced images. But the overall maximum PSNR value in these tables is obtained from Table 4, i.e. by applying Image Mean Ratio algorithm on Unsharp Edge Enhance images.

5.1 Conclusion

In this dissertation, various Digital Image Processing algorithms like Edge Enhancement algorithms and Image Change Detection algorithms have been discussed along with their applications. For different types of applications, method to detect the change in pixels of image is a very important tool. These changes are mainly due to motion or disappearance/appearance of object in target image. Change Detection has lots of applications like, video surveillance, agricultural surveys, remote sensing, urban studies, medical diagnosis and treatment, environment monitoring, driver assistance system, forest monitoring, civil infrastructure and underwater sensing. For better decision making, it is necessary, to accurately detect the change in earth's surface features for better understanding between human and natural phenomena. It becomes very easy in medical analysis, to compare and analyse the missing part of organs, using Change Detection algorithms.

Some methods to detect the change are Image Differencing, Image Log Ratio, Image Mean Ratio etc. depending upon the application each techniques have some advantages and disadvantages. In this dissertation for better Change Detection, images are firstly enhanced and then calculation of the Change Detection has been done. A parameter related to image i.e. PSNR has been maximized. It has been achieved using edge enhancement algorithms like Sobel operator, Prewitt operator, Compass Edge Detection algorithm, Unsharp Masking and Zero Crossing methods on source images, and then calculating the Image Change Detection using Image Difference algorithm, Image Log Ratio algorithm and Image Mean Ratio algorithm. Mathematical analysis have been performed on two different images of same area, captured at different times. By calculation it is very clear that to calculate the maximum value of PSNR, first of all apply Unsharp edge enhancement algorithm on source images and when edges are enhanced then apply Image Mean Ratio technique on edge enhanced images. Best result or maximum PSNR value is **4.3567 dB** and MSE is minimised in order to get better quality of change image, and it is obtained by implementing Unsharp edge detection technique followed by applying Image Mean Ratio technique on enhanced images as shown in eq. (3.78). Change Detection after Image enhancement provide better results.

5.2 Future Scope

With the use of Change Detection techniques in remote sensing, medical diagnosis, video surveillance etc. it becomes necessary to detect the change and other parameters in the image accurately. In this dissertation maximum PSNR value of two different images of same area is calculated, by applying edge enhancement algorithm first on images and after that calculating the Change Detection of edge enhanced images with Change Detection algorithms. This PSNR value can be further maximised and MSE value can be minimised by using better Edge Detection algorithms to obtain better result. This improvisation may be very helpful to detect change in image more accurately. In this work, Edge and Change Detection algorithms has been used, results can be further enhanced by using better edge enhancement algorithms.

LIST OF PUBLICATIONS

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2. Nishant Kush and Ankush Kansal, “Comparative Analysis of Change Detection Techniques on Edge Enhanced Images”, communicated to *Journal of Real-Time Image Processing, Springer*

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