IMPROVED IMAGE WATERMARKING USING DWT WITH PREDICTIVE CODING FOR HIDING THE ENCRYPTED WATERMARK

A DISSERTTION SUBMITTED TO

DEPARTMENT OF ELECTRONICS AND COMMUNICATION

OF

LOVELY PROFESSIONAL UNIVERSITY

BY

PANKAJ KUMARI
(11305517)

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF TECHNOLOGY

IN THE DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

UNDER THE GUIDENCE

OF

MANIE KANSAL

DECEMBER 2016

CERTIFICATE

This is to certify that _______________has completed M.Tech dissertation titled ____ under our guidance and supervision. To the best of our knowledge, the present work is the result of her original investigation and study. No part of the dissertation has ever been submitted for any other degree or diploma. The dissertation is fit for the submission and the partial fulfilment of the conditions for the award of M.Tech Electronics and Communication Engineering.

Date: _______________

Name and Signature of Guide:

DECLARATION

I hereby certify that the work which is being presented in the thesis entitled "Improved Image watermarking using DWT with predictive coding for hiding the encrypted watermark" by "Pankaj Kumari" in partial fulfilment of requirements for the award of degree of M.Tech. (ECE) submitted in the Department of Electronics and Communication at Lovely Professional University is an authentic record of my own work under the supervision of Manie Kansal madam. The matter presented in this thesis has not been submitted by me in any other University / Institute for the award of M.Tech Degree.

Signature of the Student

This is to certify that the above statement made by the candidate is correct to the best of my/our knowledge

Signature of the Supervisor(s)

The M.Tech Viva –Voce Examination of (   ) has been held on ____and accepted

Signature of Supervisor(s)   **Signature of External Examiner**

Signature of H.O.D.

ACKNOWLEDGEMENT

As it often happens that words sun out when you are really thankful and your sincere wish to express your feelings of gratitude towards someone. It gives immense pleasure to acknowledge great fully the debit of all the persons who directly or indirectly helped me in the completion of this Dissertation. I heartily thank my supervisor Manie Kansal madam for her valuable guidance, suggestions and continuous encouragement during the course of Dissertation and for providing me all sorts of help that were needed throughout my work. The help she provided me can never be redeemed.

I am also very grateful for the help and suggestions given by Dr. Gurusharan Singh sir during my Dissertation work.

My sincere regards to my parents who never let me down at any time. Their blessings and inspirations always helped me to do everything good.

Pankaj Kumari

ABSTRACT

Digital watermarking technique is becoming more important in this developing society of internet. Digital watermarking is used as a key solution to make the data transferring secure from illegal interferences. Image watermarking has many applications like temper detection, fingerprinting, content authentication, bank currency, safeguarding of medical images, etc. Image watermarking technology hides a secret data or signature or a logo belonging to some organization into the main image which is transferred from source to destination. The hidden secret data should be hidden in such a way that it do not affect the image quality and should be secure and robust to common filtering, compression, tempering, noises, etc. Image watermarking is done in spatial as well as frequency domain. The main aim of digital watermarking is to maintain high robustness and imperceptibility. The effectiveness of any technique is evaluated by evaluation parameters that are PSNR and NC. But there is trade-off between robustness and imperceptibility. Here an algorithm is developed which is highly robust, secure and imperceptible compared to previous schemes developed in related field. Here a technique using DWT with Predictive Coding is implemented. DWT converts image into frequency domain which increases robustness and Predictive Coding selects proper location to high watermark which increases imperceptibility without degrading image quality. Finally, Arnold Transform is used to encrypt watermark which further enhances security of watermark as well as watermarking scheme. Experimental results show much better results than previous schemes in both cases without Arnold and with Arnold. Without Arnold scheme gives PSNR 76.70 and NC 0.92 and with Arnold PSNR is 76.75 and NC is 0.77. Some common attacks are also applied to test robustness and imperceptibility of proposed scheme. In both cases, scheme has shown satisfactory results.

TABLE OF CONTENTS

LIST OF FIGURES

Figure **Page no.**

LIST OF TABLES

LIST OF ABBREVIATIONS

DCT	Discrete Cosine Transform
DFT	Discrete Fourier Transform
DWT	Discrete Wavelet Transform
SVD	Singular Value Decomposition
ESD	Encrypted Secret Data
PSNR	Peak Signal to Noise Ratio
JPEG	Joint Photographic Expert Group
NC	Normalized Correlation
PPV	Predicted Pixel Value
HVS	Human Visual System
PSO	Particle Swarm Optimization
MOPSO	Multi Objective Particle Swarm Optimization
MSF	Multi Scaling Factor
SSF	Single Scaling Factor
RGB	Red Green Blue
MPPV	Modified Predicted Pixel Value

CHAPTER 1

INTRODUCTION

With the advancement in the internet, the availability of resources the digital data like text, image, audio, video, etc. can be can be transmitted, distributed and reproduced without the lost of quality and much cost. These advances in society of software, hardware and internet have created menace to copyright protection and content authenticity. For instance, data can be easily copied, modified and distributed. One technical way for copyright protection and content authenticity is 'information hiding' which hides the content in the pathway and automatically detects and prosecute the copyright infringements. So information hiding is a powerful tool in today's world as we are living in digital era. It is very important to secure data while transmission through the internet as this path is highly not secure. Therefore there has been a significant research in the field for the past few years.

1.1 Information Hiding Technique

Information hiding techniques hides the information in another media/content. The information can be in any form like text, image, etc and similarly the host content/media can be in any form like text, image, video, etc depending upon the requirement. By this techniques information can be sent through internet safely without being destroyed and altered.

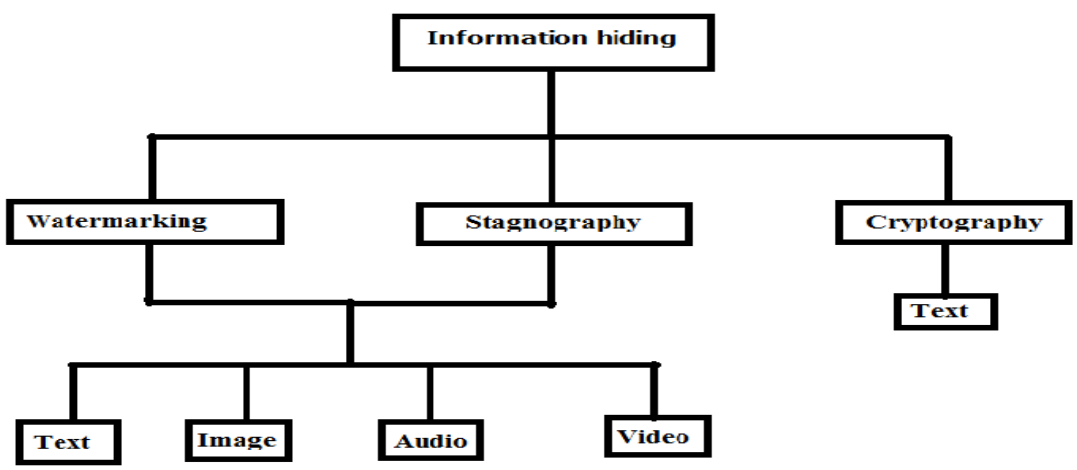


Fig. 1.1 Information Hiding types

Below different specifications of information hiding are presented:

Table 1.1 Information hiding techniques specifications

Method	**Watermarking**	**Stenography**	**Cryptography**
Carrier	Text, image, audio, video	Text, image, audio, video	Text
Key	Optional	Optional	Necessary
Secret message	Watermark	Payload	Plain text
Main objective	Copyright protection	Secret communication	Secret message protection
Result	Watermarked file	Stego file	Dipher
Attacks	Data processing	Steganalysis	Cryptanalysis
Fail	Removed watermark	Detected message	Decipher

1.2 Need of watermarking

A watermarking technique embeds watermark in different kind of data like image, text, audio, and video. The watermarking algorithm contains a watermark, an embedding algorithm and an extraction algorithm. According to properties of watermarking, the implemented algorithm must be robust. For practical applications the embedded watermark should be invisible, robust and of high capacity. The watermark is either embedded into spatial domain or transform domain. The watermark is a text or image that appears in the main content with variation in its visible intensity. The watermarking plays a vital role in analyzing a document or an image or a painting, it tells about the original owner with complete details, also identifies if any tempering has been done on the content and at which location. Encryption techniques further provides security to the watermark which is to be embedded in the main content. Encryption techniques make the watermark into meaningless data. Information hiding on the other hand, hides the information (main data) in any other meaningful data. But during transmission there are issues regarding copyright protection, content authentication, tempering the content, etc. to avoid these kinds of problems we need watermarking technology. There can be several attacks also after watermark is embedded because the online object can be digitally processed. Hence the watermarking algorithm must satisfy the robustness criteria so that the watermark is robust against all types of attacks in the meanwhile. When the owner wants to check the watermarks in the attacked and damaged multimedia object, the extraction algorithm is needed that was used in the watermarking technique. This detected watermark may or may not correlate/match with original watermark because the image might have been attacked for this original watermark is compared with the extracted watermark. Various watermarking scheme have been developed in the recent years. To track the illegal copies, a specialized watermark is required at the receiver end. Watermarking is generally embedding watermark into the main content with some manipulation which are not perceptible to human visible system. Generally, the watermark is chosen to be signature or identification mark of any particular owner which varies with the owner mark. This extracted watermark verifies the original owner of the document/content.

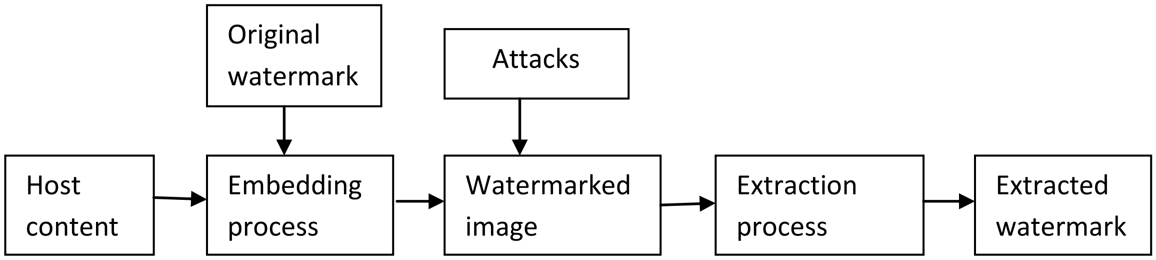


Fig. 1.2 Image Watermarking Technique

1.3 Digital Image Watermarking Technology

Digital image watermarking is when the content in which the secret data is to be hidden is an image. The secret data to be hidden can be any text, image or audio. The cover can be of any type like gray, color, binary or indexed; similarly secret image can be of any of these types. In image watermarking the secret data is embedded into cover image by any many techniques/algorithms. These techniques can be in spatial domain or frequency or hybrid i.e. combination of spatial and frequency domain techniques. This is called embedding process. The extraction process extract the watermark/secret data from the cover image and compare it to the original one. During transmission of the content or cover image over the internet, distortions are introduces to it. The distortions are the changes made on the watermarked image. These distortions can be lossy compressions, geometrical operations or common image processing, etc. these are also sometimes called attacks. To deal with digital image watermarking, one should know the fundamental properties of watermark; which includes imperceptibility, robustness, capacity and security. The computational complexity of the proposed algorithm of the image watermarking plays an important role. The image watermarking methods applied can be robust, fragile and semi-fragile. Robust image watermarking methods are resistant to distortions, fragile image watermarking methods are easily destroyed by all common distortions and semi-fragile image watermarking methods are resistant to certain type of distortions but destroyed by others. Finally, performance of any image watermarking technique/method is evaluated by applying different distortion intentionally to the watermarked image and then calculating its PSNR and NC.

1.4 Types of Digital Watermarking

The different types of digital watermarking are presented below:

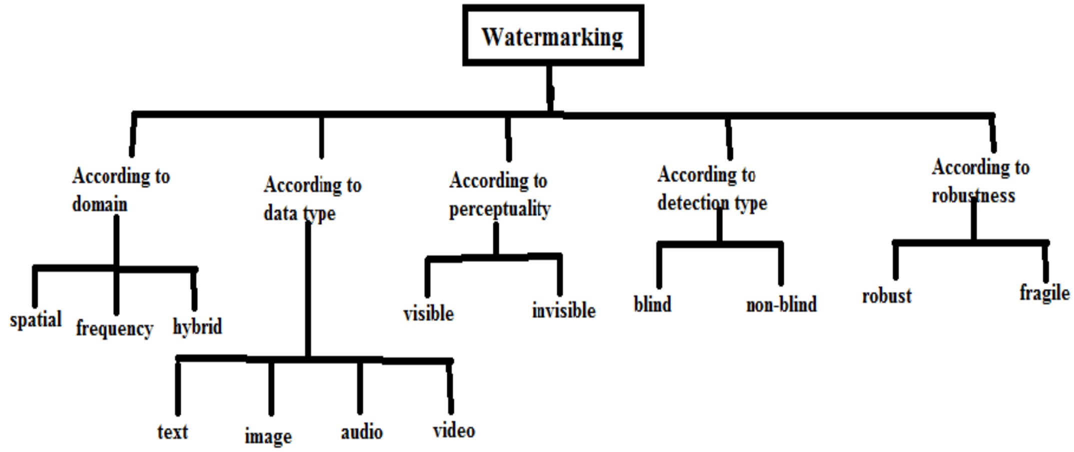


Fig. 1.3 Types of Digital Watermarking

There are many watermarking techniques based on different categories. Various categories based on which watermarking is divided are the domain its working, type of watermark it is using, after embedding the watermark is visible or invisible, the extraction algorithm it uses is blind or non-blind and to various attacks the implemented scheme is robust or fragile. On basis of domain, watermarking can be done in spatial domain and frequency domain. It has seen that the frequency domain schemes are more robust than spatial domain ones. In Spatial domain technique, the watermark is inserted in the cover image changing pixels. The algorithm should carefully weigh the number of changed bits in the pixels against the possibility of the watermark becoming visible. These approaches modify the least significant bits of original contents. The watermark can be hidden into the data with the assumption that the LSB data are visually irrelevant [25]. In frequency domain techniques, these insert the watermark in spectral coefficients of the host content [4]. The most commonly used transforms are the Discrete Cosine Transform (DCT), Discrete Fourier Transform (DFT), Discrete Wavelet Transform (DWT) and Singular Value Decomposition. The DCT and DWT are mostly used in many watermarking schemes and SVD is the latest technique to be used in the digital watermarking. In these first the host or main data is transformed and then modifications are applied to transformed coefficients. On the basis of type of data, the watermarking schemes are divided into a text watermarking if it watermarks a text document, an image watermarking scheme if it watermarks an image, a audio watermarking scheme if it watermarks an audio, a video watermarking scheme if it watermarks a video. Here the watermark can be any type in combination with any other type of host content. On the basis of perceptuality, if the watermark is visible in the watermarked host content it is called visible watermarking scheme otherwise called invisible watermarking scheme if watermark is invisible in the watermarked host content. On the basis of detection, watermarking schemes are divided into blind (public) and non-blind (private). In blind, during the detection or extraction algorithm cover content is not needed, solely the key which was used during embedding is needed. In non-blind, during detection is cover content is required. Finally on the basis of robustness, if the implemented watermarking scheme is robust to various basic attacks it is said to be robust otherwise fragile scheme. It is desirable that the developed watermarking technique should have as high as robustness. But again there is tradeoff between robustness of a technique and its imperceptibility. Therefore, optimization is required to meet this tradeoff.

Transform Domain

There are basically three types of frequency domain techniques that are DCT, DFT and DWT. In this domain, the techniques apply a mathematical formula on the content/data to divide the content into its different levels of frequency that is high and low frequency components [24]. In DCT, DCT watermarking can be divided into two categories i.e. Block–DCT watermarking and Global-DCT watermarking. In this technique the signal is decomposed into cosine sinusoidal frequencies with different amplitudes. When 2- dimensional DCT is applied on a matrix then it produces another matrix containing frequency coefficients. In this produced matrix, the left topmost frequency coefficients represent low frequency coefficients whereas right bottom frequency coefficients represent high frequency coefficients [9]. DCT has a property that most of the perceptually significant information of an image is concentrated in just few frequency coefficients of DCT. This DCT watermarking technique is more robust as compared to spatial domain techniques. It is robust to operations such as contrast adjustment, low pass filtering, blurring, brightness adjustment, etc. However this DCT technique have limitations like difficult to implement and computationally costly. This transform is applied on complete image including every part which then separates the spectral regions based on their energy content.

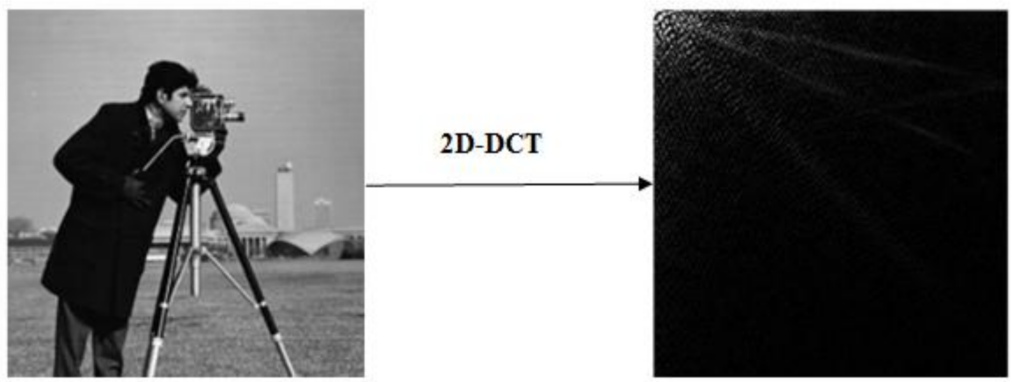


Fig. 1.4 DCT application on an image

DFT domain was developed to provide robustness against the geometrical attacks like scaling, cropping, rotation, translation etc. It is resistant to cropping because effect of cropping leads to the blurring of spectrum. But now-a-days this techniques is not used due to its drawback that DFT of an original signal is generally complex valued, which results in the magnitude and phase representation of signal. Further processing has to be done on both magnitude and phase representation separately. In the last few years wavelet transform (DWT) has been widely used in signal processing in watermarking and image compression schemes. The wavelet transform decomposes the image into three spatial directions, i.e. vertical, horizontal and diagonal. Magnitude of DWT coefficients is high in the lowest bands (LL) at each level of decomposition and is least for other bands (HH, LH and HL). The high magnitude of the wavelet coefficient is more significant. DWT concentrate almost complete energy of the signal in its approximate coefficients this is LL band.

Fig.1.5 DWT decomposition of an image

1.5 Desired characteristics of watermark

The desired characteristics of watermark are:

a) The unauthorized person must face difficulty in removal process of the watermark. On the other hand, the removal process should be costly and time consuming for the third party.

b) The watermark should spread in the as much as large area of the cover image or in its important areas to avoid easy removal of the watermark.

c) The watermark should be able to embed/hide in cover image with less human effort.

d) The watermark should not reduce the quality of the cover image in which it is embedded.

e) The invisible watermark is considered better than the visible watermark in image watermarking which further lowers the chances of its removal.

f) The fragile invisible watermark should be easily susceptible to tempering done to cover image.

g) The watermark hidden in cover image should be secure i.e. the watermark should not be easily extracted even after watermarking procedure is known.

h) The watermark should be embedded successfully with less number of pixel modifications in order to maintain the high quality of cover image.

1.6 Methodology of Watermarking Process

Digital image watermarking is the process of embedding a watermark into a host/cover image. The watermark can be any digital signature, image, text or video. The watermark can be any mark belongs to any particular identity/person/organization. After the extraction process the embedded watermark is extracted. That extracted watermark is the compared with the particular identity mark of any person/organization. By the comparison, the host image is tested for copyright and content authentication. Generally, any watermarking technique consists of the following necessary steps to be implemented.

a) The watermark
b) The host image
c) The embedding process
d) The extraction process
e) Attacks
f) Evaluation

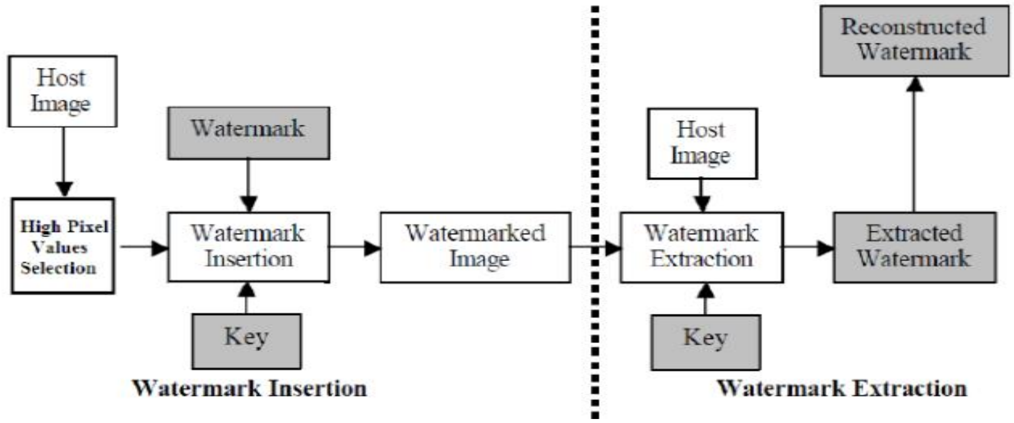


Fig 1.6 Methodology of image watermarking

1.7 Attacks on Watermarked image

The transmission media can cause some loss in the signal leading to a damaged content these are called attacks. There are some unintentional attacks like compression, etc. Some are intentional attacks like cropping, filtering, etc. Some of the common attacks are:

a) **Lossy compression:** These attacks degrade the quality of image in such a way that it becomes difficult to retrieve the original quality of the image. Some significant data is lost after applying these lossy compressions.

JPEG compression: It stands for Joint Photographic Expert Group in honor of group which created this standard. This compression permanently loses the data from the original image which cannot be restored. Thus it destroys the quality of image. This type of compression can be applied to color images, gray scale images, photographs and nowadays even on videos. The typical compression ratio is taken as 20:1 to 25:1 which maintains the image quality to much extent without much degradation. In higher compression ratio the difference is noticeable by human visual system duet to its much degraded image quality. But, these compressions save the disk space/ memory and reduce the transmission time through the channel.

b) **Geometric attacks:** These attacks do not actually remove the watermark, but manipulate the watermarked image in such a way that the detector cannot find the watermark data. These include affine attacks like rotation, translation, scaling, cropping, line/column removal also comes under this category.

c) **Noise attacks:** The robustness of watermarking technique can be tested through noise attacks like salt and pepper noise, speckle noise, gaussian noise, etc. noise is actually the unwanted signal interfering the main signal or wanted signal. The source of these signals can be a defective device, electric humming, etc.

Salt and Pepper noise: These are 1 (white) and 0 (black) pixel values on the bright and dark regions of the image. The source of such type of noise can be A/D converter, dead pixels, etc. these pixels randomly spread over the image.

Gaussian noise: It is the statistical noise whose probability density function is equal to Gaussian distribution. The gaussian distributed values are chosen from the image to introduce noise.

d) **Filtering:** A filter is defined by an array applied to a particular pixel along with its neighbors. This array is defined by a kernel. Mostly kernel is a square of odd numbers like 3, 5, 7, etc. to each pixels. The filters are applied to images by the process of convolution. These are used in many applications like de-noising, smoothening, edge detection, etc. Some of the filters are:

Average filter: It averages the fixed number of pixel values and gives a single value as its output. The high frequency components are eliminates after applying average filter.

Gaussian filter: As its impulse response is a Gaussian function so called Gaussian filter. It convolutes the image pixel values with the Gaussian function.

e) **Forgery:** In this, the unauthorized person/ third party generate various copies of watermarked image with same embedded watermark. Therefore, the watermark should be embedded by such a technique that the watermarked image with same embedded watermark cannot be forged.

1.8 Performance evaluation parameters of an algorithm

The performance of any image watermarking algorithm is evaluated on the basis of below mentioned parameters. The main objective is evaluation of performance parameters like MSE, PSNR and NC for the proposed scheme to get maximum robustness against as many as possible attacks with maximum imperceptibility.

MSE (Mean Square Error) =it is the measure of error between original image and watermarked image. It should be as minimum as possible. New technique or proposed technique is desired to have reduced value than the previous employed scheme.

$$MSE=\frac{1}{M\times N}\sum_{i=1}^{M}\sum_{j=1}^{N}(I_{ij}-W_{ij})^2$$

Where, I_{ij}=pixel of original image of size M×N

W_{ij}=pixel of watermarked image of size M×N

PSNR (Peak Signal to Noise Ratio) =It is the measure of imperceptibilty of watermark image in the cover image. Higher the value of PSNR higher the imperceptibilty of watermark image. PSNR values greater than 28 are acceptable.

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

NC (Normalized Cross Correlation)=It evaluates the similarity and differences between original watermark image and extracted watermark image. It determine the robustness of digital image watermarking. NC values ranges 0-1. Values greater than 0.7 are acceptable. It is given by:

$$NC=\frac{\sum_{i=1}^{M}\sum_{j=1}^{N}(W_{orig\ ij}-W_{extr\ ij})}{\sum_{i=1}^{M}\sum_{j=1}^{N}(W_{orig\ ij}^{2})}$$

Where, $W_{orig\ ij}$ = pixel of original watermark image of size M×N

$W_{extr\ ij}$ = pixel of extracted watermark image of size M×N

1.9 Watermarking Applications

There are many application areas of the digital watermarking now-a-days. One of them is copyright protection. In this, watermarking is used for protecting the distribution of copyrighted material over the non-trusted or unauthorized network like internet. By applying the watermarking technologies to the material the copyrighted material can be filtered out from such networks. Other application area is Meta-data insertion or content description where meta-data refers to the data that describes a particular data. Labeling and content information of the host image can be used as watermark. Images can be labeled with its content [2]. Audio files can carry the lyrics or the name of singer. Journalists can use the photograph of the incident to insert the cover story of that particular news. Digital watermarking is also used for temper detection**.** In this, digital content can be detected for tempering by embedding fragile watermark, if this fragile watermark is demolished, it is indicated as the presence of tempering and hence the digital content is modified and is not trust worthy. Temper detection and safeguarding the integrity of data plays a vital role in applications that involve highly sensitive data like satellite images or medical images [22]. Temper detection is also useful in court of law where digital images can be used as forensic tool to prove whether the image is tampered or not. One of its important application areas is digital fingerprinting; it is used to trace the source of illegal copies whereby, the owner can embed different watermarks in the copies of the data that are supplied to different customers which enables him to identify customers who have broken their license agreement by supplying the data to third parties. Another application area is covert communication**;** in this, the embedded signal is employed in the transmission of secret message from one place to another without knowing anyone of the information in the way of transmission. It includes exchange of secret message inserted within image. Visible watermarking scheme can be used for content protection, in this visible watermark makes it very difficult to modify the image content.

1.10 Objective and Scope of thesis

Watermarking has become an essential requirement for the security of the images, videos and different types of data.

Problem Formulation

To implement digital image watermarking various techniques can be used. But most of them have limitations. As we can see, watermarking is implemented in spatial domain as well as frequency domain. Watermarking scheme in spatial domain uses pixel modification to embed watermark into cover image. But schemes in this domain give lower PSNR which increases risk to imperceptibility with lower robustness. So frequency domain is used to get better robustness and imperceptibility. In frequency domain firstly, DCT techniques robust against simple image processing operations like low pass filtering, contrast and brightness adjustment, etc. And it is weak against geometric attacks. But it has one advantage that it is robust to compression techniques as embedding is done in significant portion. So DWT comes in picture, from last few years wavelet transform has been widely used in signal processing in watermarking and image compression schemes. DWT is mathematically efficient and can be implemented by using filter convolution simply which is an advantage over DCT. Then we go for combination of frequency domain techniques which combine advantages of these both techniques and give higher imperceptibility and robustness when used alone. The main objective of every image watermark is to hide watermark into main image such that it do no degrade image quality and is robust to common attacks. The technique should also fulfill the demand of security parameter.

Solution

The frequency domain techniques have high computational complexity as compared to spatial domain techniques but in terms of robustness frequency domain techniques are much better than spatial domain techniques. So combining positive points of both domains we can get a technique having low computational complexity and high robustness with adding security parameter as well to further increase robustness, security and imperceptibility. Here we have used spatial domain technique Predictive Coding with frequency domain DWT. First image is transformed into frequency domain then Predictive Coding is used to find better locations for watermark bits embedding in such a way that it does not degrade the quality of image. Further, Arnold Transform is used for security purpose and enhances the security of technique. Results show the high PSNR and NC than the previous related schemes. Thus, this technique fulfills our demands of imperceptibility, robustness and security.

CHAPTER 2

LITERATURE SURVEY

Shankar Parimi, A.SaiKrishna, N.Rajesh Kumar, N.R.Raajan [2015]: In [5], the cover image is divided into 8*8 non-overlapping blocks first, then DCT II version is applied to every sub block of the cover image. The watermark bits are embedded into these sub blocks. Experimental results show the high security and watermark is successfully extracted.

Saiful Islam, Mangat R Modi and Phalguni Gupta [2014]: In [6], a novel steganography is presented. This paper uses the concept of edges to embed watermark bits into the cover image. According to this paper, the amount of secret data bits to be embedded plays a vital role in image-hiding scenario. More number of bits to be embedded, more the use of weaker edges for embedding. Experimental results show the better performance than the other ongoing steganography techniques and also ensure increased embedding capacity.

K. Loukhaoukha, M. Nabti, K. Zebbiche [2014]: In [7], an optimal image watermarking scheme using multi−objective particle swarm optimization (MOPSO) and singular value decomposition (SVD) is used. Original image is decomposed by LWT then SVD is applied to a chosen sub-band. To embed the singular values of watermark image multiple scaling factors (MSF) are used to modify the singular values of chosen sub-band. Here MOPSO is used to achieve high robustness and imperceptibility. Optimum multiple scaling factors are obtained using particle swarm optimization technique. Experimental results of the proposed algorithm shows improvement in imperceptibility and robustness under various attacks.

Ehab H. Elshazly, Osama S. Faragallah, Alaa M. Abbas, Mahmoud A. Ashour, El-Sayed M. El-Rabaie, Hassan Kazemian, Saleh A. Alshebeili, Fathi E. Abd El-Samie, Hala S. El-sayed [2014]: In [8], fractional wavelet transform (FWT) image watermarking technique is presented which is the combination of discrete wavelet transform (DWT) and the fractional Fourier transform (FRFT). In this, 2 resolution level DWT is applied on the host image and then, FRFT is applied on the middle frequency sub-bands. Then the watermark is hidden by altering these selected FRFT coefficients. Two pseudo-random noise (PN) sequences are used to modulate the selected FRFT coefficients with the watermark pixels, and then finally inverse transforms are applied to get the watermarked image. Experimental results show that increasing the length of coefficients to be watermarked decreases similarity between the original and watermarked image and improves the similarity between the original and extracted watermarks.

Amit Kumar Singh, Mayank Dave, Anand Mohan [2014]: In [9], a watermarking scheme based on DWT (Discrete Wavelet Transform), DCT (Discrete Cosine Transform), and SVD (Singular Value Decomposition) is proposed. First the cover image is decomposed into one-level DWT. Then Low frequency (LL) band transformed by DCT and then SVD. Then the singular values of watermark image are embedded into singular values of cover image. The watermarked image is produced by applying inverse SVD on modified singular values and original U and V vector followed by inverse DCT and inverse DWT. Finally watermark is extracted using extraction algorithm. Experimental results of proposed scheme show high imperceptibility and robustness against various attacks.

Qingtang Su Gang Wang, ShaoliJia, Xiaofeng Zhang, Qiming Liu, Xianxi Liu [2013]: In [10], watermarking scheme is presented to embed the color image watermark into the direct current (DC) coefficients and the alternating current (AC) coefficients of the color host image. Here the host image is divided into 8×8 non-overlapping blocks, and then one-level DCT is applied on these blocks. Then its left uppermost 4 × 4 coefficients are further transformed by two-level DCT, then these coefficients are ordered in zigzag arrangement. The digital watermarks are embedded into the DC coefficient and the first seven AC coefficients of these blocks. Experimental results show that the proposed watermarking algorithm is robust to many common image processing attacks and geometric attacks.

Nidhi Bisla, Prachi Chaudhary [2013]: In [11], a comparative study of two most recent techniques in image watermarking DWT and hybrid DWT-SVD is done. Both of these techniques are very robust and imperceptible. In DWT, the original image is decomposed to embed watermark and in hybrid DWT-SVD firstly image is decomposed by DWT and then watermark is embedded in singular values obtained by applying SVD. Here, the techniques are compared on the basis of PSNR value at different scaling factor values, high value of PSNR shows good imperceptibility of the technique.

Shi-Jinn Horng, DidiRosiyadi, Pingzhi Fan, Xian Wang, and Muhammad Khurram Khan [2013]: In [12] , an adaptive scheme is proposed that combines the discrete cosine transform (DCT) and the singular value decomposition (SVD) using luminance masking to improve noise sensitivity. Here Genetic algorithm (GA) is used for the optimization of the scaling factor of the masking. First mask of the host image using luminance masking is calculated. It is then continued by transforming the mask on each area into all frequencies domain. The watermark image is embedded by modifying the singular values of DCT-transformed host image with singular values of mask coefficient of host image and the strength factor optimized by Genetic Algorithm (GA). The use of both the singular values and the control parameter/strength factor improves the sensitivity of the watermark performance and avoids the false positive problem. The experimental results show that adaptive performance improves the robustness of an image from any attacks.

Punit Pandey, Shishir Kumar and Satish K. Singh [2013]: In [13], an adaptive watermarking scheme has been proposed, which is based on DWT and SVD. An attempt has been made to solve the problem of false positive detection while maintaining the robustness and imperceptibility with the help of principal component and perceptual tuning of the image which is a non-blind technique based on the objective quality of image. Here scaling factor is made dependent on features of watermark and host in wavelet domain by using tuning parameter which is user specific. Then intermediate frequency sub-band of watermark image is embedded into singular values of intermediate frequency sub-band of host image. The proposed algorithm is providing the adaptive behavior towards the image content for perceptual transparency and at the same time avoiding the possibility of false watermark extraction.

Bhupendra Ram [2013]: In [14], a watermarking scheme is proposed which adds a code to digital images in frequency domain. In this, a pseudo random sequence of real numbers as watermark is embedded into the selected DCT coefficients. It is a blind watermarking algorithm as it do not use original image for extraction of the watermark. The watermark is embedded in high frequency to maintain the imperceptibility of the watermark. Experimental results show better robustness against various attacks while maintaining the imperceptibility.

Cheonshik Kim, Ching-Nung Yang [2013]: This paper [15] used same size of watermark image as cover image. In this the image watermarking scheme embedded watermark after applying Arnold transform, which scrambles every bit of the watermark. This scrambled image is the further encrypted using one way hash function. The digital signature algorithm (DSA) is applied to the encrypted watermark, which further strengthen the security of the watermark. Finally, a predictive coding is applied to the cover image to embed encrypted watermark into it. The predictive coding predicts the current pixel value using the neighboring pixels according to the provided conditions. The scheme embeds the watermark bits using the difference between the current pixel and predicted pixel. The experimental results show that the proposed technique has high PSNR with high robustness. This technique also claims the less complexity image watermarking scheme.

HabibollahDanyali, MortezaMakhloghi, FardinAkhlagian Tab [2012]: This paper [16] presents a robust and blind digital image watermarking scheme based on DWT and SVD. The basic idea of the scheme is to embed the singular values of the watermark into the singular values of transformed host image. At the first step, the host image is transformed to wavelet domain and then SVD transform is applied on each sub-band. Then singular values of each sub-band and the singular values of watermark image are embedded into the selected values of SVs of the decomposed host image's sub-bands. The experimental results show high transparency of the watermarked images as well as strong robustness of the proposed watermarking scheme against different geometrical attacks and non geometrical attacks.

AkshyaKumar Gupta and Mehul S Raval [2012]: In [17], a blind watermarking scheme is proposed based on DWT and SVD. To optimize imperceptibility and robustness constraints singular values of high frequency sub-band is used. Experimental result shows improvement in robustness and security by using the signature-based authentication aspect.

Gaurav Bhatnagar, Q. M. Jonathan Wu and Balasubramanian Raman [2011]: In [18], a watermarking scheme is proposed where the size of watermark image is larger than the host image size. Here the size of host image is made equal to the size of watermark through over-sampling and then it is decomposed by stationary wavelet transform. The watermark is embedded in the low frequency sub-band by SVD. A binary watermark is also embedded to prevent ambiguity and enhance the security. Experimental results show that the scheme provides better imperceptibility and robustness against the image processing attacks.

Manjit Thapa, Dr. Sandeep Kumar Sood, A.P Meenakshi Sharma [2011]: In [19], a watermarking scheme is proposed which uses SVD frequency domain technique. Both S and V components are explored in this algorithm. Experimental results show better imperceptibility and robustness against various attacks.

Yixin Yan, Wei Cao, Shengming Li [2009]: In [20], block based adaptive image watermarking technique is presented using Just Noticeable Difference (JND). In this first the cover image is divided into 8*8 non-overlapping blocks. Now DCT is applied to each block. After this, capacity of each block is calculated to embed watermark bits without being perceptible. This capacity is calculated by using the concept of JND threshold. JND threshold concept is one of the features of Human Visual System (HVS) model. JND threshold measures the minimum difference between the watermarked image and original cover image that can be just detectable to human vision. Then, the DCT coefficients of every block are modified with the watermark bits according to JND threshold value. Experimental results show the high robustness with better imperceptibility.

Yuan-Hui Yu, Chin-Chen Chang, Yu-Chen Hu [2004]: In [21], the proposed scheme embeds the watermark using predictive coding. It hides the watermark in the compression codes during the cover image compression process. Here the watermark is embedded into the difference values calculated after applying prediction stage. In this paper, different compression schemes with embedded watermark are compared. Experimental results show that this prediction based scheme is better in terms of robustness and imperceptibility as compared to other compression based techniques.

CHAPTER 3

DEVELOPMENT OF THE ALGORITHM

3.1 Requirements for the algorithm

Basic requirements of digital watermarking technique are:

a) **Transparency**: The digital watermark should not affect the quality of the original image after it is watermarked. Distortions occurred in original image should not be visible because it reduces the commercial value of the image.

b) **Robustness**: Watermarks can be removed by intentional and unintentional image processing operations like contrast or brightness enhancement, lossy compressions, etc. Hence watermarking should be robust against all such type of attacks.

c) **Capacity**: It describes that how much data can be embedded as a watermark to successfully detect after extraction. The watermark should be able to able to carry enough information to represent the uniqueness of the image.

d) **Security**: Watermarking technology provides security as both the embedding process and extraction process make use of secret key.

e) **Computational complexity**: This property is the measure of the amount of the time any algorithm or technique takes to encode or decode image.

3.2 Techniques Used in the Current Algorithm

Below are the different techniques used in the current algorithm:

3.2.1 Discrete Wavelet Transform (DWT):

The discrete wavelet transform decomposes the image into three spatial directions, i.e. vertical, horizontal and diagonal. Magnitude of DWT coefficients is high in the lowest bands (LL) at each level of decomposition and is least for other bands (HH, LH and HL) [1]. The high magnitude of the wavelet coefficient is more significant. DWT concentrate almost complete energy of the signal in its approximate coefficients this is LL band.

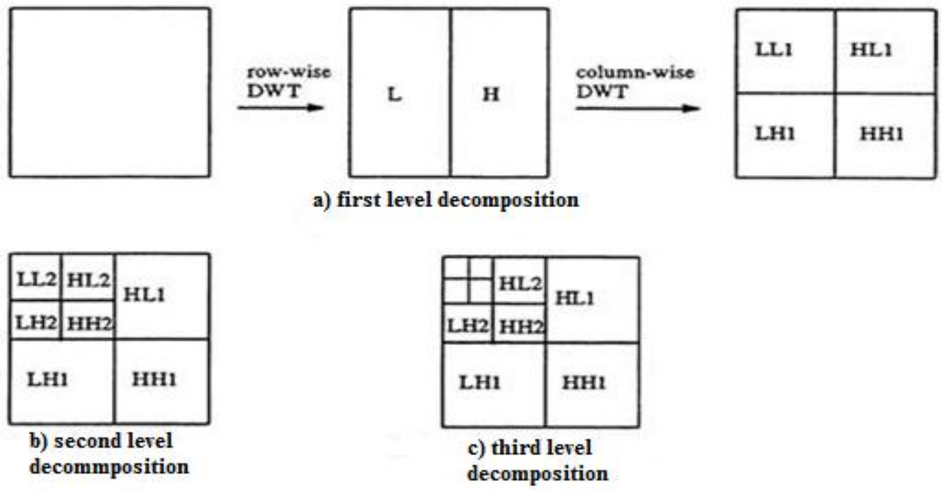


Fig 3.1 DWT application on image

3.2.2 Predictive Coding:

This technique is called predictive coding as it contains two parts one is prediction and other is entropy coding. In this, first the image is divided into blocks of size 2*2. The blocks can be overlapping or non-overlapping as per the designers choice. Each pixel of block is assigned as a, b, c, x (OPV) as shown in the figure [23].

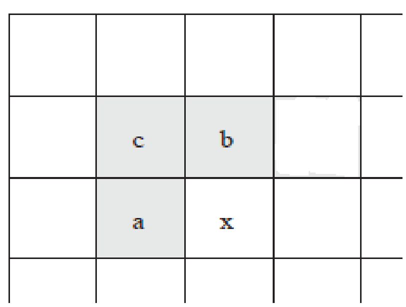


Fig 3.2 Predictive Coding block assignment

Where OPV stands for original pixel value. The prediction of PPV is done on the basis of following defined conditions [21]:

$$PPV = \begin{cases} \min(a, b) & ; \text{if } c \geq \max(a, b) \\ \max(a, b) & ; \text{if } c \leq \min(a, b) \\ (a + b)/2 & ; \text{otherwise} \end{cases}$$

Second part is entropy coding, in this PPV is modified in order to embed watermark bits in it to give MPPV (modified predictive coding). Entropy coding varies from paper to paper as per the demand of designer. In paper [15], the watermark bits are embedded using concept of LSB and exclusive or. In paper [21], the watermark bits are embedded into the difference of OPV and PPV. In entropy coding, the modification must be such that it should maintain the imperceptibility of image after embedding. In proposed scheme, in entropy coding MPPV is generated by small modification done to PPV such that it maintains imperceptibility of image.

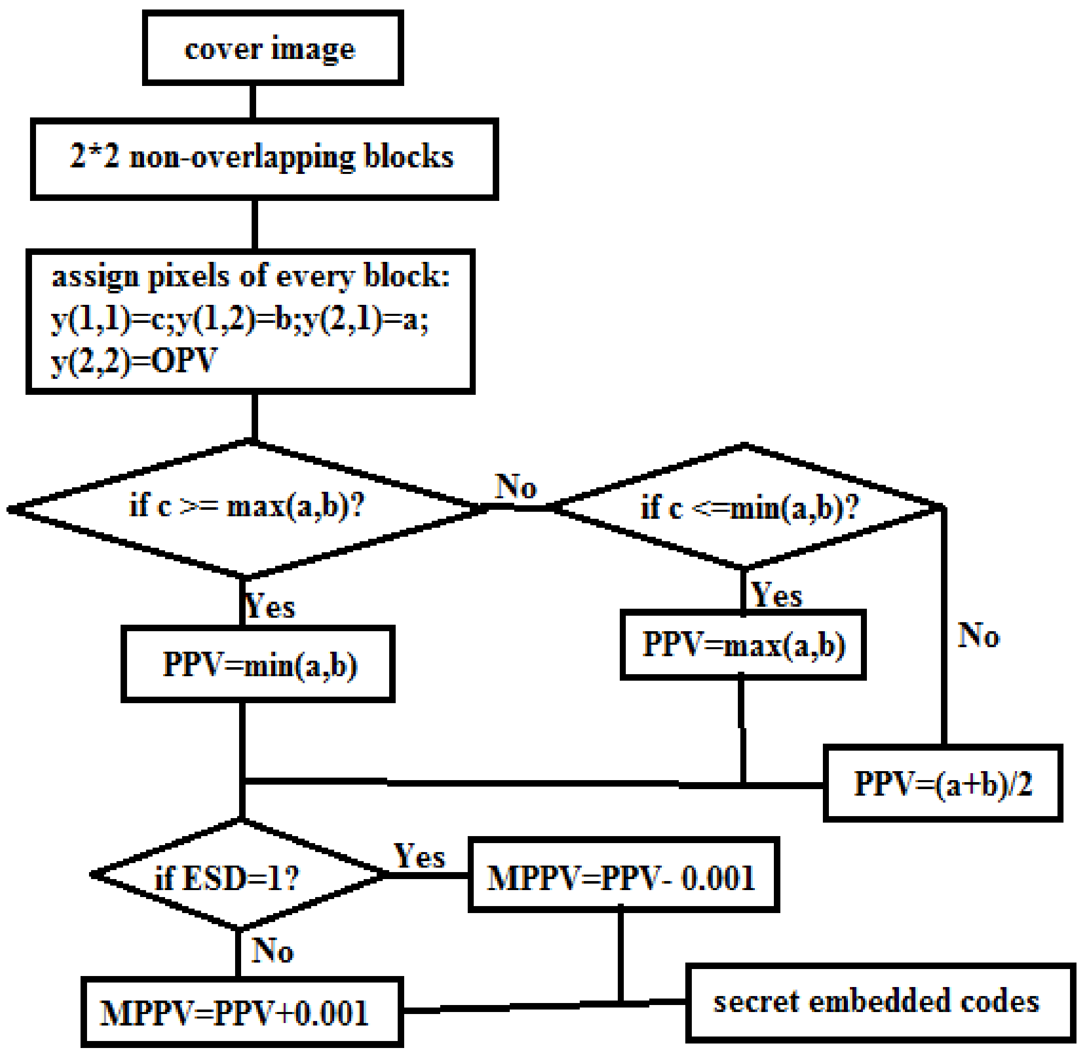


Fig 3.3 Proposed Predictive coding flow chart

3.2.3 Arnold Transform:

Arnold Transform (AT) was invented or developed by Vladimir Arnold in 1960. This is actually a chaotic map that shuffles the bits/pixels of image to which it is applied [15]. As a result it produces a noisy image from which one cannot identify the original image to which it was applied. The output image is just random orientation of pixels. The iteration period (p) is provided while applying Arnold Transform which acts as secret key in embedding process and at extraction process same number of iteration is to provided, otherwise original image cannot be recovered. The generalized chaotic map defined by Arnold Transform is given as:

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} 2 & 1 \\ 1 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} (mod\ N)$$

Where x, y are bits of original image of size N*N. x', y' are new bits of output scrambled image to be formed. This scrambled output image is completely noisy and different from original image.

Arnold Transforms simplicity and periodicity it is widely used to increase robustness and security in image watermarking techniques. Its periodicity depends on size of image on which it is applied.

3.3 Watermarking Process

Digital image watermarking is the process of embedding a watermark into a host/cover image. The watermark can be any digital signature, image, text or video. The watermark can be any mark belongs to any particular identity/person/organization. After the extraction process the embedded watermark is extracted. That extracted watermark is the compared with the particular identity mark of any person/organization. By the comparison, the host image is tested for copyright and content authentication.

3.3.1 Watermark Embedding Scheme

Below is the flowchart and algorithm of Watermark Embedding Scheme:

a) **Flow chart**

The flow chart of Watermark Embedding Scheme is shown as below:

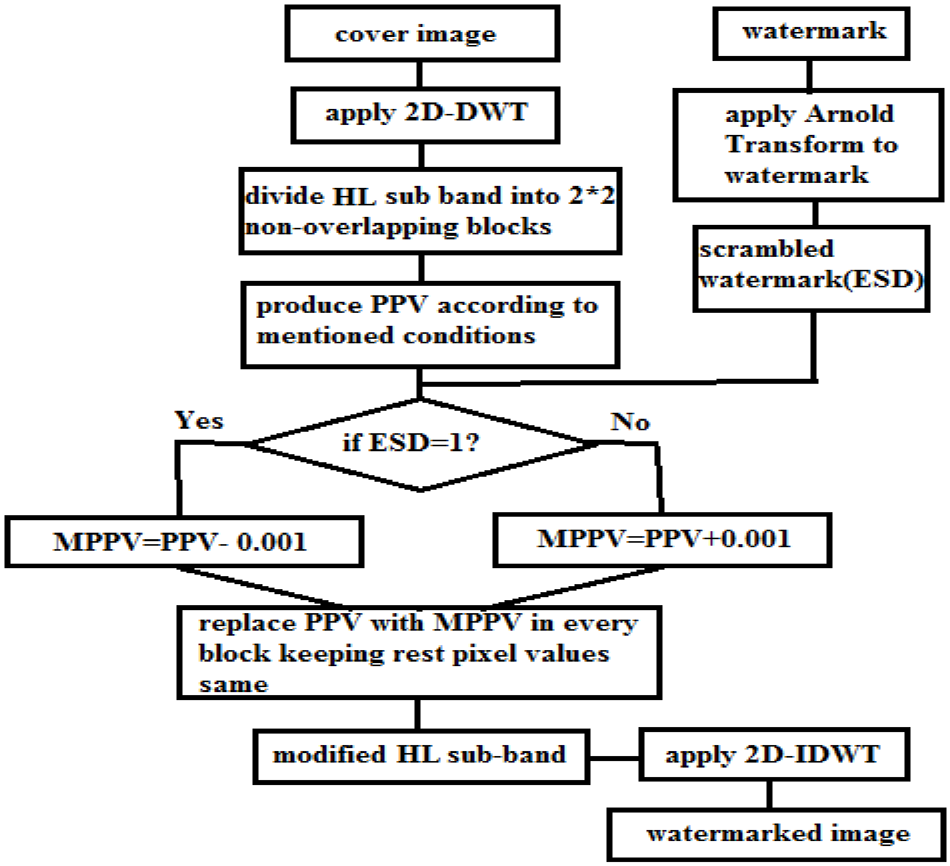


Fig.3.4 Flow chart of Embedding Scheme

b) **Algorithm**

The algorithm of Watermark Embedding Scheme is shown as below:

Step1: Binary watermark of 65*65 is taken and Arnold Transform is applied for watermark encryption.

Step 2: The cover image of 256*256 is taken and DWT is applied on cover image using db4 wavelet to get four 131*131 sub bands i.e. LL, HL, LH, HH.

Step 3: HL sub band is divided into 2*2 non-overlapping blocks.

Step 4: Assign y(1,1)=c, y(1,2)=b, y(2,1)=a and y(2,2)=original pixel value (OPV) in each block of HL sub band.

Step 5: Produce predicted pixel value (PPV) on the basis of following conditions:

$$PPV = \begin{cases} \min(a, b) \; ; \text{ if } c >= \max(a, b) \\ \max(a, b) \; ; \text{ if } c <= \min(a, b) \\ (a + b)/2 \quad ; \text{ otherwise} \end{cases}$$

Step 6: Produce modified predicted pixel value (MPPV) as follows. Where b(i,j) are pixel values of binary encrypted watermark.

If b(i,j)=0; MPPV=PPV+0.001

If b(i,j)=1; MPPV=PPV-0.001

Step 7: Replace PPV with respective MPPV in each block of HL sub band to get HL*.

Step 8: Apply inverse DWT using LL, HL*, LH, HH to get watermarked image I*.

3.3.2 Watermark Extraction Scheme

The flow chart of Watermark Extraction Scheme is shown as below:

a) **Flow chart**

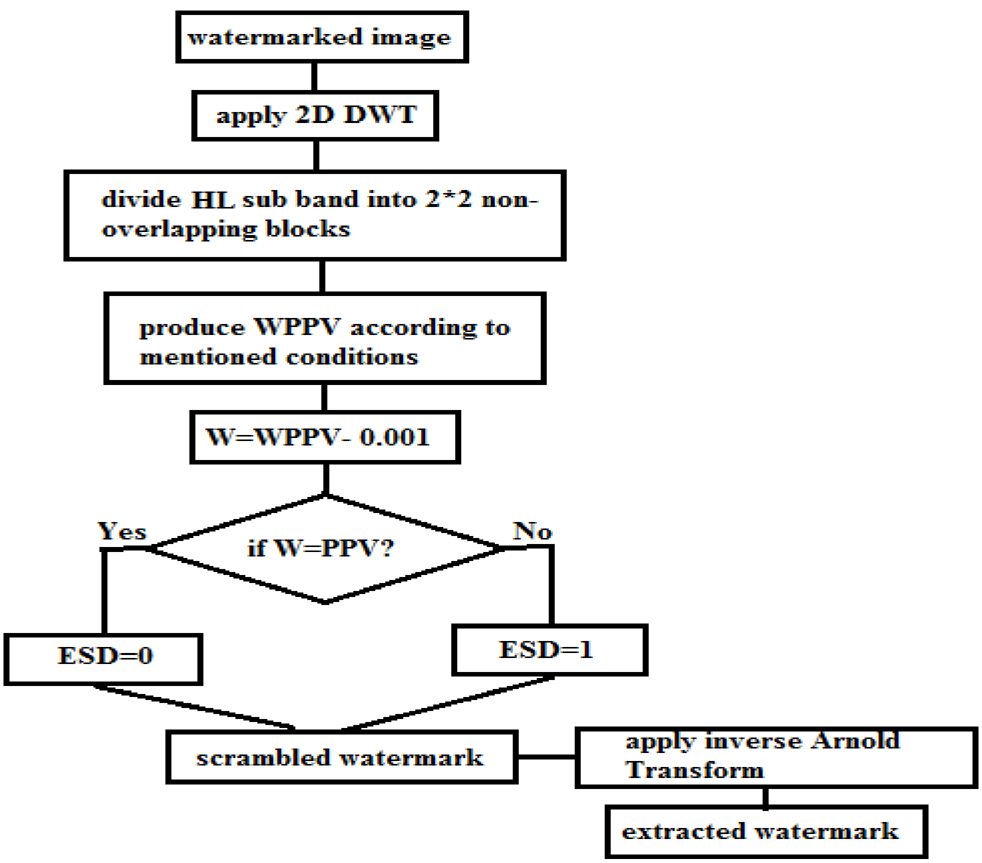


Fig 3.5 Flow chart of Extraction Scheme

b) **Algorithm**

The algorithm of Watermark Embedding Scheme is shown as below:

a) DWT is applied to watermarked image I* to get LL, HL*, LH, HH.

b) HL* sub band is divided into 2*2 non-overlapping blocks.

c) PPV* are produced according to above mentioned conditions in embedding process.

d) Extract encrypted watermark pixel values as follows. Where b*(I,j) are extracted encrypted watermark pixel values.

$$\text{If } PPV^*-0.001=PPV;\ b^*(i,j)=0$$

$$\text{If } PPV^*+0.001=PPV;\ b^*(i,j)=1$$

e) Apply inverse Arnold Transform on extracted encrypted watermark to get extracted original watermark W*.

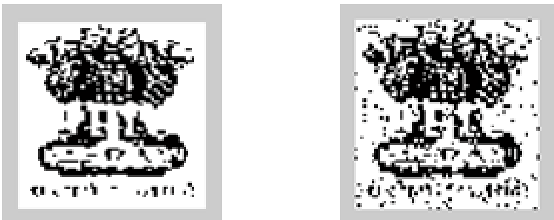
CHAPTER 4

EXPERIMENTAL RESULTS

Experimental results show that the proposed technique of image watermarking is highly imperceptible, robust and secure. This is shown by means of various applied common attacks. The results are shown with and without Arnold Transform proving that it is imperceptible and robust in both cases except that Arnold Transform further increases security. Simulation is done in Matlab 2011 platform. Results are shown by various figures and table.

4.1 Without Arnold Transform

The watermarking scheme without Arnold Transform on watermark gives PSNR 76.70 and NC is 0.92. The watermark, cover image, watermarked image are shown below. The watermarked image with various attacks is also shown.



(a) (b)

Fig 4.1 (a) Watermark (b) Extracted watermark

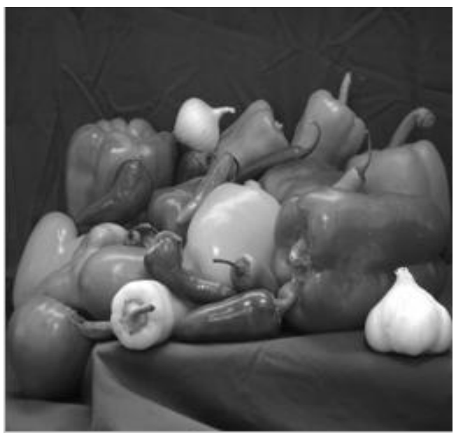


Fig 4.2 Cover image

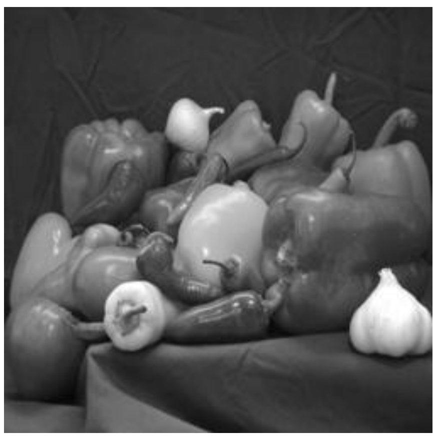


Fig 4.3 Watermarked image

Fig 4.4 Salt and Pepper noise (var0.01)

Fig 4.5 Speckle noise (var0.01)

Fig 4.6 Gaussian noise (var0.01)

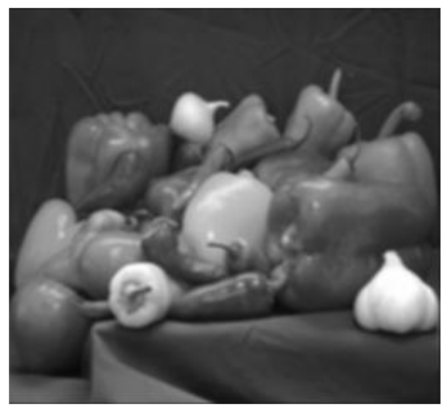


Fig 4.7 Average filter [3 3]

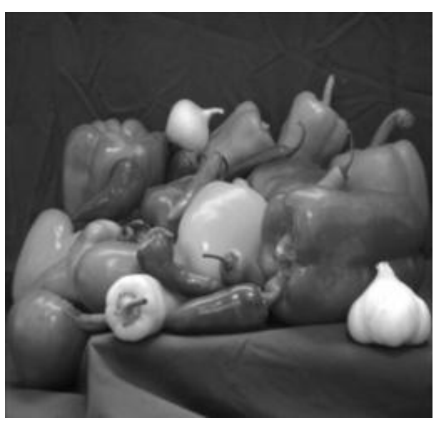


Fig 4.8 Gaussian filter [3 3]

Fig 4.9 Laplacian filter (var0.1)

Table 4.1 Effect of Salt and Pepper noise on PSNR

Variance	PSNR
0.01	47.52
0.02	44.17
0.03	42.41
0.04	41.10
0.05	39.97
0.06	39.31
0.07	38.80
0.08	38.25

Plot of Salt and Pepper noise with PSNR

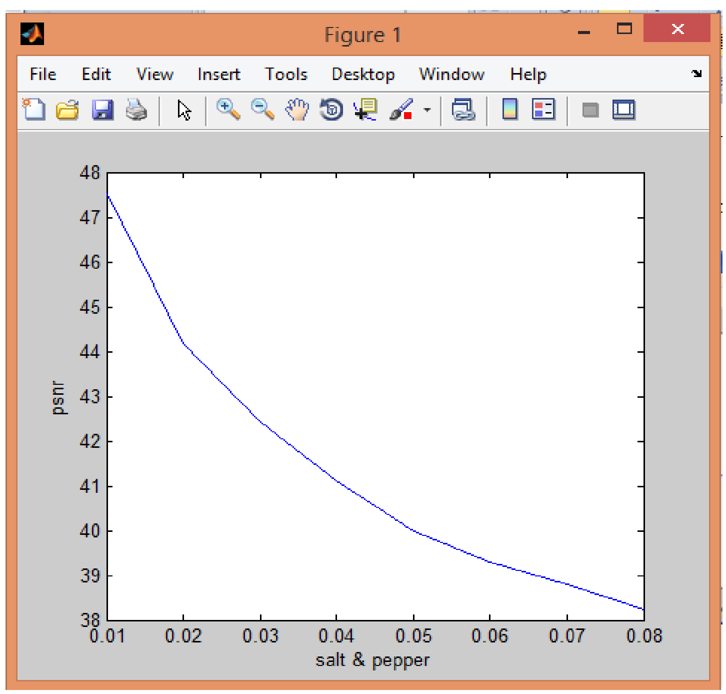


Table 4.2 Effect of Speckle noise on PSNR

Variance	PSNR
0.01	33.11
0.02	31.35
0.03	30.45
0.04	29.90
0.05	29.57
0.06	29.29
0.07	29.04
0.08	28.97

Plot of Speckle noise with PSNR

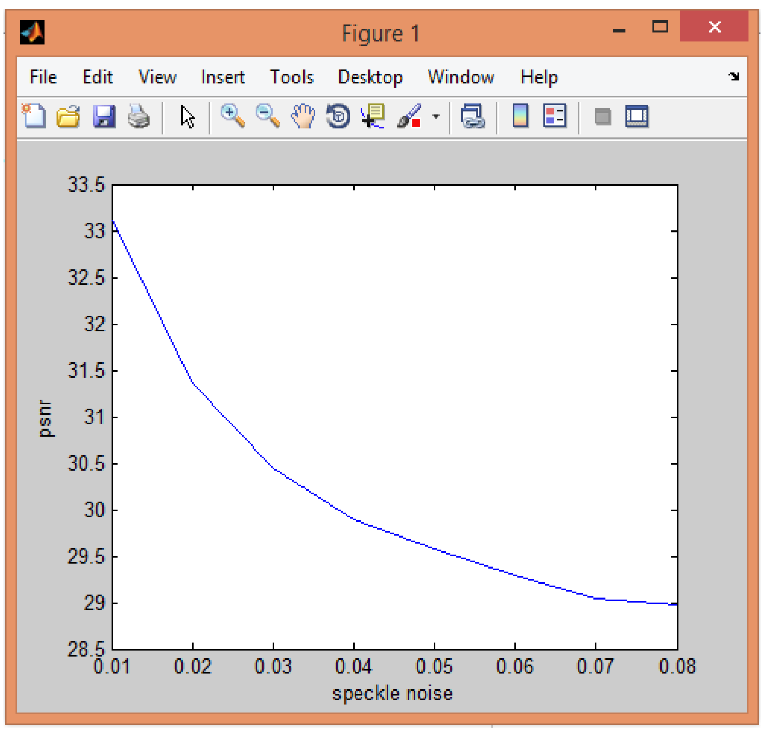


Table 4.3 Effect of Gaussian noise on PSNR

Variance	PSNR
0.01	28.35
0.02	27.90
0.03	27.51
0.04	27.14
0.05	26.83

Plot of Gaussian noise with PSNR

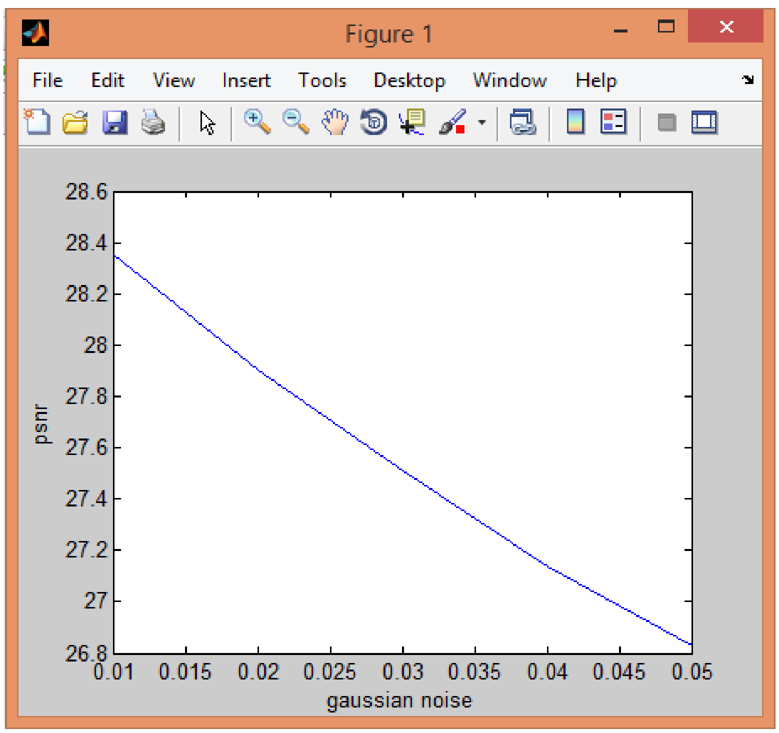


Table 4.4 Effect of Average filter on PSNR

Size	PSNR
[3 3]	39.32
[5 5]	36.14
[7 7]	34.65

Table 4.5 Effect of Gaussian filter on PSNR

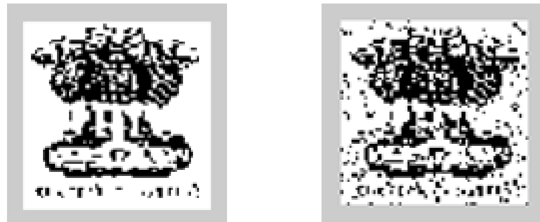
Size	Sigma	PSNR
[3 3]	0.5	46.74
[5 5]	0.6	43.27
[7 7]	0.7	41.49

Table 4.6 Effect of Laplacian filter on PSNR

Variance	PSNR
0.1	45.62
0.2	45.98
0.3	46.34
0.4	46.60
0.5	46.81

4.2 With Arnold Transform

The watermarking scheme without Arnold Transform on watermark gives PSNR 76.75 and NC is 0.77. The watermark, scrambled watermark, cover image, watermarked image are shown below. The watermarked image with various attacks is also shown.



(a) (b)

Fig 4.10 watermark and extracted watermark

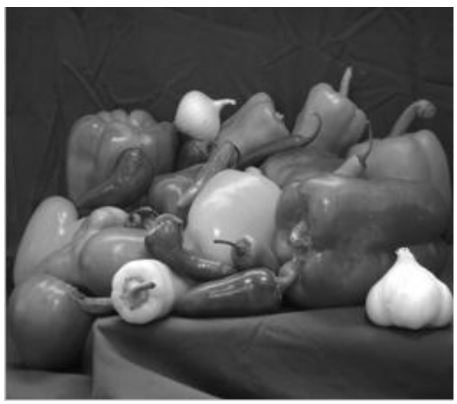


Fig 4.11 Cover image

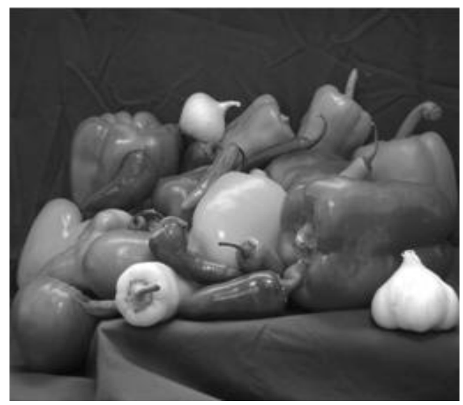


Fig 4.12 Watermarked image

Fig 4.13 Salt and Pepper (var0.01)

Fig 4.14 Speckle noise (var0.01)

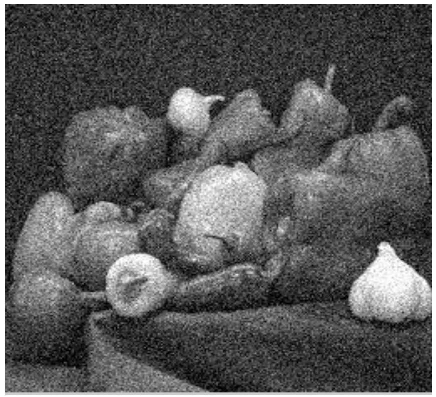


Fig 4.15 Gaussian noise (var0.01)

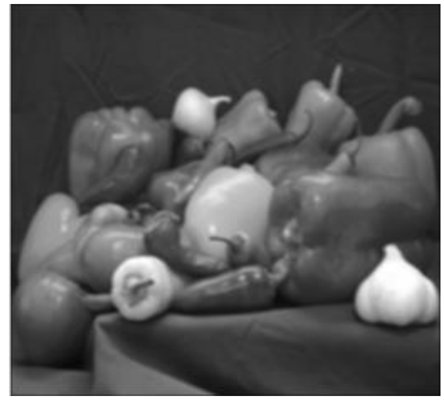


Fig 4.16 Average filter [3 3]

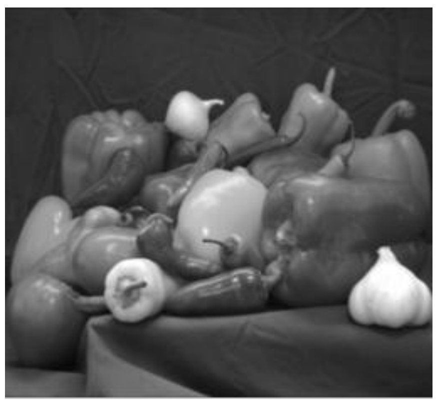


Fig 4.17 Gaussian filter [3 3]

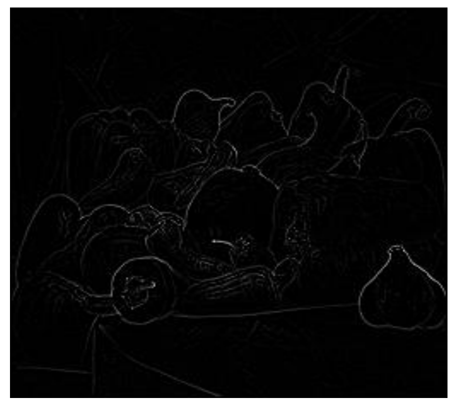


Fig 4.18 Laplacian filter (var0.1)

Table 4.7 Effect of Salt and Pepper noise on PSNR

Variance	PSNR
0.01	47.05
0.02	44.04
0.03	42.23
0.04	40.91
0.05	40.05
0.06	39.39
0.07	38.66
0.08	38.17

Plot of Salt and Pepper noise with PSNR

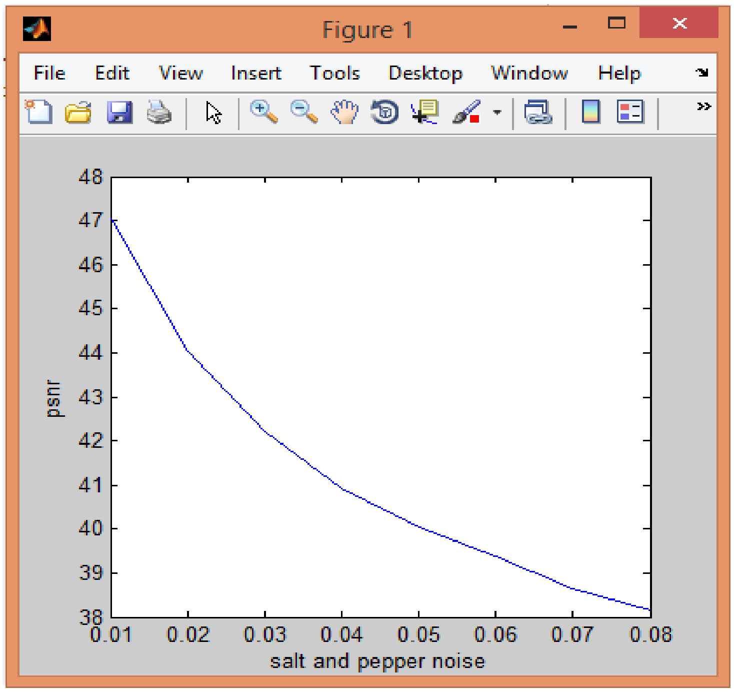


Table 4.8 Effect of Speckle noise on PSNR

Variance	PSNR
0.01	33.16
0.02	31.33
0.03	30.53
0.04	29.93
0.05	29.53
0.06	29.23
0.07	29.07
0.08	28.94

Plot of Speckle noise with PSNR

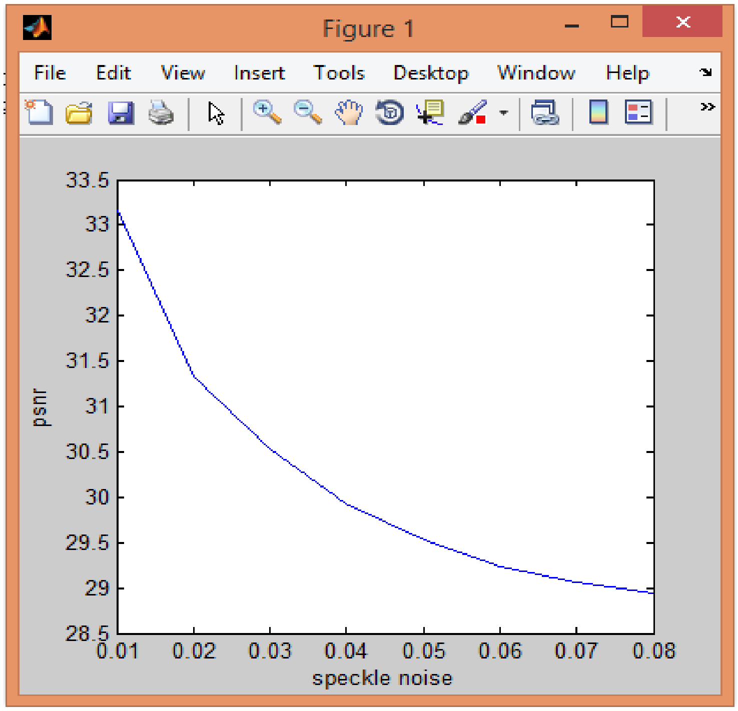


Table 4.9 Effect of Gaussian noise on PSNR

Variance	PSNR
0.01	28.33
0.02	27.91
0.03	27.53
0.04	27.15
0.05	26.82

Plot of Gaussian noise with PSNR

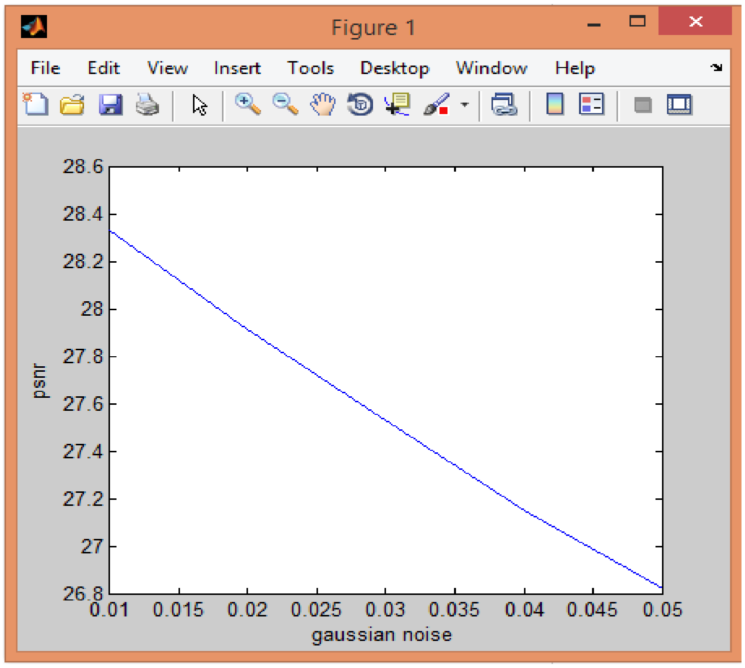


Table 4.10 Effect of Average filter on PSNR

Size	PSNR
[3 3]	39.32
[5 5]	36.14
[7 7]	34.65

Table 4.11 Effect of Gaussian filter on PSNR

Size	Sigma	PSNR
[3 3]	0.5	46.74
[5 5]	0.6	43.27
[7 7]	0.7	41.49

Table 4.12 Effect of Laplacian filter on PSNR

Variance	PSNR
0.1	45.62
0.2	45.98
0.3	46.34
0.4	46.60
0.5	46.81

4.3 Summary

The digital image watermarking is mainly used for copyright protection, authentication purpose and temper detection. Here DWT with Predictive Coding has proved to be highly imperceptible, robust and secure image watermarking technique. DWT converts cover image into frequency domain which has high robustness than spatial domain techniques. Predictive Coding successfully find the optimized locations for embedding watermark bits so that it do not degrade its imperceptibility. Various applied attacks like noises and filters shows that the scheme maintains its imperceptibility and robustness without much loss. Arnold Transform further enhances the security of the proposed scheme.

CHAPTER 5
COMPARISON OF RESULTS

The Digital Image Watermarking techniques can be considered as better only when evaluation parameters are giving values as per defined in watermarking rules. The digital image watermarking is mainly used for authentication purpose. Predictive coding with DWT is proved to be efficient image watermarking scheme from the results. In previous schemes, predictive coding is applied in spatial domain which gives somewhat satisfying results in terms of imperceptibility and robustness but proposed scheme implements predictive coding in frequency domain which further increases imperceptibility and robustness and Arnold Transform further enhances the proposed schemes security. High PSNR and NC shows proposed technique is efficient than related previous schemes.

Table 5.1 Comparison of Proposed Scheme with related Previous Schemes

Test Images	Paper [15] PSNR	Paper [21] PSNR	Proposed scheme PSNR
Peppers	51.16	-	76.75
Lena	51.16	51.16	69.19
Barbara	51.15	-	61.08
Boat	51.15	51.14	60.63
Baboon	51.11	51.11	57.25

CHAPTER 6

CONCLUSION AND FUTURE SCOPE

The proposed scheme has given efficient results which can be evaluated by evaluation parameters of digital image watermarking techniques. By using DWT and Predictive Coding an improved digital image watermarking scheme is presented here. As predictive coding here select optimized location for embedding here gives increased imperceptibility and robustness in terms of PSNR and NC respectively. All the test images considered are giving PSNR values above 36dB and NC values close to 1 presenting that it is better scheme than the previous schemes in related field. Maximum PSNR and NC mean better imperceptibility and robustness by which unauthorized persons cannot detect the watermarked image and damage it. After applying various common attacks, the scheme has proved to be efficient scheme in terms of imperceptibility, robustness and security. Without Arnold transform the scheme has PSNR 76.70 and NC is .92 and with Arnold it gives PSNR 76.75 and NC is 0.77 which are very well satisfied results.

The presented scheme of image watermarking can also be applied to color images and videos with other encryption techniques in combination with other frequency domain and spatial domain techniques.

CHAPTER 7

REFERENCES

[1]. Chunlin Song, Sud Sudirman, Madjid Merabti, "Recent Advances and Classification of Watermarking Techniques in Digital Images", 2009

[2] Vinita Gupta, Mr. Atul Barve, "A Review on Image Watermarking and Its Techniques", International Journal of Advanced Research in Computer Science and Software Engineering, 2014.

[3] Y. Shanti kumar Singh, B. Pushpa Devi, and Kh. Manglem Singh, A Review of Different Techniques on Digital Image Watermarking Scheme, International Journal of Engineering Research, 2013.

[4] Athanasios Nikolaidis, Local distortion resistant image watermarking relying on salient feature extraction, EURASIP Journal on Advances in Signal Processing, 2012.

[5]. Shankar Parimi, A. SaiKrishna, N. Rajesh Kumar, N. R. Raajan, "An imperceptible Watermarking Technique for Copyright content using Discrete Cosine Transformation", International Conference on Circuit, Power and Computing Technologies, 2015

[6]. Saiful Islam, Mangat R Modi , Phalguni Gupta , "Edge-based image steganography", EURASIP Journal on Information Security, 2014

[7]. K. Loukhaoukha, M. Nabti, K. Zebbiche , "A robust SVD-based image watermarking using a multi-objective particle swarm optimization", Springer Opto−Electron. Rev., 2014

[8]. Ehab H. Elshazly, Osama S. Faragallah, Alaa M. Abbas, Mahmoud A. Ashour, El-Sayed M. El-Rabaie, Hassan Kazemian, Saleh A. Alshebeili, Fathi E. Abd El-Samie, Hala S. El-sayed, "Robust and secure fractional wavelet image watermarking", Signal, Image and Video Processing, 2014

[9]. Amit Kumar Singh, Mayank Dave, Anand Mohan, “Hybrid Technique for Robust and Imperceptible Image Watermarking in DWT–DCT–SVD Domain”, The National Academy of Sciences, Springer, 2014

[10]. Qingtang Su Gang Wang, ShaoliJia, Xiaofeng Zhang, Qiming Liu, Xianxi Liu, “Embedding color image watermark in color image based on two-level DCT”, Signal, Image and Video Processing, 2013

[11]. Nidhi Bisla, Prachi Chaudhary , “Comparative Study of DWT and DWT-SVD Image Watermarking Techniques”, International Journal of Advanced Research in Computer Science and Software Engineering, 2013

[12]. Shi-Jinn Horng, Didi Rosiyadi, Pingzhi Fan, Xian Wang, and Muhammad Khurram Khan, “An adaptive watermarking scheme for e-government document images”, Multimedia Tools and Applications An International Journal, Springer, 2013

[13]. Punit Pandey, Shishir Kumar and Satish K. Singh, “Rightful ownership through image adaptive DWT-SVD watermarking algorithm and perceptual tweaking”, Multimed Tools Application, Springer, 2013

[14]. Bhupendra Ram, “Digital Image Watermarking Technique Using Discrete Wavelet Transform And Discrete Cosine Transform”, International Journal of Advancements in Research & Technology, 2013

[15]. Cheonshik Kim, Ching-Nung Yang, “Watermark with DSA signature using predictive coding”, Multimed Tools Application, Springer, 2013

[16]. Habibollah Danyali, Morteza Makhloghi, Fardin Akhlagian Tab, “Robust blind DWT based Digital Image Watermarking using Singular Value decomposition”, International Journal of Innovative Computing, Information and Control, 2012

[17]. Akshya Kumar Gupta and Mehul S Raval, “A robust and secure watermarking scheme based on singular value replacement” Indian Academy Of sciences, 2012

[18]. Gaurav Bhatnagar, Q. M. Jonathan Wu and Balasubramanian Raman, “A new aspect in robust digital watermarking”, Multimedia Tools and Applications, 2011

[19]. Manjit Thapa, Dr. Sandeep Kumar Sood, A.P Meenakshi Sharma, “Digital Image Watermarking Technique Based on Different Attacks”, (IJACSA) International Journal of Advanced Computer Science and Applications, 2011

[20]. Yixin Yan, Wei Cao, Shengming Li, “Block based Adaptive Image Watermarking Scheme Using Just Noticeable Difference”, International Workshop on Imaging Systems and Techniques, 2009

[21]. Yuan-Hui Yu, Chin-Chen Chang, Yu-Chen Hu, “Hiding secret data in images via predictive coding”, Pattern Recognition Society, 2004

[22]. Mamtha Mohan, Dr Sujatha B K, “An approach to protect medical images using DWT+SVD in watermarking”, International Journal of Advanced Information Science and Technology, 2014

[23]. Rajesh Mandale, Akshay Mhetre, Rahul Nikam, “Image Compression based on Prediction Coding”, International journal & magazine of engineering and technology, 2014

[24]. Sameh Oueslati, Adnane Cherif, and Bassel Solaiman, “Multiple Binary Images Watermarking in Spatial and Frequency Domains”, International Journal of Computer Theory and Engineering, 2014

[25]. FrankY. Shih∗, Scott Y.T. Wu, “Combinational image watermarking in the spatial and frequency domains”, Pattern Recognition, 2003